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Installation & Monitoring Of Instream Benthic Macroinvertebrate Platforms

(HabiTubes & Habi-Mats) For Four Streams in Prince William County, Virginia

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Installation & Monitoring Of Instream Benthic Macroinvertebrate Platforms

(HabiTubes & Habi-Mats) For Four Streams in Prince William County, Virginia

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Abstract

The Prince William County Department of Public Works Environmental Services Division has implemented a program to restore and stabilize stream channels affected by urbanization. Monitoring of these streams has previously been limited to evaluating the stabilization success of the restored channel, installed structures, and vegetation. This study examined the collection of baseline benthic macroinvertebrate data from these streams, plus a review of instream platforms (HabiTubes & Habi-Mats). The resulting information on the instream platforms demonstrated that they could provide a habitat and food source, deliver an ecological improvement/boost (increasing the number of taxa), and improve the biotic index of the benthic macroinvertebrate population.

Introduction and Background

The Prince William County (PWC) Department of Public Works Environmental Services Division has implemented a program to restore and stabilize stream channels affected by urbanization. PWC realized the need to monitor the conditions of the stream stabilization projects. Currently, monitoring is limited to evaluating the stabilization success of the restored channel, installed structures, and the survival of newly planted trees in the riparian zone. The two metrics not previously measured are the benthic macroinvertebrate population and water quality (pH, dissolved oxygen, conductivity, and temperature) to determine the possible factors affecting macroinvertebrates. PWC wanted a baseline evaluation of the macroinvertebrate population to compare to future monitoring events of these restored streams.

The Environmental Services Division of the PWC Department of Public Works decided to conduct baseline benthic macroinvertebrate sampling per the "Methods for Multi-habitat Benthic Macroinvertebrates Collection". HabiTubes & Habi-Mats were utilized to determine how instream platforms for creating benthic macroinvertebrate habitats would perform as part of the restoration monitoring protocol. PWC selected four streams for this study (Figure 1).

The purpose of this study was to determine the current stream conditions and whether the use of new benthic macroinvertebrate platforms (i.e., HabiTubes, Habi-Mats) provided a biological boost/improvement to the restored streams (providing a source of leaf pack and/or woody debris). This study also collected baseline data in the non-restored streams.

Sampling Sites

The study includes four stream sites that are a part of the PWC Stream Restoration Program (Table 1). The Dewey's Creek site and the Cow Branch 4 sampling reaches are proposed restoration candidates. The East Longview stream restoration was completed in late 2016, and Cow Branch 2 restoration was completed approximately three years ago (2013-14). The impervious surface area of each of the sample locations is greater than seventy percent. The first phase of the study is to provide baseline benthic macroinvertebrate data on two restored streams (Cow Branch 2 and East Longview) and two streams selected for future restoration (Cow Branch 4 and Dewey's Creek) (Figure 1). The second phase is to determine whether the instream platforms provide an increase in the benthic macroinvertebrate population and diversity, and if so, to what extent.

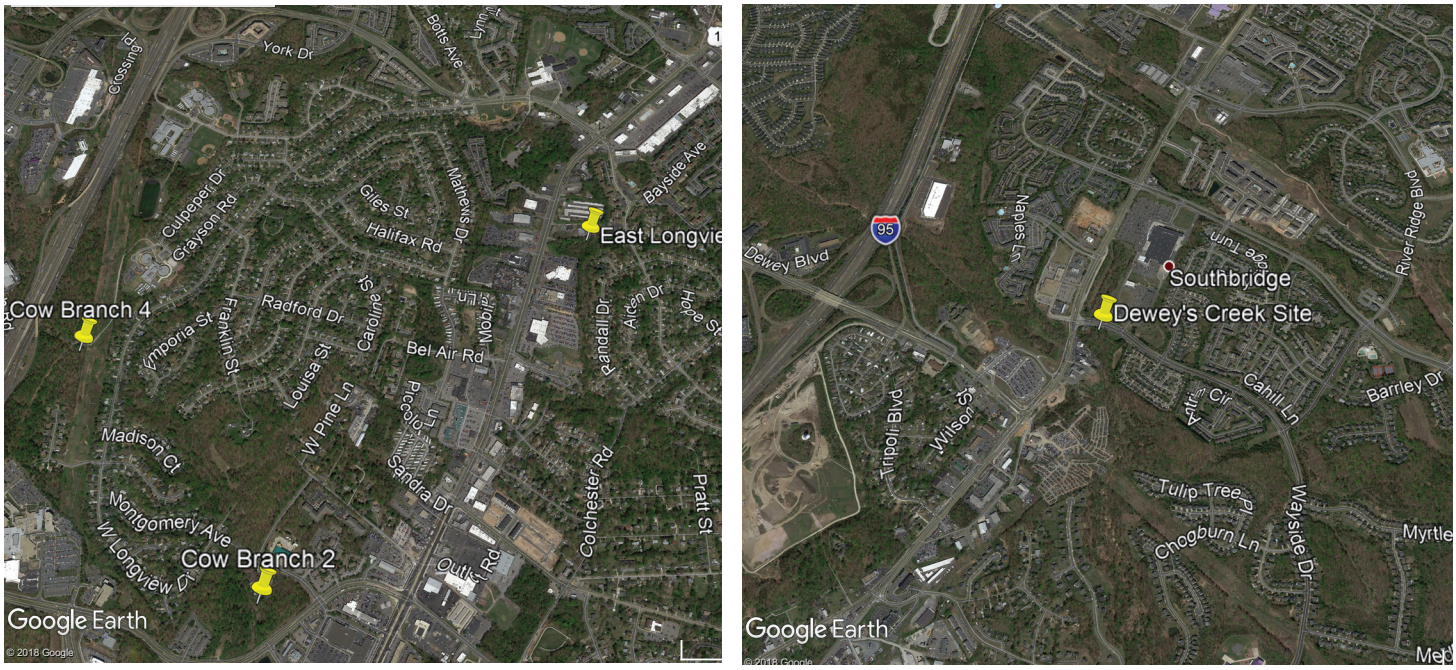

Figure 1. General location map of study streams three of four (left) and four of four (right).

Table 1. Selected stream sites for study in Prince William County, VA.

Stream	Date Monitored	Condition
Cow Branch 2	5/4/2017	Restoration complete
Cow Branch 4	5/4/2017	Proposed restoration site
East Longview	5/3/2017	Restoration complete
Dewey's Creek	5/5/2017	Proposed restoration site

Artificial Instream Platforms (HabiTubes & Habi-Mats)

HabiTubes and Habi-Mats are artificial instream platforms created by Acer Environmental, LLC, and made of natural materials able to restore leaf packs and woody debris *in situ* for the restoration of benthic macroinvertebrates. Leaf packs and wood debris are critical in the creation of macro- and micro-habitat and serve as a food source for the benthic macroinvertebrates, bacteria, and fungi in a stream (Stroud Water Research Center 2017). Leaf packs are transient in nature and can appear and disappear as waters rise and drop due to variable flows. The artificial instream platforms allow for the semipermanent creation of leaf packs and woody debris in the riffles and glides of streams. These products are the only production-grade systems that can hold leaf packs and woody debris in place for extended periods of time. By holding the leaf packs and woody debris in place, the habitat and food source for benthic macroinvertebrates is created, enabling the establishment of these organisms. By implementing these products, macrobenthic organisms can be recruited in place, or they can be recruited and transplanted from one stream to another.

HabiTubes are a patent-pending system that are comprised of an elongated pillow/tube made of coir fabric and filled with leaves or woody debris to provide habitat and food for benthic macroinvertebrates (Figure 2). They are placed in riffles and glides of streams to provide a semipermanent platform where these organisms can aggregate. The HabiTubes are used in urban channels where leaf packs do not occur due to a lack of riparian corridor or other impacts to detrital accumulation from storm events. This system can be used to enhance habitat in place or attract and grow organisms in a reference/donor reach and then relocated to a stream to kickstart a population where the organisms have been depleted.

Habi-Mats is a patent pending product that increases channel surface roughness and provides stable structures to allow the formation of natural leaf packs (Figure 3). Woody debris is woven into a coir fabric mat that allows for the capture, decomposition, and breakdown that reduces the release

Figure 2. HabiTubes recently installed (left), and HabiTubes 2 months after installation (right).

Figure 3. Habi-Mat prior to installation (left) and Habi-Mat 2 months after installation (right).

of organic matter downstream and facilitates slow release of in-channel detrital material. This roughness and detrital capture creates habitat and food opportunities for benthic macroinvertebrates that are lacking in many urban channels. It is also worth mentioning that restoring these "leaf pack" features to streams also restores the basic ecological function of decomposition (providing a structure where leaf breakdown can occur, as well as supporting both microbial and invertebrate communities that in turn support fish communities).

Both of these platforms can be instrumental in enhancing habitat in various types of streams and also used to boost a benthic macroinvertebrate population of a restored stream. This is conducted by placing HabiTubes in a healthy/donor stream where they can attract and hold organisms. Then they can be relocated to a restored/receiver stream that has an impaired benthic macroinvertebrate population. The HabiTubes installed in the restored/receiver stream support the relocated organisms/new population of organisms while they are adjusting to the new stream/habitat. There are few healthy stream reaches within the studied streams, and the relocation of desirable macroinvertebrates was not conducted for this study.

Methods

The sampling protocol consisted of six riffles per stream reach. Riffles 1 and 2 on the upstream portion of the project reach served as control/baseline sampling areas. The next two

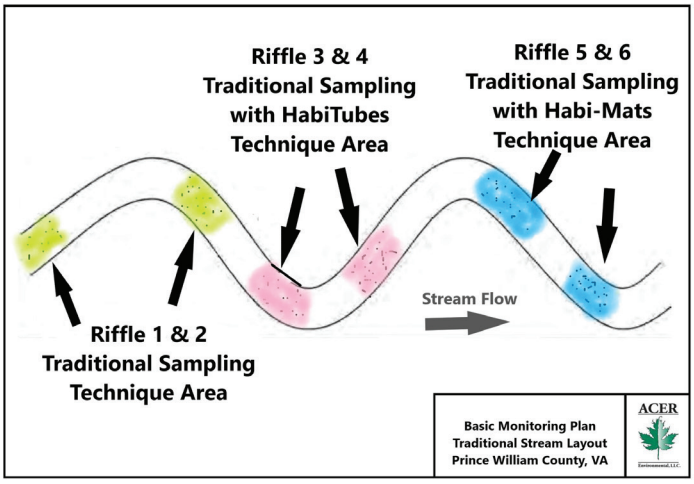

Figure 4. Basic monitoring plan for a traditional stream layout.

downstream riffles (Riffles 3 and 4) had HabiTube platforms installed, and the next two downstream riffles (Riffles 5 and 6) had Habi-Mat platforms installed (Figure 4).

The "Methods for Multi-habitat Benthic Macroinvertebrate Collections" from the *Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers* (Virginia Department of Environmental Quality 2008) were conducted at all six riffles. This technique requires 20-jab samples by which the sample is collected from downstream to upstream jabbing a D-frame net into productive and stable habitats for a total of 20 times. The habitat sampling is divided into samples proportionally to the amount of habitat in the study area (e.g., riffle, stream edge) (Table 2).

In the sampling areas that included HabiTubes and Habi-Mats, the platforms were evenly spaced throughout the streams to cover the various types of habitat and collect/attract as many organisms as possible. The exact location of the installed HabiTubes and Habi-Mats in the stream is determined in the field because of the variability of habitat and water depth in the stream reach. During the sampling event, the HabiTubes and Habi-Mats were shaken or kicked to dislodge benthic macroinvertebrates on or adjacent to the platform. One of the HabiTubes locations was sampled by harvesting the bag and conducting a kick for a 1-m^2 area upstream of the standard kick net placed in the stream. This was conducted to determine whether the HabiTubes by themselves would create a biological boost/improvement. All samples of macroinvertebrates were collected and identified by Mr. Dave Penrose of Penrose Environmental Consulting.

Sample Procedure

The sampling area that included the HabiTubes used the multihabitat sampling system required in the Virginia Department of Environmental Quality (2008) protocol. The HabiTubes were included in the percentage of habitat and sampled around as part of the sampling. Next, one HabiTube was removed from the stream reach. A kick net was placed below the HabiTube, and the surrounding substrate was kicked for approximately 1 m^2 to collect organisms residing on or around the outside of the HabiTube. The collected HabiTube and kick sample were placed in a sieve bucket, the HabiTube opened, and its contents washed using clean stream water, isolating the macroinvertebrates from the organic material. The macroinvertebrates and the remaining fine organic material were placed into a separate container that was marked for the sample location and later sorted for identification and analysis.

The samples collected from inside and underneath the HabiTubes were collected and analyzed as a single separate collection. The material and macroinvertebrates collected from the HabiTubes were also analyzed as one sample.

The sampling areas that included the Habi-Mats used the 20-jab methods as required by the Virginia Department of Environmental Quality (2008) protocol (Figure 5). The Habi-Mats were included as a part of the sampling protocol as a habitat to be jabbed. The data collected from this sample were presented in the final data as an independent habitat or data set (as shown later in Tables 5–8).

Table 2. Platforms and streams upstream to downstream.

Riffle Number	Material Used	Number of Platforms
1	No HabiTubes or Habi-Mats	0
2	No HabiTubes or Habi-Mats	0
3	HabiTubes	3
4	HabiTubes	3
5	Habi-Mats	1
6	Habi-Mats	1

Figure 5. Conducting a jab sample.

Figure 6. Midges (courtesy of Dave Penrose).

Water Quality

Water quality sampling was conducted to determine the current condition of the stream. Physicochemical data were recorded with a YSI Professional Pulse multimeter in the field, and water samples were further analyzed at the laboratory. The water quality parameters taken in the field by the meter were water temperature, pH, dissolved oxygen, specific conductivity, and barometer. The chemical parameters analyzed in the laboratory were nitrate as NO_3^-, nitrite as NO_2^-, nitrate/nitrite, total Kjeldahl nitrogen (TKN), orthophosphate as PO_4^{3-}, total phosphorous, *Escherichia coli*, and biochemical oxygen demand (BOD) (Table 4).

Analytic Methods

The analytic methods used on this project included six types of calculations: total taxa, total abundance, EPT taxa, EPT abundance, biotic index, and bioclassification value. A description of each of these analytic methods is provided below:

- The total taxa is the number of taxa or species identified during sampling effort. This measures the overall variety of the benthic macroinvertebrate assemblage.
- The total abundance is the number of individuals collected during the sampling effort.
- EPT taxa is the number of taxa or species from the orders of Ephemeroptera (mayflies), Plecoptera (stone flies), and Trichoptera (caddis flies).
- EPT abundance is the number of individuals from the EPT orders collected during the sampling event.
- The biotic index scores for each of the sites are a weighted average of the benthic macroinvertebrates tolerance values with respect to their abundance. The biotic index is scaled from 0.0 to 10.0 and represents the relative tolerance of the benthic community to the presence of general stressors. A low value indicates a more pristine/undisturbed environment, and a higher value indicates a stressed/disturbed/polluted environment.
- As part of this study, Acer utilized the bioclassification value system developed by the North Carolina Department of Environmental Quality to aid in describing the data at each site. This method utilized a range of data represented by nomenclatural values such as "Poor," "Fair," "Good-Fair," "Good," and "Excellent." Specifically, the small streams bioclassification method was utilized in locations where streams are less than 4 m in width. These streams are expected to have lower EPT taxa richness relative to larger streams (North Carolina Department of Environmental Quality 2016). Therefore, this method utilizes the biotic index values that were developed for small piedmont streams.

These values as related to biotic index values are as follows:

Bioclass Biotic Index Values

Excellent: <4.3

Good: 4.3–5.2

Good-Fair: 5.2–5.9

Fair: 6.0–6.9

Poor: >6.9

Results

Samples were collected on April 20 and April 21, 2017, in accordance with the "Methods for Multi-Habitat Benthic Macroinvertebrate Collections" sampling protocol required by the Commonwealth of Virginia (Virginia Department of Environmental Quality 2008). The collection of benthic macroinvertebrate includes sampling in and around the HabiTubes and Habi-Mats. This effort constitutes the first year of sampling at each station. All samples were collected during a dry weather period at base flow conditions that occurred for 2 weeks prior to sampling. (This occurred after a previous 3-week period of storms, high rainfalls, and flooding in the region). The results of the water quality analysis are provided in Tables 3 and 4.

The investigation results of the benthic macroinvertebrate samples (Tables 5-8), water quality samples, and visual observations are as follow:

- The benthic macroinvertebrate study found 64 taxa identified from all of the sites. Taxa abundance ranged from 34 to 225 individuals sampled at each of the sites for a total of 1,462 specimens collected during the entire project.
- At all of the sample locations, the HabiTubes and Habi-Mats improved the biotic index numbers. The scores moved from a Poor bioclassification value in the control to a Fair or Good-Fair score for the HabiTubes or Habi-Mats.
- The benthic fauna was dominated by the order Chironomidae, with 35 species (taxa) identified during this investigation, which constitutes more than half of the 64 taxa identified

Table 3. Field water quality measurements.

Stream	Water Temperature	pH	Dissolved Oxygen	Specific Conductivity	Barometer
Cow Branch 2	61.8°F	7.21	7.18 mg/L	741 µs/cm	762.5 mm/Hg
Cow Branch 4	68.3°F	6.92	8.16 mg/L	870 µs/cm	758 mm/Hg
East Longview	67.7°F	6.85	5.52 mg/L	300 µs/cm	757.3 mm/Hg
Dewey's Creek	65.2°F	7.02	7.88 mg/L	330 µs/cm	757 mm/Hg

Table 4. Laboratory water quality analysis (non-detect values shown as "<").

Analyte	Cow Branch 2	Cow Branch 4	East Longview	Dewey Creek
Nitrate as NO_3^-	<0.02 mg/L	<0.02 mg/L	<0.02 mg/L	<0.02 mg/L
Nitrite as NO_2^-	0.27 mg/L	0.29 mg/L	<0.18 mg/L	0.19 mg/L
Nitrate/Nitrite	0.27 mg/L	0.29 mg/L	<0.2 mg/L	Not analyzed
Total Kjeldahl Nitrogen	<0.5 mg/L	<0.5 mg/L	0.72 mg/L	<0.5 mg/L
Orthophosphate as PO_4^{3-}	<0.05 mg/L	<0.05 mg/L	<0.05 mg/L	<0.05 mg/L
Total Phosphorous	<0.05 mg/L	<0.05 mg/L	0.05 mg/L	<0.05 mg/L
Escherichia coli	90.8 CFU/100mL	30.1 CFU/100mL	114.5 CFU/100mL	133.3 CFU/100mL
Biochemical Oxygen Demand	<2mg/L	3 mg/L	5 mg/L	<2mg/L

in this study. The Chironomids were also the largest number of individuals, representing 1,307 specimens of the 1,462 total specimens collected. An interesting observation was the collection of an unusual species of Chironomidae (*Smittia* sp.) from a HabiTube sample at the Cow Branch 2 site. This midge is typically associated with hyporheic flow, suggesting that groundwater flow is occurring at this location.

- The benthic study observed only one mayfly found in a Habi-Mat sample from the East Longview site, whereas there the amount of stoneflies was zero.
- The review of the water physicochemical data indicated conductivity (Total Dissolved Solids) of all the streams were high. However, Cow Branch 2 and Cow Branch 4 were high, with specific conductivities at 640 µS/cm in Cow Branch 2 and 870 µS/cm in Cow Branch 4. Conductivity is the ability of water to conduct electricity. The presence of inorganic dissolved solids that have anions (e.g., chloride, nitrate, sulphate, phosphate) or cations (e.g., sodium, magnesium, calcium, iron aluminum) are usually considered high when any measurement exceeds 500 µS/cm (see Table 3). Once this limit is exceeded, the ability of benthic macroinvertebrates to function, grow, and breed becomes hindered.
- *E. coli* is not a direct stream quality measurement, but it can be utilized as an indicator of poor water quality in a stream. When it is detected in high concentrations, it is an indicator that other parameters or contaminants are very high (Maryland Department of Environmental Quality 2018). Three of the studied stream reaches had levels between 90 and 133 colony forming units (CFU)/100 ml (Table 4). A high *E. coli* concentration for water in Virginia is considered to be 126 CFU/100 ml (Virginia Department of Environmental Quality 2017). These organisms do not directly affect benthic macroinvertebrates.
- The East Longview site had a large algal bloom present (possibly resulting from a nutrient runoff from an adjacent plant nursery) and a foamy soap-like sheen (possibly related to a car wash operation upstream). The water level in this stream was very low and had slow movement through the reach. These conditions may have accounted for the high BOD results and higher TKN and phosphate concentrations compared to the other sites; however the nutrient concentrations are relatively low overall..
- The low water level and slow flow at the East Longview site resulted in the HabiTubes placed in this stream segment to be stranded out of the water. No data were taken directly from the HabiTubes because no water was on or in the bag to support the benthic macroinvertebrates.
- A very thick coating of iron flocculent on the streambed was observed at the Cow Branch 4 site. This coating covered the entire bottom area of the stream in the study reach. It resulted in a very slick coating that stained the water a reddish-orange and made walking in the stream treacherous. In the pool areas and eddies of the stream, there were large areas of underwater globs or wads of flocculent.

Table 5. Cow Branch 2 benthic macroinvertebrate results.

Parameter	Control/Baseline	Sample w. HabiTubes	HabiTubes Only	Sample w. Habi-Mats
Total Taxa	19	14	15	16
Total Abundance	149	73	152	145
EPT Taxa	2	2	2	2
EPT Abundance	9	10	11	10
Biotic Index	7.59	7.36	5.78	6.62
Bioclassification	Poor	Poor	Good-Fair	Fair

Table 6. Cow Branch 4 benthic macroinvertebrate results.

Parameter	Control/Baseline	Sample w. HabiTubes	HabiTubes Only	Sample w. Habi-Mats
Total Taxa	15	10	7	14
Total Abundance	96	65	92	50
EPT Taxa	0	0	0	1
EPT Abundance	0	0	0	1
Biotic Index	7.36	5.74	6.16	5.38
Bioclassification	Poor	Good-Fair	Fair	Good-Fair

Table 7. East Longview benthic macroinvertebrate results.

Parameter	Control/Baseline	Sample w. HabiTubes	HabiTubes Only*	Sample w. Habi-Mats
Total Taxa	10	11	0	11
Total Abundance	133	191	0	130
EPT Taxa	0	1	0	2
EPT Abundance	0	1	0	2
Biotic Index	7.64	7.76	0	8.48
Bioclassification	Poor	Poor	N/A	Poor

*HabiTubes were not sampled because they were stranded on the rocks in the stream and left out of the water by low water conditions.

Figure 7. Looking upstream from a Habi-Mat.

Figure 8. HabiTubes sampling area in Cow Branch 4. (Reddish color is iron flocculent.)

Table 8. Dewey's Creek benthic macroinvertebrate results.

Parameter	Control/Baseline	Sample w. HabiTubes	HabiTubes Only	Sample w. Habi-Mats
Total Taxa	10	19	14	18
Total Abundance	57	55	34	40
EPT Taxa	1	1	0	2
EPT Abundance	2	2	0	3
Biotic Index	7.15	7.36	6.79	6.92
Bioclassification	Poor	Poor	Fair	Fair

Figure 9. East Longview looking downstream at Habi-Mat.

Figure 10. Dewey Creek just after installing HabiTubes.

Summary and Conclusions

In summary, the streams that were utilized for this study have been negatively impacted by urbanization. The instream platforms allowed for the collection of more taxa that were not in the control/baseline samples and in turn resulted in an improved biotic index than the non-platform/control/baseline sampling. The improvement of the biotic index numerical values generally improved with the addition of the HabiTubes and Habi-Mats. The Bioclassification Value Categories improved from Poor to Fair or Good-Fair at several stream sites, which could be attributed to the amount of time the instream structures were available to benthic macroinvertebrates as a food source and habitat (i.e., the period between installation and removal of the platforms).

The HabiTubes and Habi-Mats exhibited better bioclassification values and biotic scores when compared to the baseline/control samples. This improvement could be due to the retention of organic material and stable instream habitat that the HabiTubes and Habi-Mats provide. The HabiTubes and Habi-Mats retained large amounts of organic material in the limbs woven into the mats and the natural accumulation of organics (leaves and plant material). The researchers noted from visual assessments that HabiTubes and Habi-Mats provided an increase in the retention of organic matter at the instream platforms and the area immediately downstream of the platforms. This encouraged and promoted more habitat and food sources to be retained for the aquatic organisms.

The lower numbers of benthic macroinvertebrates at the sampling sites may have been due to the impervious land use in these watersheds that only exacerbated storm flows and created increased scour of the substrate or sediment deposition. The storm flows removed some of the Habi-Mats from their locations and smothered HabiTubes and Habi-Mats with sediment. There was also a lack of attention and maintenance, such as cleaning the sediment off the platforms and resetting them in the substrate after each storm event. The increased sediment or burying of the instream platforms greatly reduce the amount and type of organisms that can utilize them. Other considerations for reduced benthic macroinvertebrate numbers could be the high anions or cations in the minerals from urban runoff that created extremely high conductivity readings in Cow Branch (U.S. Environmental Protection Agency n.d.).

The high iron content in the stream channel that was observed in Cow Branch 4 site is a common site in this region of Virginia. This is considered a natural condition, as the groundwater flows through shallow iron deposits and transports iron depositing it in the local surface water (Gooch, 1954). When the dissolved ferrous iron (Fe^{2+}) is exposed to the air in surface waters, it is oxidized to ferric iron (Fe^{3+}) and precipitates as iron(III) oxyhydroxides; this process consumes oxygen and results in an orange-colored precipitate (iron floc). In addition, iron bacteria incorporate the dissolved iron into their metabolic processes, forming the insoluble Fe^{3+}. This insoluble ferric iron is surrounded by filamentous bacteria colonies that create a sticky orange slime, which blankets the substrate. This results in increased conductivity and the loss of habitat for the benthic macroinvertebrates (Koski and Herrick 1999).

Cow Branch 2 had the highest number of taxa, abundance, and biotic index of all of the streams. The stream, restored 3 years ago, has established a good canopy cover, allowing for consistent detrital deposition. In previous years, this stream contained large amounts of iron precipitant and bacterial slime on the streambed. During the sampling, small pockets of precipitant and slime in the stream were seen.

The East Longview site, a recently restored stream segment, had little riparian vegetation at the time of the sampling effort. The East Longview sampling site did not have an eligible individual HabiTube to pull and sample because water levels in the stream fell below the level of the HabiTubes, leaving them stranded and dry on the rocks. In addition, soapy foam and algal mats were observed in the stream water.

Dewey's Creek and Cow Branch 4 are to be restored in the near future. Both streams exhibit signs of large sediment load deposits carried by flashy stream flows that are typical of urban channels. The Cow Branch 4 stream reach displayed large amounts of iron precipitant and slime throughout the sampled reach. In addition, the large storm flows in the 3 weeks prior to the sampling on Dewey's Creek buried the HabiTubes and ripped the Habi-Mats off of the bottom of the stream. HabiTube and Habi-Mat installers will need to be more diligent with their installation and maintenance of the platforms in the future.

The stream sampling effort on the four stream reaches did not provide the amount of data anticipated but provided interesting results. The instream platforms demonstrated that they could provide a habitat and food source, deliver an ecological improvement/boost (increasing the number of taxa), and improve the biotic index of the benthic macroinvertebrate population. Even though the streams are under great pressure from urbanization and storm events, their populations have the potential to improve from enhancing habitat and food sources. Stream restoration and riparian planting efforts will help to improve water quality, storm flow, and bed and bank stabilization; increase organic material input into the streams; and improve storm water management.

The improvement of habitat and food sources through instream platforms such as HabiTubes and Habi-Mats is a viable technique that is a fraction of the cost of conventional stream restoration practices. These platforms can be readily and cost effectively retrofitted into a stream within a short period of time. For the cost of placing a woody stream structure in a stream, many platforms can be placed in stream. If lost or destroyed by a storm, they can be quickly and cost-effectively replaced.

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