

Anthropogenic Debris Concentrations in the Beargrass Creek Watershed, Louisville, Kentucky: Litter Amounts, Composition, and Potential Conservation Solutions

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ABSTRACT

Beargrass Creek is one of the largest watersheds in Louisville, Kentucky, draining over 60 square miles within Louisville and outpouring into the Ohio River. The creek consists of three branches – the South, Middle, and Muddy forks – each flowing through a variety of residential and commercial areas as well as a multitude of parklands. Despite this creek's prominence in the city, little research has been done documenting the concentration of anthropogenic debris within its watershed. This study documents man-made debris accumulation at 15 sites located within the Louisville metropolitan area as a continuation of the work conducted by the University of Louisville Aqlan Lab in summer of 2022. The study assesses the debris build-up within the creek and establishes debris patterns in hopes of diminishing future buildups and improving conditions within this Louisville watershed. The amount of litter increased from June 2022 to July 2023, and litter amounts also increased during the summer of 2023. Middle Fork contained the highest total amount of debris, closely followed by South Fork. Plastic bottles, bags, and fragments made up over 70% of total litter, with glass (11%) and lumber (4%) being the second and third highest categories. The most common litter items were plastic bags, foam fragments, and food wrappers. Further analysis is still needed to investigate the magnitude, character, and sources of debris in Beargrass Creek across different seasons.

INTRODUCTION

Beargrass Creek is one of the largest watersheds in Louisville, Kentucky, draining over 60 square miles and flowing into the Ohio River (Figure 1). Beargrass Creek consists of three branches – South Fork, Middle Fork, and Muddy Fork, each containing unique features (Figure 2). South Fork runs around the southwestern side of Louisville, keeping west of I-65. It is characterized mainly by parklands and industrial landscapes. Middle Fork runs through the heart of Louisville, slightly east of I-65, and flows through residential areas and non-industrial commerce such as restaurants. Muddy Fork differs from both, running nearly parallel to the Ohio River on the north side of Louisville and flowing westward. This stream is characterized by sparse residential regions and is the most underdeveloped of the three forks,

despite also containing considerable industrial land use.

Because Beargrass Creek spans a significant portion of the Louisville metropolitan area and beyond the Inner Loop (I-264), this watershed is vital to Louisville's waterway health and access to outdoor recreation as it flows through many of the city's largest parks and neighborhoods. Since Louisville's founding in 1778, the creek has had a longstanding problem with pollution. We shall review prior research on debris, water quality, and land use; describe and analyze the current characteristics of anthropogenic debris within the watershed; and discuss potential solutions and future steps to help improve this vital waterway as the city continues to develop.

Anthropogenic Debris

Various studies document the impact of anthropogenic debris on stream health, in addition to documenting the composition of said debris (Walker et al. 2006; Honingh et al. 2020; Treilles et al. 2021; Winston et al. 2023).

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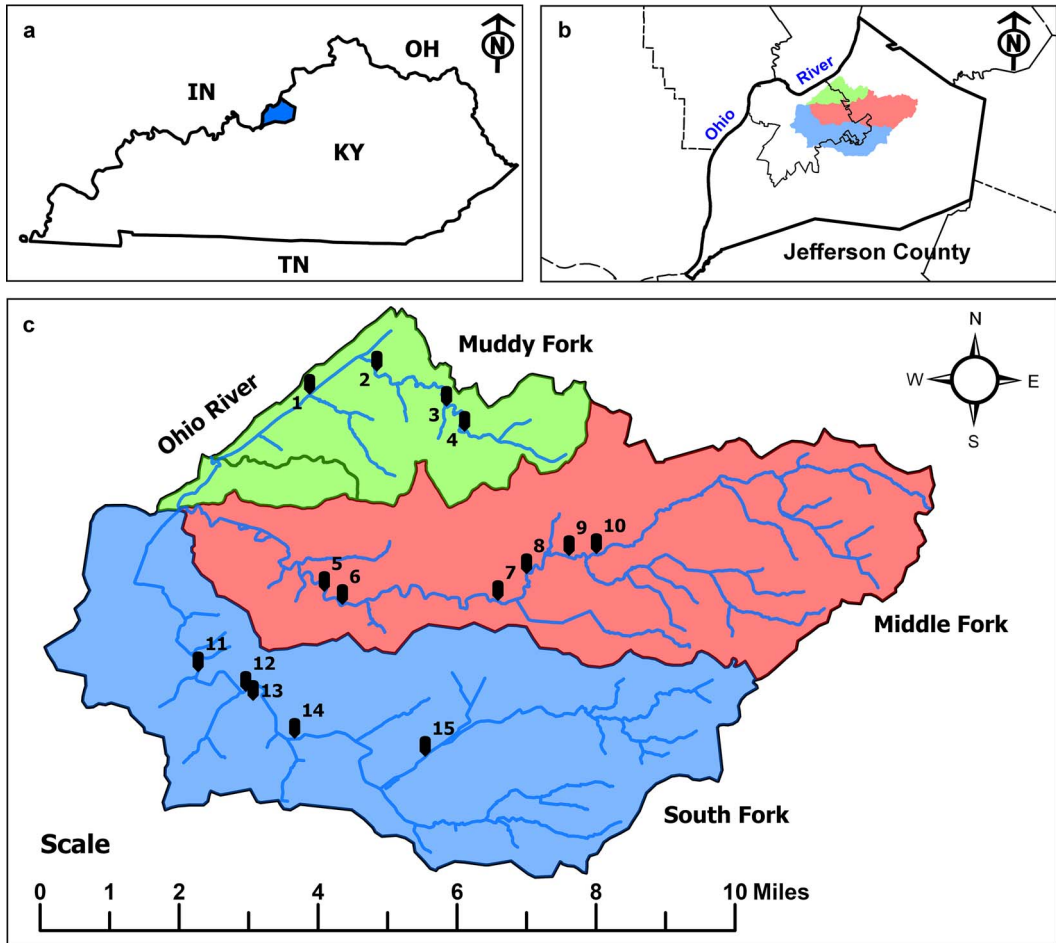


Figure 1. Maps showing the location of the study area. a) Location of Jefferson County, Kentucky that contains metropolitan Louisville. b) Map showing outline of the city Louisville within Jefferson County (bold) and the location of the Beargrass Creek watershed. Note that the Beargrass Creek watershed is located within the eastern part of metropolitan Louisville. c) Detailed map of the Beargrass Creek watershed showing the three forks of the watershed: Muddy Fork (green), Middle Fork (red), and South Fork (blue). Also shown are the streams within the watershed and the sampling sites used in this study.

Walker et al. (2006) examined monthly accumulation rates and varieties of marine debris washed ashore at a recreational beach in Point Pleasant Park, Halifax Harbour, Nova Scotia. Eighty-six percent of this debris was plastic material, including but not limited to plastic fast-food packaging, confectionary wrappers, Styrofoam fragments, and plastic bottles and caps. Similarly, Silva-Iniguez and Fischer (2003) classified litter types at Municipal Beach of Ensenada, Baja California, Mexico from April to August 2000, collecting 16,474 objects (both naturally-occurring and anthropogenic

debris). Wood was the most numerous debris type, making up 34.73% of debris collected, whereas plastics, such as bags, bottles, and synthetic materials made up 16.30% of debris. Finally, glass (flasks, bottles, and broken glass) made up 11.86%. Silva-Iniguez and Fischer (2003) note that human activity resulted in higher concentrations of all types of anthropogenic litter.

Walker et al. (2006) further provides evidence of the influence of human activity. A majority of plastic materials (52%) in their study were generated by recreational use of the park, while

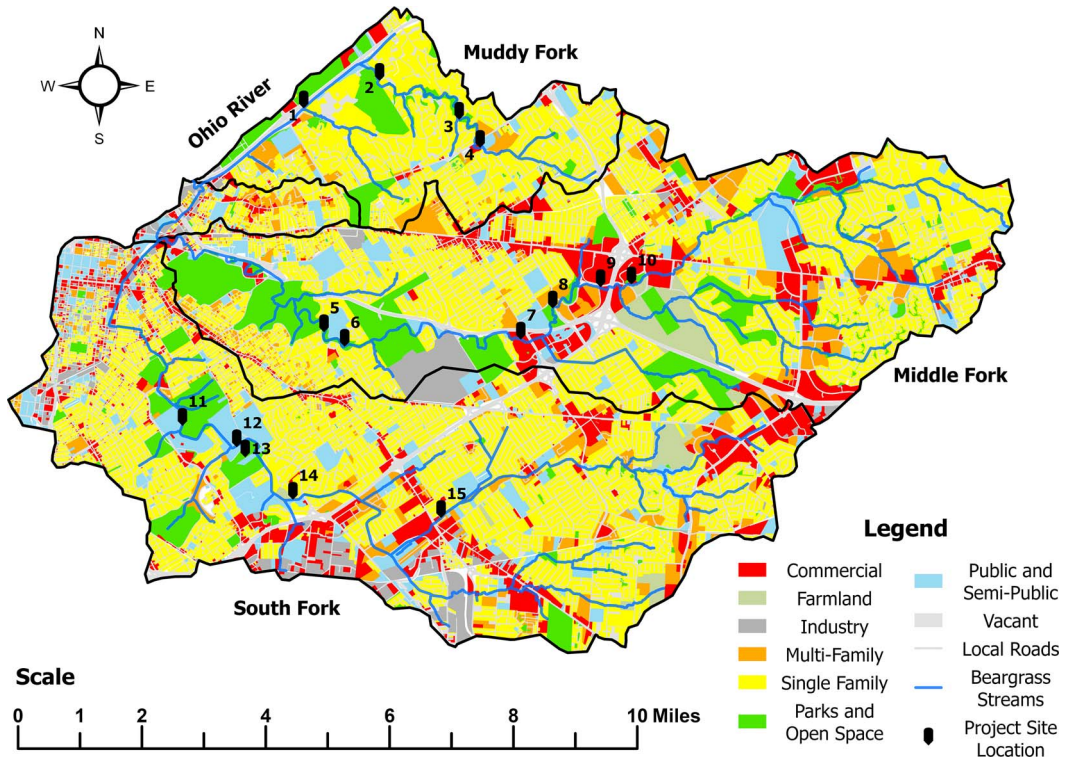


Figure 2. Land use map of the Beargrass Creek watershed, color coded according to the legend. The Muddy, Middle, and South sub-watersheds are divided by bold, solid lines. Sample locations are also shown and are the same as appearing in Figure 1 and listed in Table 1. Land use data sourced from ArcGIS online portal.

sewage disposal and shipping/fishing activities generated 14% and 7% of debris. Kim *et al.* (2006) similarly found that 10% of total captured gross items (both natural and anthropogenic debris) from roadside runoff in southern California were man-made, further suggesting the relationship between human activity and anthropogenic debris.

Anthropogenic debris is not only unsightly but also changes stream hydraulics. Honingh *et al.* (2020) discovered that plastic debris could increase flood risk in urban areas, causing more effective blockages than organic matter. Plastic trash build-ups have lower porosity and therefore have a higher blockage efficiency. Upon further analysis, Clamann *et al.* (2022) concluded that trash presence is more strongly influenced by stream roughness (mainly riparian vegetation) than by source inputs. No significant relationships were found between potential sources and the amount of anthropogenic debris.

Beargrass Creek Watershed

The United States Army Corp of Engineers (2022) conducted the most recent, prominent, Louisville-based project related to our study. Their primary goal was to restore both in-stream and riparian habitat within the Beargrass Creek watershed with the overarching purpose of providing habitat for threatened and endangered species. Potential actions associated with improving biodiversity and habitat include eradication and excavation of invasive species as well as restoring natural rock outcrops, establishing native plants, and constructing woody debris dams and other water control structures within creek beds and surrounding environments (USACE 2022). The study serves as a blueprint for stream restoration within the Beargrass Creek watershed.

A pilot investigation related to our study was conducted by Aqlan *et al.* (2022) in association with the University of Louisville. Over a two-month period, interns traveled to various locations along the creek, and tracked

Table 1. List and coordinates of sampling sites in the Beargrass Creek watershed. Louisville Metropolitan Sewage District is labeled as MSD here and in all following tables and figures. See Figure 1 for map of sub-watersheds and site locations.

Site number	Fork	Site name	Latitude	Longitude
1	Muddy	Mellwood Avenue	38.27656°N	85.69359°W
2	Muddy	Indian Hills	38.28068°N	85.67471°W
3	Muddy	Northwind Road	38.27465°N	85.65700°W
4	Muddy	Louisville MSD	38.26988°N	85.65131°W
5	Middle	Cherokee Park	38.23618°N	85.68802°W
6	Middle	Big Rock	38.23285°N	85.68378°W
7	Middle	First Watch	38.23443°N	85.64288°W
8	Middle	Brown Park	38.23995°N	85.63501°W
9	Middle	St. Matthews	38.24379°N	85.62415°W
10	Middle	Top Golf	38.24431°N	85.61645°W
11	South	St. Xavier	38.21732°N	85.72205°W
12	South	Bellarmine	38.21458°N	85.70917°W
13	South	Joe Creason	38.21277°N	85.70646°W
14	South	Schuff Lane	38.20483°N	85.69499°W
15	South	Hikes Lane	38.20144°N	85.66106°W

macroplastic litter using the National Geographic Marine Debris Tracker mobile app on a trash-per-mile basis. They concluded that major contributors to the debris pollution of the watershed were surface runoff and sewage. People throwing trash straight into or near the creek had a significantly lower impact (Aqlan et al. 2022).

Our Study

While litter composition has been thoroughly examined in coastal regions, little research has been published to analyze the accumulation of debris within metropolitan waterways. The purpose of our study was to provide initial documentation of the concentration and composition of man-made debris/litter at 15 sites located within the Louisville metropolitan area (Table 1, Figure 1).

The goals for our study were fourfold: 1) to measure litter concentration within the three forks of Beargrass Creek; 2) to assess litter composition (plastic, metal, etc.); 3) to note any correlations between land use to debris concentration; and 4) to analyze litter concentration over time, utilizing data from Aqlan et al. (2022). Our aim is to use this information to ultimately diminish debris build-ups in Beargrass Creek and improve its overall condition with reference to debris contamination.

METHODS

Our study combines data from Aqlan et al. (2022) and from our data collection efforts in

summer 2023. In 2022, Aqlan et al. collected data on a trash-per-mile basis to identify trends and hotspots of debris accumulation within the three forks of Beargrass Creek. In 2023, we utilized a different methodology to be more efficient. Researchers noted three main variables at all 15 sites: 1) total amount of trash, 2) type of trash, and 3) habitat quality. Amount of trash and type of trash allowed the team to compare 2023 data to the 2022 data set to assess similarities and differences. The stream habitat assessment allowed the team to measure how different sites with different land uses and channel characteristics impacted the creek’s debris accumulation.

To measure these data, researchers utilized the National Geographic Marine Debris Tracker mobile app. This application works on a mobile phone and allows field workers to enter and tabulate GPS position, trash type, trash location, and trash quantity for each site (National Geographic 2021). For the habitat criteria, we utilized the Stream Corridor Assessment, a protocol created by the Maryland Department of Natural Resources (2016) (Appendix A). This protocol was chosen because it was standardized, was the most accessible, was straight-forward, and assessed channel characteristics.

Research sites were chosen based on the following criteria: replication, accessibility, and land usage (Table 1, Figure 1). In terms of replication, we re-occupied seven of the 15 sites used by Aqlan et al. (2022). All 2022 sites were not used due to alterations in data collection methodology and overall goals of the project. Aqlan et al. (2022) focused on gathering a broad

data set for 11 sites, tracking general debris across a one-mile diameter. In 2023, we focused on 15 sites and limited the range data collection to a diameter of 400 meters around each entry point. This method of gathering data allowed for more efficient data collection and analysis over the course of five visitations.

The second criterion for choosing the 2023 research sites was accessibility. Many stream channels within the Inner Circle (I-264) of Louisville, Kentucky have been straightened or deforested. Consequentially, the banks are often heavily eroded, making data collection difficult at many urban creek entry points. Sites were thus chosen based on ability to safely descend into the creek beds. The steepest descents were 70- to 90-degree slopes at Sites 1, 2, 4, and 5; however, these sites were still chosen to analyze how creek channelization, stream flow, and adjacent industrialization impacts debris accumulation and water quality.

Lastly, our sampling sites cover a variety of land uses to assess whether there was a relationship between land usage and total amount of debris at each site and, consequently, within each fork of Beargrass Creek. Examples of land uses include agricultural, industrial, residential, and parklands (Figure 2).

Once sites were chosen, data collection was divided amongst the three researchers. At each site, one researcher would document debris up to 200 meters upstream and another researcher would do the same downstream. The third would collect water quality data, which is not addressed in this paper. Non-natural litter, such as plastics, glass, rubber, etc., were identified and documented by type in the National Geographic Marine Debris Tracker app. The application would then collate data to include location of debris, total debris amounts, and debris composition.

Each site was visited five times during the study, five to seven days apart. Additionally, data was collected between 9:30 AM and 4:00 PM for each site, with data being recorded and compiled into graphs via *Microsoft Excel* at the end of each day. ArcGIS was used to analyze any relationship between debris concentration to infrastructure and topography near site locations. Habitat assessments were also completed by the third researcher at each site during each visit.

It is important to note that debris was not collected during the study. As such, many pieces of litter were documented multiple times if they remained at a specific location. Unfortunately, we were unable to document debris movement over time.

Our data analysis focuses on the three primary aspects presented above: debris concentration, debris composition, and habitat quality. Firstly, the data on debris concentration involves mapping the spatial distribution of debris across the study area, identifying both high and low concentration zones and examining patterns or clusters. We also explore temporal variability to understand how debris concentration fluctuates over time, from 2022 to 2023 and also during the summer of 2023. For debris composition, we categorize the anthropogenic debris by material types and analyze their proportions within the total debris collected. Finally, the habitat quality assessment evaluates stream characteristics such as erosion, turbidity, vegetation cover, and stream flow that may affect debris accumulation. Together, these analyses aim to provide a comprehensive understanding of debris impacts on the environment, informing strategies for mitigation and conservation.

RESULTS

Debris Concentration in Beargrass Creek

Overall, 6,918 pieces of litter were observed between 26 June and 31 July 2023 (Tables 2, 3). From site to site, litter amounts range from 11 to 209 pieces with a median litter value of 78 pieces and a mean and standard deviation of 92 ± 60 pieces.

The stream with the largest amount of litter is Middle Fork (3,351 pieces total with an average number of 111.8 pieces per visit) closely followed by South Fork (2,914 pieces total, an average of 116.6 pieces per visit) (Table 2). Muddy Fork had far less debris with only 653 pieces of debris total and an average amount of 32.6 pieces (Table 2). Regarding the lowest sample counts, Muddy Fork samples occupy 17 of 22 samples (77%; Table 2). The difference between Muddy Fork and Middle Fork debris totals are statistically significant with a p-value of less than 0.0001 at the 95% confidence interval using a two-tailed, unpaired t-test. Similarly, the difference between Muddy Fork and South

Table 2. Total amount of trash, counted piece-by-piece, within each sub-watershed of Beargrass Creek. Values in italics within parentheses are average number of pieces of trash per location per visit in that sub-watershed. See Figure 1 for map of sub-watersheds.

Beargrass Creek site visit	South Fork	Middle Fork	Muddy Fork	Total
Visit 1	398 (79.6) Date: 6/28/2023	529 (88.2) Date: 6/30/2023	102 (25.5) Date: 7/5/2023	1,029 (64.4)
Visit 2	507 (101.4) Date: 7/6/2023	540 (90.0) Date: 7/7/2023	111 (27.8) Date: 7/10/2023	1,158 (73.1)
Visit 3	650 (130.0) Date: 7/13/2023	717 (119.5) Date: 7/14/2023	142 (35.5) Date: 7/17/2023	1,509 (95.0)
Visit 4	691 (138.2) Date: 7/20/2023	744 (124.0) Date: 7/21/2023	153 (38.3) Date: 7/24/2023	1,588 (100.2)
Visit 5	668 (133.6) Date: 7/27/2023	821 (136.8) Date: 7/28/2023	145 (36.3) Date: 7/31/2023	1,634 (102.2)
Total	2,914 (116.6)	3,351 (111.8)	653 (32.6)	6,918 (87.0)

Fork debris totals are also statistically significant with a p-value of <0.0001.

Additionally, each fork had specific patterns of debris concentration (Figure 4). Middle Fork contains the majority of higher litter concentration sites, whereas Muddy Fork contains the majority of lower litter concentration sites (Table 3, Figure 4). Sites with the highest amount of litter are Joe Creason (209, 204, and 188 pieces; South Fork), St. Matthews (209 pieces; Middle Fork), Cherokee Park (204 pieces, Middle Fork), and First Watch (199 and 199 pieces; Middle Fork) (Table 3, Figure 4). Sites with the lowest amount of litter are Indian Hills (13, 13, and 22 pieces; Muddy Fork), Mellwood Avenue (17, 19, and 20 pieces; Muddy Fork), and Northwind Road (23 and 28 pieces; Muddy Fork) (Table 3, Figure 4). South Fork

frequently contains moderate litter concentrations, including Schuff Lane (71, 89, and 99 pieces), St. Xavier (51, 71, and 124 pieces), and Bellarmine (60, 142, and 175 pieces) (Table 3).

Debris Composition

The top three debris materials found within Beargrass Creek were plastic, metal, and paper/lumber along with glass, rubber, cloth, and other miscellaneous materials (e.g., surgical masks/gloves and PPE) (Figure 5). The most common debris documented was plastic bags, followed by plastic fragments from various objects such as food wrappers, water bottles, etc. Overall, plastic made-up over 73% of the total litter observed, with metal making up 11.35% and paper/lumber making up 4.16% (Figure 5a). The most common metal objects observed were

Table 3. Amount of debris, counted piece-by-piece, per site per visit. First five sites are South Fork, next six sites are Middle Fork, and the last four sites are Muddy Fork. See Table 1 for site numbers and coordinates. See Figure 1 for a map of Beargrass Creek watershed and site locations.

Sub-Watershed	Site	Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Average
Muddy	Mellwood Avenue	19	20	20	31	17	21
Muddy	Indian Hills	13	13	26	22	31	21
Muddy	Northwind Road	34	41	39	28	23	33
Muddy	Louisville MSD	36	37	57	72	74	55
Middle	Cherokee Park	176	101	125	121	204	145
Middle	Big Rock	11	53	50	62	78	50
Middle	First Watch	140	119	199	167	199	164
Middle	Brown Park	22	37	47	68	47	44
Middle	St. Matthews	136	104	142	209	155	149
Middle	Top Golf	44	126	154	117	138	115
South	St. Xavier	133	63	71	51	124	88
South	Bellarmine	26	174	60	175	142	115
South	Joe Creason	117	89	209	204	188	161
South	Schuff Lane	30	71	148	99	89	87
South	Hikes Lane	92	110	162	162	125	130

fencing wire followed by aluminum cans and metal fragments. Lumber was in the form of building materials such as wooden planks, and paper was in the form of paper wrappers and paper towel-like fragments. However, Muddy Fork deviated from this trend with a more varied distribution of material types as compared to the Middle and South Forks – it had a decreased amount of plastic (55.59%) and more glass (12.1%), rubber (4.13%), and lumber (10.26%) (Figure 5b).

Habitat Assessment

Habitat assessments were utilized to rate the hydraulic properties of water flow at each site such as channel alteration, stream bed material, and erosion that may influence debris concentrations. Bellarmine (South Fork) and Big Rock (Middle Fork) both received relatively high habitat assessment scores of 29 (Figure 6). Cherokee Park, despite being less than a mile away from Big Rock (both Middle Fork), received a score of 27, with Hikes Lane (South Fork) and Brown Park (Middle Fork) both receiving scores of 23. The lowest score occurs at First Watch with an average score of 17.

DISCUSSION

As part of metropolitan Louisville, the Beargrass Creek watershed is heavily influenced by human activities that impact man-made debris within its streams. Obviously, humans are the source of anthropogenic litter with human activity also determining land use and affecting stream channel properties and habitat quality (e.g., Silva-Iñiguez and Fischer 2003; Walker *et al.* 2006; Clamann *et al.*, 2022; McLaughlin *et al.*, 2023). These differences in drainage landscape makeup allow us to link the debris types and concentrations within each fork to land use as well as proximity to major roads, parkland, and shopping areas.

At the watershed-scale, the South and Middle sub-watersheds have the highest amount of development that translates into significantly higher amounts of litter (Table 2, Figures 2, 3, 4). The South Fork contained slightly less litter than the Middle Fork despite having a higher average, suggesting that significant variation occurs from site-to-site over the study period (Table 2, Figure 4).

The Muddy Fork sub-watershed is less developed and displays roughly a quarter the amount of litter compared to the developed forks (Table 2, Figures 2, 3, 4). This trend also persists at the site-level with the top 38 instances (~45%, $N = 85$) of litter concentration occurring in the South or Middle Forks (Figure 4). The lowest debris concentrations occur in the Muddy Fork, accounting for the bottom 16 of 22 occurrences ($N = 85$; Figure 4).

At the site scale, proximity to population centers and major thoroughfares likely broadly determine debris amounts. The Joe Creason, Bellarmine, and Hikes Lane sites of the South Fork consistently show high debris concentrations, as do the St. Matthews, Cherokee Park, and First Watch sites of the Middle Fork (Figure 4). All these listed locations are in areas of high foot traffic and human activity, near busy roads, and in environments where stream clean-ups are not typically conducted due to steep banks and low accessibility (Figures 2, 3). For example, the Joe Creason and Cherokee Park sites are in parks and should exhibit less debris; however, these sites were in areas with low accessibility, steep banks, and close to main roads, resulting in high debris accumulation due to source proximity and difficult terrain. The First Watch, Bellarmine, and Hikes Lane sites are all in similarly heavily trafficked, commercial areas off main roads and thus consistent with high debris accumulation (Figures 2, 3).

It is worth noting that the Louisville MSD site (Figure 1) is the only sampling location of the Muddy Fork with trash accumulation at the same level of intensity as the highly-developed forks. Unlike the other Muddy Fork sites, Louisville MSD is off Brownsboro Road, a main route closer to commercial areas, and contains steeper banks (Figure 2). Other sites within the Muddy Fork have low debris count probably because they are in more residential, less-developed neighborhoods.

Results from Aqlan *et al.* (2022) support our findings. For example, despite different data collection methodologies, the top site of Aqlan *et al.* (2022) (Confluence) reflects similar characteristics with our study's top site (First Watch). Both sites are in heavily-trafficked areas near busy roads and are not in environments where clean-ups are usually conducted due to steep banks and low accessibility. Finally, both sites exhibit

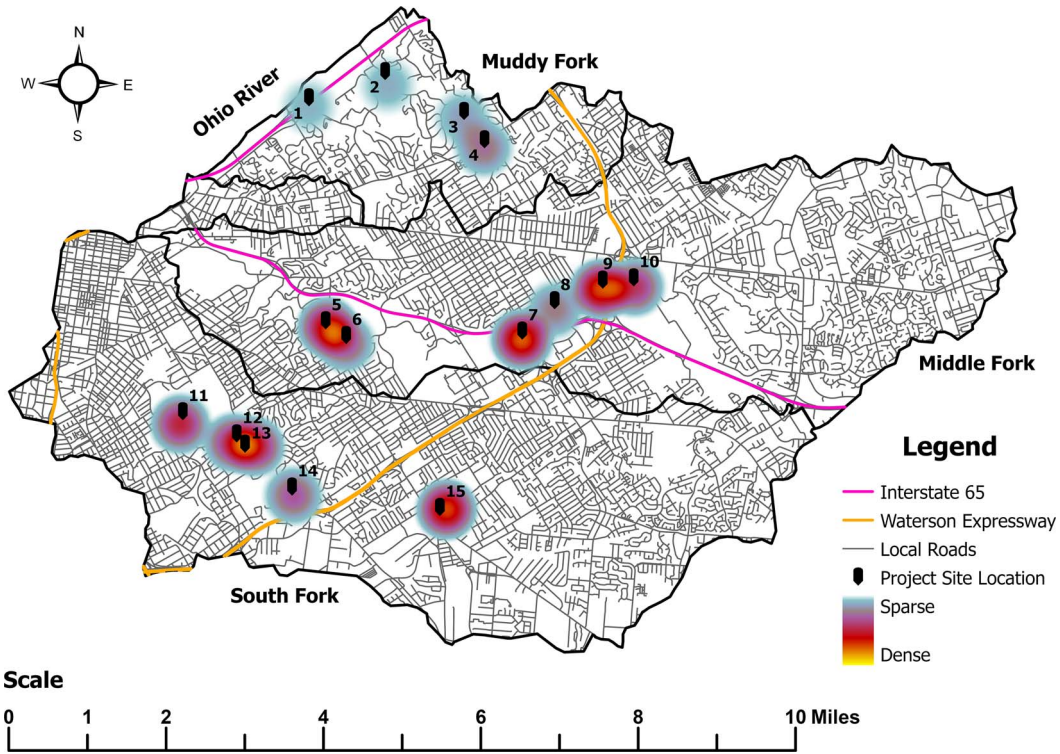


Figure 3. Map displaying the relative concentration of debris at each data collection site (see Table 1). Note the higher density of debris characteristic of Middle Fork, the higher debris sites in South Fork, and the lower amounts of debris in Muddy Fork. Public roadside data sourced from ArcGIS online portal.

build-ups of natural debris consisting of large tree trunks, limbs, sticks, and other woody material accumulating around bridges with narrow straits. Interestingly, Aqlan et al. (2022) found that the Confluence, Hikes Lane, and St. Xavier sites were the top three sites for trash accumulation, differing only slightly from 2023 results but showing the dynamic nature of debris build-ups. The amount of litter at any given site may change over time but sites placed near hotspots for human activity recurrently exhibit higher litter counts. Low-debris sites within Muddy Fork remained consistent across both studies.

Debris Type

The material composition of debris accumulations should be reflective of proximity to their source and perhaps their hydrodynamic properties. Plastic litter is the most common material in all three sub-watersheds likely because of its wide utility in society, low density, and

easy transport. Likewise, Aqlan et al. (2022) found that plastics were by far the most common material, making up approximately 80% of their collected debris. Denser items such as metals, including aluminum containers, pipes, and electronics, appear to accumulate closer to their point of origin. Metal debris is the next most common litter type and occurs in similar amounts in all the forks (Figure 5). The remaining litter categories – lumber, glass, cloth, rubber, and other materials – each accounted for less than 5% of the total debris recorded and exhibited roughly the same abundance within the South and Middle forks.

Muddy Fork deviates from this overall trend with a lower proportion of plastics and higher fractions of other materials. Plastic accounted for only 55.59% of documented debris, while glass made up 12.1%, paper and lumber 10.26%, and rubber 4.13%. Although Muddy Fork is less developed, its proximity to litter sources makes it

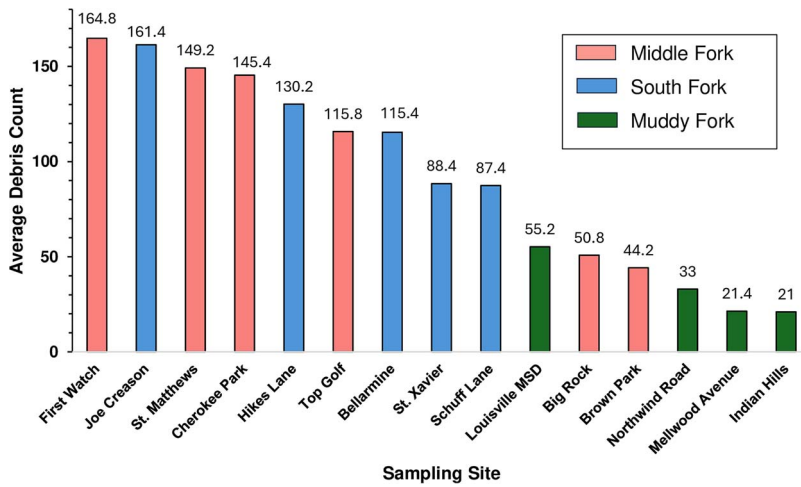


Figure 4. Graph of anthropogenic debris averages by site and sub-watershed (Table 3). Note that the highest amounts of litter occur in the Middle and South forks, which have similar litter amounts. Much lower debris amounts occur in the Muddy Fork.

more vulnerable to glass, paper, and rubber pollution. These materials are often discarded carelessly and occur within channelized areas, private properties, and wooded spaces.

Riparian Habitat

There seems to be little correlation between habitat assessment scores and debris concentration. Although the highest average debris score at First Watch (Middle Fork) does indeed have the worst habitat assessment (17; Figure 6), Cherokee (Middle Fork) has the fourth largest debris amount with a good habit score (27). Other high accumulation sites, Joe Creason (second highest; Figures 4, 6) and St. Matthews (third highest), have habitat scores of 21 (Figure 6) so that sites with the highest debris amounts span a range of habitat scores. Moreover low-debris sites like Indian Hills and Northwind (both Muddy Fork) have poorer habitat scores of 21 and 22, respectively with low debris counts (Figure 6). The habitat assessment index we use (Maryland Department of Natural Resources, 2016) contains criteria for channel character, stream flow, and riparian buffer but other factors within the instrument only loosely connect stream transport characteristics to land usage and contain no assessment of litter sources. Thus, we find that the index criteria does not assess debris sources or accumulation adequately.

Debris Mitigation

Several techniques have been implemented elsewhere to limit the amount of made-made debris entering and being transported by stream systems. These include the use of catch basins, inlet trash capture technologies, linear radial devices, end-of-pipe netting, and other trash traps such as litter booms (or “litter gitters”). Catch basins (or storm drains) are drainage structures that gather trash, preventing its downstream transport. Inlet trash capture technologies such as outlet screens, catch basin hoods, and fabric inserts can be placed inside storm drains and block trash from entering stormwater intake pipes (EPA 2017). These inserts are fairly cheap and easy to install and use.

A more substantial technology includes in-line devices, which capture and remove debris directly from a waterway. A linear radial device, for example, is a cement, vault-based, rigid, louvered linear screen cage. Stormwater and trash enter the cage and the trash is contained within. They are ideal for narrow and flat-water courses with limited space, and are commonly utilized in linear systems such as transit corridors. The Environmental Protection Agency (2017) reported that the City of Los Angeles captured about 2.5 million pounds of trash by constructing over 38,000 catch basins and using about 15 large, in-line devices. Such

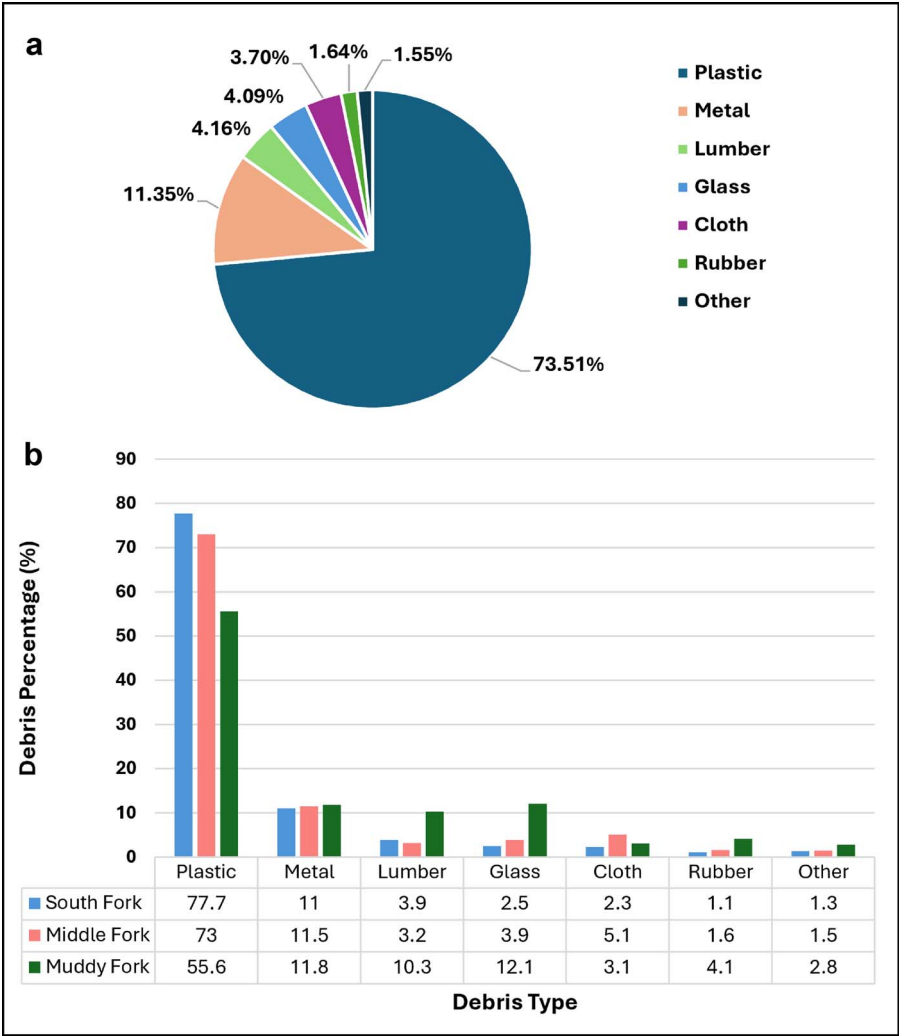


Figure 5. Graphs showing debris types within the Beargrass Creek watershed. a) Pie chart showing the abundance of each debris type. b) Distribution of debris types in per cent within each sub-watershed.

success has been repeated in several other cities (EPA, 2017) and could be useful at sites within Beargrass Creek, at its confluence with the Ohio River, or at the confluence of the three forks.

Smaller-scale techniques to trap trash include “litter gitter” devices. There are many available styles, but litter gitters are open-water, floating devices that collect litter, preventing it from continuing downstream. Litter gitters have been employed with success at Georgia’s Proctor Creek and Alabama’s Three Mile Creek (EPA 2023) — two locations that share

many similarities with Beargrass Creek. Sites with heavy litter concentrations, such as Joe Creason (South Fork) and First Watch (Middle Fork), are likely sites for the installment of appropriate litter gitter devices.

Community involvement is often essential in implementing indirect solutions to debris sources and transport, and to stormwater runoff (Walker et al. 2006). As an example of effective community engagement, the Bronx River Alliance Project WASTE (Waterway and Street Trash Elimination) has removed more than 200,000 debris pieces from the Bronx River, engaging over 1,300

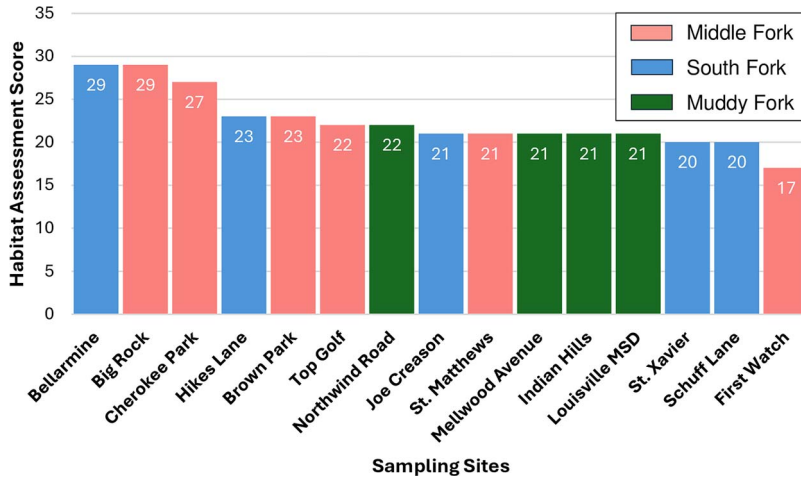


Figure 6. Average habitat assessment scores for all 15 sites. See Appendix A for the habitat assessment criteria and form.

students, educators, volunteers, and interested citizens (EPA 2023). This community effort utilized two litter gitters, situated at different sections of the river, to hold the trash prior to collection.

Meijer *et al.* (2021) focused on plastics delivered to the ocean by riverine systems and found that only about 1,000 rivers worldwide account for about 80% of the global amount of plastics that eventually enter the oceans. Urban rivers, like Beargrass Creek, are the biggest polluters. Therefore, mitigating entry and transport of man-made debris within streams can not only decrease trash within streams locally, but also have cumulative effects for larger systems.

Study Caveats

This study gives a substantive snapshot of man-made debris quantity and composition but only systematically samples the Beargrass watershed during the summer months and only for 2023. Aqlan *et al.* (2022) occupied many of the same sites, but only adds data from an additional summer sampling period. The detailed pattern of debris accumulation differs between the two studies, suggesting that considerable variation indeed occurs, highlighting the need for more perspective. We envision a longitudinal sampling effort spanning subsequent years that gives a more complete view of debris accumulation and sources. Moreover, such an effort can assess any mitigation efforts that are implemented within the watershed.

CONCLUSION

Our study is a continuation of a pilot investigation by Aqlan *et al.* (2022) that aims to identify sources and amounts of anthropogenic debris in the Beargrass Creek watershed, a metropolitan stream system in Louisville, Kentucky. Human activity controls the amount and type of litter that enter stream systems by determining land use in terms of human developments, location of major thoroughfares, etc. Middle Fork and South Fork are highly developed and consequently contain higher anthropogenic debris accumulations whereas Muddy Fork contains the least debris because of less development. Plastics are the most common type of litter found in the streams, comprising about 73.5% of all debris because of its wide utility in society, low density, easy transport, and slow decomposition. Acting to reduce litter in small and large urban waterways with feasible action plans can have a significant impact on global occurrences of plastic waste.

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LITERATURE CITED

- Aqlan et al. 2022. Pilot study. Unpublished.
- Clamann, A., M. Scoggins, J. Collins, and J. Walker. 2022. Trash in creeks: A field survey of trash intensity and source types in Austin, Texas. RR-22-01. <https://services.austintexas.gov/edims/document.cfm?id=396554>.
- EPA (Environmental Protection Agency). 2023. Trash capture projects. United States Environmental Protection Agency. Web page available at: <https://www.epa.gov/trash-free-waters/trash-capture-projects>.
- EPA (Environmental Protection Agency). 2017. The Clean Water Act and trash-free waters. United States Environmental Protection Agency. Web page available at: https://19january2017snapshot.epa.gov/trash-free-waters/clean-water-act-and-trash-free-waters_.html.
- Honingh, D., T. van Emmerik, W. Uijttewaal, H. Kardhana, O. Hoes, and N. van de Giesen. 2020. Urban river water level increase through plastic waste accumulation at a rack structure [brief research report]. *Frontiers in Earth Science*, 8. <https://doi.org/10.3389/feart.2020.00028>.
- Kim, L.H., J. Kang, M. Kayhanian, K.I. Gil, M.K. Stenstrom, and K.D. Zoh. 2006. Characteristics of litter waste in highway storm runoff. *Water Science & Technology*, 52(2), 225–234. <https://iwaponline.com/wst/article-abstract/53/2/225/12605/Characteristics-of-litter-waste-in-highway-storm>.
- Maryland Department of Natural Resources. 2016. Stream corridor and habitat assessment data sheet stream. Maryland Department of Natural Resources: 3–4. Online pdf available at: https://dnr.maryland.gov/education/Documents/StudentDataSheet_Coastal.pdf.
- McLaughlin, K., R. Mazor, M. Sutula, and K. Schiff. 2023. Regional assessment of trash in Southern California coastal watersheds, United States [Original Research]. *Frontiers in Environmental Science*, 11. <https://doi.org/10.3389/fenvs.2023.1210201>.
- Meijer, L.J.J., van Emmerik, T., van der Ent, R., Schmidt, C., and Lebreton, L. 2021. More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances*, 7(18), eaaz5803. <https://doi.org/10.1126/sciadv.aaz5803>.
- National Geographic. 2021. Debris tracker citizen science to local action guide. National Geographic. Online pdf available at: https://www.nationalgeographic.org/wp-content/uploads/2023/08/Debris_Tracker_Citizen_Science_-_Action_Guide_Update_12.23.21.pdf.
- Silva-Iníiguez, L., and D.W. Fischer. 2003. Quantification and classification of marine litter on the municipal beach of Ensenada, Baja California, Mexico. *Marine Pollution Bulletin*, 46, 132–138. https://www.researchgate.net/profile/Silva-Iniguez-Lidia/publication/10943526_Quantification_and_classification_of_marine_litter_on_the_municipal_beach_of_Ensenada_Baja_California_Mexico/links/5b610bad458515c4b256d2d8/Quantification-and-classification-of-marine-litter-on-the-municipal-beach-of-Ensenada-Baja-California-Mexico.pdf.
- Treilles, R., J. Gasperi, M. Saad, R. Tramoy, J. Breton, A. Rabier, and B. Tassin. 2021. Abundance, composition and fluxes of plastic debris and other macrolitter in urban runoff in a suburban catchment of Greater Paris. *Water Research*, 192. <https://www.sciencedirect.com/science/article/abs/pii/S0043135421000452>.
- United States Army Corps of Engineers (USACE). 2022. Three forks of Beargrass Creek ecosystem restoration feasibility study. US Army Corps of Engineers Louisville District Website. Available at: https://www.lrl.usace.army.mil/Portals/64/docs/CWProjects/Planning/Beargrass%20Placemat_20%20Apr%202022.pdf?ver=82DVIV1vq6q6nqRYSCkxw%3d%3d.
- Walker, Tony R., J. Grant, and M. Archambault. 2006. Accumulation of marine debris on an intertidal beach in an Urban Park (Halifax Harbour, Nova Scotia). *Water Quality Research Journal*, 41(3), 256–262. <https://iwaponline.com/wqrj/article/41/3/256/39831/Accumulation-of-Marine-Debris-on-an-Intertidal>.
- Winston, R.J., J.D. Witter, R.A. Tirpak, L. Sester, H. Jenkins, and V. Lillard. 2023. Abundance and composition of anthropogenic macrolitter and natural debris in road runoff in Ohio, USA. *Water Research*, 239. <https://www.sciencedirect.com/science/article/abs/pii/S0043135423004724>.

APPENDIX

Appendix A. Criteria used to assess stream habitat quality, which we used to assess channel properties. Developed by the Maryland Department of Natural Resources (2016).

Physical Assessment: Stream Corridor Assessment

Based on Stream Corridor Assessment protocols developed by Kenneth Yetman, adapted by Amanda Sullivan and Alison Armocida, MD Department of Natural Resources.

Instructions: Observe the stream habitat in and around the water and use the accompanying Stream Corridor Assessment [photographs](#) to rank each characteristic. Based on your findings, you will give your stream habitat a rating.

CHARACTERISTIC	Good (4)	Fair (3)	Marginal (2)	Poor (1)	Score
Floodplain Vegetation	Lots of plants, bushes, and trees along banks and floodplain.	Some plants, bushes, and trees along banks and floodplain.	Most trees and bushes are gone.	Very little plant life at all along banks and floodplain.	
Channel Alteration	Channel formed by natural processes and allowed to bend often around rocks and wood.	Channel straightened in some places but some natural bends are still present.	Channel mostly straightened but vegetation still present and no cement.	Channel straightened and flowing along a paved channel.	
Embeddedness – Are there rocks on the bottom covered in silt?	Rocks and cobbles cover almost all of the stream bed. Very little sand or silt between rocks.	Rocks and cobbles cover most of the stream bed. Some sand/silt between and on rocks.	Rocks and cobbles more than halfway buried (embedded) into sand/silt.	Rocks and cobbles entirely buried by sand and silt.	
Erosion	Banks only slightly above the surface of the water.	Banks somewhat higher above the surface of the water.	Banks significantly above the surface of the water.	Banks extremely high compared to water surface.	
Attachment Sites for Macroinvertebrates	Lots of different sized rocks, wood, and plenty of leaf litter.	Only small, gravel sized rocks, some wood and leaf litter present.	No rocks or wood but some leaf litter present.	No rocks, no wood, no leaf litter present.	
Shelter for Fish	Lots of pools, woody debris, and undercut banks present in the water.	Some pools, wood, and undercut banks present.	Few pools, wood, and undercut banks present.	No pools, no wood, no undercut banks present in the water.	
Riparian Buffer Width (Estimate or Measure)	More than 50ft of trees and brushy vegetation extending out from EACH bank of the stream.	20-50ft of trees and brushy vegetation extending out from EACH bank of the stream.	5-20ft of trees and brushy vegetation extending out from EACH bank of the stream.	0-5ft of trees and brushy vegetation extending out from EACH bank of the stream.	

CHARACTERISTIC	Good (4)	Fair (3)	Marginal (2)	Poor (1)	Score
Bank Stability – Are the banks of the stream eroding or could they easily erode?	Lots of roots and vegetation or large rocks on the vertical portion of the bank all the way down to the surface of the water.	Roots and vegetation or large rocks/boulders covering the vertical part of the bank 2/3 of the way down to the surface of the water.	Roots, vegetation and/or large rocks/boulders going only 1/3 of the way down vertical part of bank to surface of the water.	Steep banks of bare soil with no plants or roots or large rocks.	
Velocity and Depth – Within 30ft upstream and 30ft downstream from where you are standing There are no pictures for this category.	Stream has areas of (1) fast/deep water, (2) fast/shallow water, (3) slow/shallow areas, or (4) slow/deep areas.	Stream has 3 of the 4 types of speed and depth combinations.	Stream has 2 of the 4 types of speed and depth combinations.	Stream has only 1 type of velocity and depth combination.	
Add all scores to get a total. Total Score for Stream _____					

ANALYSIS:**If the total score is:****Then the overall stream rating is:****30 - 36****GOOD**

This stream has excellent habitat with a wide variety of traits. If the water quality is good this stream can support many different species of insects and fish, including those sensitive to pollution and habitat changes. The stream is stable; habitat quality will not get worse unless humans make changes to the area.

23 – 29**FAIR**

This stream has good habitat for many different species of insects and fish, including some sensitive to pollution and habitat changes. The stream is most likely stable. Minor changes can increase the habitat quality, such as stabilizing erosion or planting vegetation.

16 – 22**MARGINAL**

This stream can support some species of insects and fish that are tolerant to pollution. The stream is not stable and will get worse without human restoration. Habitat can be improved by planting vegetation near the stream, stabilizing erosion, or reducing water from impervious surfaces.

9 – 15**POOR**

This stream may only support a few species of insects that are highly tolerant to pollution. The stream is not stable and will get worse without human restoration. Habitat can be improved by planting vegetation near the stream, stabilizing erosion, or reducing water from paved areas.

Stream Corridor Habitat Rating: _____*"Explore and Restore Maryland Streams" – Maryland Department of Natural Resources - 2019*