North River Assessment Report

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S3G4

1. Abstract

1.1. There are many parameters and factors that contribute to the ecological health of a habitat and especially towards a complex aquatic ecosystem such as the North River. Our lab group, S3G4, has spent roughly 6 weeks executing experiments and practices that involved properly assessing and determining the overall ecological health at Sandy Bottom of the North River. We wanted to know how polluted the water is, if the species community was deteriorating, and whether the physical characteristics of the river was functioning properly. The many parameters that we focused on for determining the habitats health is water quality of the river, we have taken many samples of the river water and ran many tests on it for certain bacteria and viruses that could be present in the water while also measuring important water variables with the YSI-EXO Continuous Water Quality Monitoring Device to obtain the values of temperature, pH, turbidity, conductivity, and dissolved oxygen levels to get a more clear understanding of the rivers well-being. We would also follow the guidelines of the Habitat Assessment while observing and diligently noting the physical characteristics of the aquatic habitat so that we can attempt to score the river ecosystem on a numerical score and determine whether it is healthy or not. We have had a wide range of different types of data that leads us to the conclusion of the overall health of the river habitat and the tributary that it is moderate, further elaborating that it is neither exceptional nor is it unhealthy. It had qualities that make it better than some rivers, and some attributes that may be hurting the surrounding aquatic communities and habitat populations.

2. Introduction

The North river is a 55.3 mile long river flowing from Elkhorn Lake, a 54 acre reservoir in the George Washington and Jefferson National forests, high up in the western Shenandoah mountains. It has 14 subwatersheds and the area in which we analyzed and conducted many experiments and evaluations was located at Sandy Bottom, in the Lower North River subwatershed. The area is located south of the town of Bridgewater, right under Sandy Bottom 3-par golf course and just upstream of the Bridgewater Air Park. Our group, S3G4, collected individual data at the alluring Mossy Creek, a Subwatershed located south of the main North River stream.

Our main focus on the assessments and experiments are to determine whether the river is relatively healthy and has enough characteristics to support a diverse aquatic ecosystem suitable for life. The many lab experiments that we conducted were to evaluate the physical habitat conditions of the stream and its surrounding watershed along with measuring the concentrations of possible pollutants and necessary nutrients within the water. These methods give us great insight and understanding to how healthy the water quality of the stream is, which is one of the most important characteristics to a healthy stream. On other occasions we observed and used methods to measure, and accurately record, the effect the stream's water quality had on aquatic life. The group decided the most accurate way of determining this was to conduct bioassessment related practices. Bioassessment entails that we assess the health of the water body by observing and making direct measurements of the biotic factors of waters. This means that we monitor the species richness and species diversity which includes studying fish populations, benthic invertebrates, periphyton biomass, and other forms of vegetation in the stream beds.

Water quality parameters include the physical, chemical, or biological characteristics of the river that impact the ecological health of the freshwater river system. These parameters are temperature, pH, conductivity, dissolved oxygen, nutrients (nitrate & phosphate), and fecal coliform. These variables directly affect all the necessary attributes for a healthy and sustainable aquatic ecosystem. Temperature of the body of water dictates the structure of fish and macroinvertebrate communities. The pH level, measurement of how acidic or basic a water is, will define the community of organisms present in the river. Conductivity, which is the degree to which water transmits an electrical charge, determines the amount of ions or impurities present in the water which detects pollution. Almost all aerobic-aquatic organisms require oxygen to survive, so collecting data on dissolved oxygen gives us a good understanding on the community structure depending on the variance of the D.O. levels, directly affecting the species diversity and richness. The amount of vegetation in a water system is correlated to the health of the water body and how optimal the water quality is. In order for plants and other forms of vegetation to thrive, nitrogen and phosphorus must be present in the soil on the streambed, riparian corridor, or in the water itself. But when there is an overabundance of nutrients in the water, it leads to Eutrophication, a condition in which excess nutrients creates excessive algal growth in aquatic systems. This leads to an overgrowth of free floating plants that can impose growth on streambed vegetation and disrupt sunlight and deprive other plants from oxygen, then dying and being consumed by microorganisms and wasting available oxygen. Another water quality parameter is Fecal Coliform, which are the group of bacteria that lives in the digestive system of warm blood aquatic animals, such as E. Coli. If indicators show that it is present in the river, it just imposes a threat on humans being exposed to the water through an open wound, eyes, nose, and mouth rather than the aquatic animals.

It is vital that while conducting our experimental practices that we further observe and analyze the physical habitat and surrounding environmental characteristics of the area we are taking data from. Habitats in aquatic systems are determined by many factors including the instream and surrounding topographical features. In order for biological communities to survive in an aquatic ecosystem, the necessary caliber of conditions for the habitat must be met to suffice for living species or else they will not be present in the system, even if water quality is ideal. In order for the habitat to be truly optimal it must provide a wide range of ecological factors that can offer specific niches to an extensive range of organisms. The Habitat Assessment allows us to be able to grade the overall ecosystem on many parameters and their conditions ranging from optimal to poor. The parameters include <u>Epifaunal Substrate/Available Cover</u> which are the structures that provide shelter, hidden cover, or stable surfaces for aquatic organisms. <u>Embeddedness</u>, which is the prevalence of rocks and snags, are covered or sunken in the silt, sand, or mud of the stream bottom. <u>Velocity/Depth Regime</u> is graded based on patterns and combinations of velocity and depth. The most optimal streams have all combinations and the poor quality streams are slow and deep. <u>Sediment Deposition</u> measures the amount of sediment that has accumulated in the stream and settles at the bottom of the stream. <u>Channel Flow Status</u> assesses the degree in which the channel is filled with water. <u>Channel Alteration</u> evaluates large scale changes in the shape of the stream channel. <u>Frequency of Riffles (or Bends)</u> quantifies the sequences of riffles and the variability of what's occurring in the stream. <u>The Bank Stability (Condition of Banks)</u> section helps us analyze whether the stream banks are eroded (or have potential to erode), and we base this after observing the bank's stability. <u>Bank Vegetative Protection</u> measures the amount of vegetative protection afforded to the stream bank and the near stream portion of the riparian zone. <u>Riparian Vegetative Zone Width</u> examines the width of natural vegetation from the edge of the stream bank out through the riparian zone. All these parameters are imperative to understanding a river's habitat and assists us with what to specifically observe and focus on in order to give the river a numeral score and compare it to other rivers and habitats.

(EPA-Environmental Protection Agency Chapter 5: Habitat Assessment And Physicochemical Parameters, 2023) All of these parameters, along with water quality parameters are essential for determining the health of the river. Many of these variables all affect each other if the values were to fluctuate since they all operate in the complex aquatic ecosystem. These parameters that are integrated in the complex aquatic ecosystem are all factors that can change the health relationship of the aquatic system.

Macroinvertebrates and fish are typically used as bioindicators because they are very good for monitoring the ecosystem degradation along with measuring the level of ecosystem conditions, such as species richness and diversity, in addition to the entire community structure of the aquatic habitat. (Lab #8a data and information, Coffman, 2023)

Image #1: S3G4 Lab leader Harrison McQuillan showing off the Northern Hogsucker that he caught with his bare hands! Impeccable outdoor skills!

Image #2: Here is Harrison giving him a (consensual) smooch! Talk about love at first sight!

In 6 weeks we have conducted many experiments and ran tests that measure certain parameters that are necessary in determining the health of the aquatic ecosystem, habitat, and the river's characteristics. In almost every lab we make sure to survey the water quality parameters in case there is a change in anything and may affect our other lab data objectives. The first lab we held at river was lab #7-North River I: Water Quality, Flow, and Habitat, our objectives of the lab were to measure the temperature, pH, conductivity , dissolved oxygen, and the turbidity of the river while calculating thes discharge of the stream. After this we would then visually assess the habitat, going through all the parameters on the habitat assessment and give it an overall score. We conducted our water quality testing close by the left bank and received a 13.8°C for temperature, 376 $\mu S/cm$ for conductivity, 9.94 mg/L for dissolved oxygen, a pH of 8.30, and a turbidity of 1.42 ntu. In this lab. We measured the total discharge of the river at 2 different rows of string across the river around 30 feet away from each other. The one that was further down the stream was calculated at a total of 38.45 ft^2/s and further up the stream we calculated a total discharge of 12.66 ft^2/s. We suspected that the reason that the row further upstream had a significantly lower discharge rate is because there was a huge clump of vegetation that was right before the string at 39.2 ft and stretched from sub-section 4-6, giving us a very low discharge rate in the middle of the river. After formally assessing the river's physical habitat we calculated a habitat assessment score of 123. (Lab #7 data and information sheet, Coffman, 2023). In lab #8-Water Quality II and Benthic Macroinvertebrates our lab was tasked with auditing the benthic macroinvertebrate community in the North River, which correlates to the ecological health of the aquatic habitat. For our water quality parameters we received a temperature of 13.9℃, a conductivity of 364$\mu S/cm$, dissolved oxygen at 9.61 mg/L, a pH of 8.14. All of these parameters are very similar to Lab #7s data. The final conclusion and outcome of this lab was our Benthic macroinvertebrate multimetric score being an 8, this means that ecological conditions cannot be determined at this time since there was errors in our observations on counting the invertebrates and determining which organism was which. (Lab #8 data and information sheet, Coffman, 2023). In lab #8b-Tributary Sampling we measured the typical water quality parameters at Mossy Creek and recorded a 14.1 ℃, a conductivity level of 400 $\mu S/cm$, dissolved oxygen level was at 10.24 mg/L, and a pH of 8.11. We then assessed the habitat and rated it a score of 99. We found very little differences in comparison to Mossy Creek to the North River besides water clarity, temperature and overall habitat assessment score, which the tributary scored lower than the North River. (Lab #8b data and information sheet, Coffman, 2023). Lab #9-Water Quality and Fish Community at North River objectives were to further determine the ecological health of the North River through physical and chemical measurements, by the fish and periphyton community standards, and assessing the habitat once again. Our typical water quality parameter data was different then usual having the temperature be 10.2 ℃, a conductivity of 379 $\mu S/cm$, a dissolved oxygen level of 8.88 mg/L, a pH of 7.99, and a turbidity of 3.2 NTU. All of these parameters are less than the data we recorded the week before, besides turbidity, since we did not measure that variable last week. The parameters were affected by the drop in water temperature which we concluded had a direct effect on the other parameters lessening in value due to the colder water. We determined the fish community richness to be 12, which was then turned out to be incorrect since we failed to include a Cutlip Minnow at the end of the lab. The correct number for fish species richness was 13. We also analyzed the periphyton community and were given a sample diameter of 5.2 cm and then calculated the surface area as $0.0019m^2$ (really should be $0.002124m^2$) and then calculated the ash-free dry weight of 29.05 g/m^2 (Coffman commented that it should have been closer to 26 g/m^2). This lab contained a lot of math and calculating and we unfortunately had a lot of human errors. We assessed the habitat like every lab we have done before and scored it a 123, very similar to previous scores. (Lab #9 data and information sheet, Coffman, 2023).

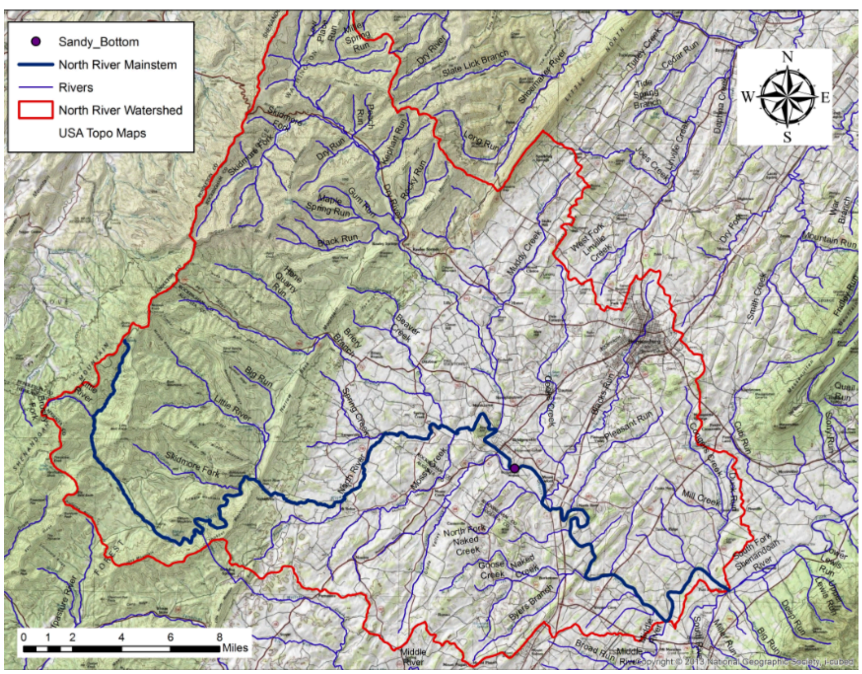


Figure 1: A map highlighting the mainstream of the North River along with an indication of where we were experimenting and taking data on the stream at Sandy Bottom.

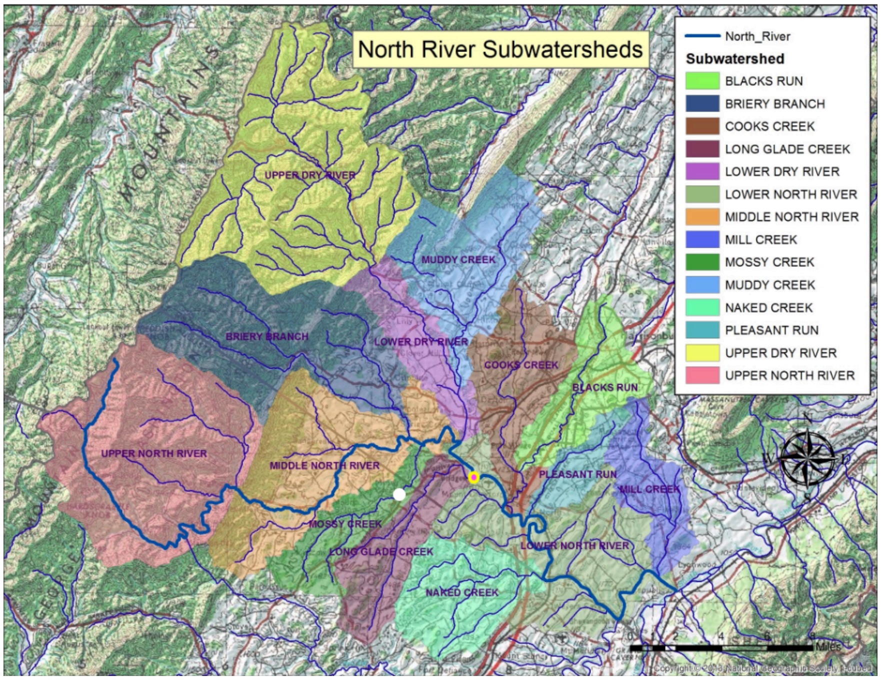


Figure 2: Showing the North River subwatersheds and tributaries that groups were assigned. Our group, S3G4, was assigned Mossy Creek, the white dot on the stream indicates where we took our data.

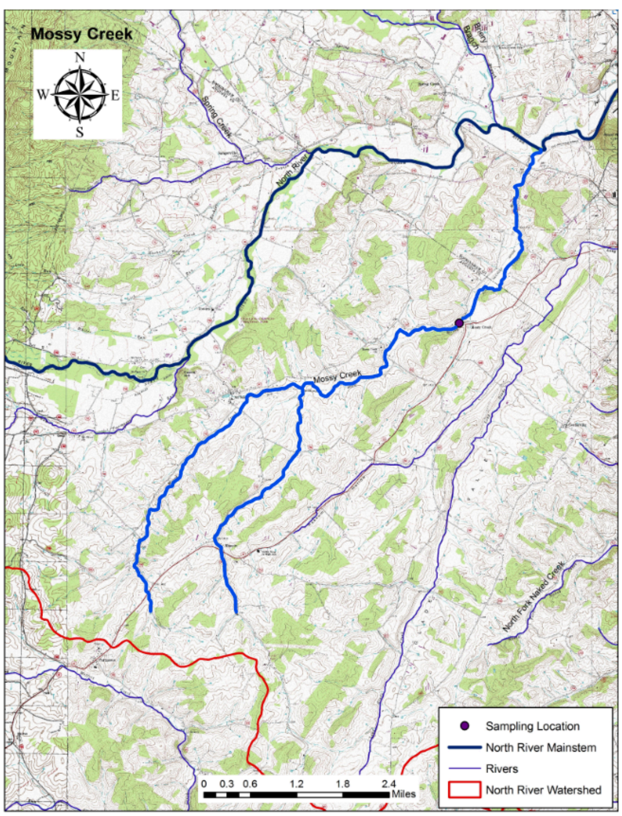


Figure 3: Here is a close up of the Mossy Creek river stream (highlighted in light blue) along with the indication on where we took our data and conducted our experiments and habitat assessment for the tributary.

3. Materials and Methods

3.1. Watershed Delineation and Land Use Analysis

Watershed delineations were conducted in Lab#6 for the North River Watershed upstream of Sandy Bottom Park to determine “the land that drains to a given water body or point on a stream” (1). We delineated the North River watershed by using a topographic map of the area and identifying the high points in the surrounding area to determine where the water will flow. To begin our delineation we drew a circle at our sampling location, Sandy Bottom Park, then we then drew dashed lines along all rivers and tributaries that flowed to our circle up to their origin. From the dashed lines we put a small ‘x’ at each high point to outline the dashed area then connected the ‘x’s’, beginning at the circle we first placed. We continued the line following the high points and making sure the line crosses contours at a right angle. Continuing this along the high points until our line passes the head of the watershed and down the opposite side of the watercourse, eventually connecting with the starting circle. We followed the same procedure for the smaller sub-watersheds that feed into individual tributaries, ours being a delineation of the Mossy Creek tributary from a sampling point.

In Lab#6 (*Coffman 2023)* we also conducted land use analysis for the North River Watershed, as well as the Mossy Creek subwatershed. We used a table given in lab which shows the percentages of land cover for the North River watershed based on 14 distinct categories, which we further categorized under 4 groupings: Forest (deciduous forest, evergreen forest, and mixed forest), Urban (developed open, developed low intensity, developed medium intensity, developed high intensity), Agricultural (pasture/hay, cropland), and Other (emergent wetlands, barren, grasslands, shrub, open water). We then analyzed the possible activities that may occur under our 4 groupings for land use type and what pollutants and effects land use could have on the watershed. We pooled the 14 categories under the 4 groupings and calculated the pooled percentages for each land use category for the North River and our Mossy Creek watershed. We then compared the percentages of the 4 groupings for the North River and Mossy Creek and compared how land cover differed, and how land cover could affect the water quality.

3.2. Stream Flow

To start our stream flow measurements, we determined the two transections that we wanted to conduct measurements on. The first one was the transection farthest downstream, refer to this as Transection 1, and the second was the transection farthest upstream, refer to this as Transection 2. To begin, we first used our tape measure to measure the stream width from bank to bank. Transection 1 was 112 feet and Transection 2 was 92.8 feet. Then, we divided this number by 10 to identify our subsections and their respective distances from the left bank (looking downstream). For Transection 1, this means each subsection was 11.2 feet long and each preceding subsection was that many times farther from the left bank. For example, our second subsection would be 11.2 x 2 feet far from the left bank. The same principle applied to Transection 2, which had subsections 9.6 feet long. However, after we calculated this we realized our numbers also accounted for measurements that consisted of land. To counteract this, we subtracted all 10 of our values for 'Distance from Left Bank' by the amount accounted for by land. For Transection 1, land accounted for 0.6 feet and for Transection 2 land accounted for 0.4 feet. For example, subsection 1 in Transection 1 was initially recorded as 11.2 feet. To adjust for the land, the math looks like:

$$11.2\, feet\; - \; 0.6\, feet \; = \; 10.6\, feet\; for\; Subsection\; 1,\; Transection\; 1$$

This principle applied to all subsections in Transection 1 and Transection 2.

Within each subsection, we had to determine our monitoring points which were one half the width of each subsection.

For Transection 1, this meant:

$$11.2\, feet\; per\; subsection \; \div \; 2 \; = \; 5.6\, feet\; in\; each\; subsection$$

For Transection 2, this meant:

$$9.6\, feet\; per\; subsection \; \div \; 2 \; = \; 4.8\, feet\; in\; each\; subsection$$

After determining the monitoring point between the width of the subsections, we added this value onto the subsection's 'Distance from Left Bank' value in our Lab 7 (Coffman, 2023) document to determine where exactly to conduct our recordings within them.

Within each subsection's monitoring point, our instructions in Lab 7 (Coffman, 2023) were to find its respective depth and velocity. To find the depth, one team member would stick the meter stick straight down till it touched the streamflow. Then the individual recording our data would read the meter stick on its bank side to avoid flow distortion around the meter stick. With velocity, one team member held the flow probe above the stream floor at a height of .6 of the total depth at each respective subsection. For example, if one monitoring point had a depth of 2.1 feet, the individual with the flow probe would hold it approximately 1.26 feet above the stream floor. To get the most accurate data, no one stood upstream of the probe (including the individual who held it) and the probe was held at its respective position for around 40 seconds. This data was recorded for each monitoring point onto a data sheet.

After that, we then calculated the cross-sectional area of each subsection with the formula provided for us in our Lab 7 (Coffman, 2023) document. The formula for cross sectional area follows:

$$Cross\ Sectional\ Area\ (ft^2)\ =\ Depth\ (ft)\ \times\ Subsection\ Width\ (ft)$$

Finally, we then calculated the discharge rate of each subsection given to us in our Lab 7 (Coffman, 2023) document with a supporting visual aid presented in Figure #: Cross-sectional Measurement of Stream Discharge. The formula for discharge rate:

$$Q\ (Discharge\ Rate\ ft^3)\ =\ V(Velocity\ ft)\ \times\ A\ (Cross\ Sectional\ Area\ ft^2)$$

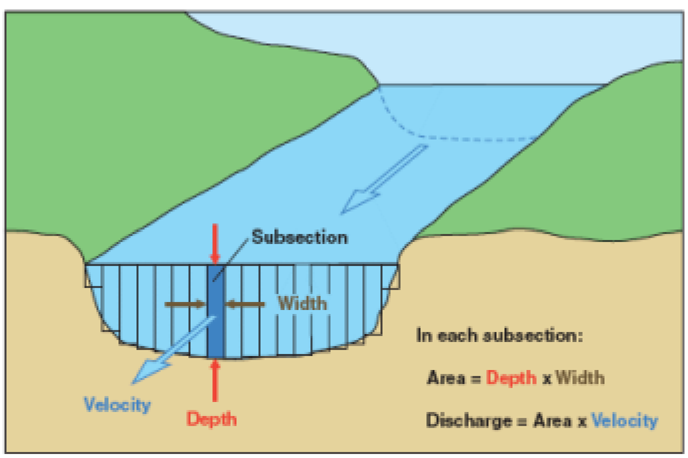


Figure 4: Cross-sectional Measurement of Stream Discharge

We then compared our results to data from USGS water monitoring stations located downstream from our research site. In order to get its data, we accessed their graph of the North River near Burketown, Virginia on their website (https://www.usgs.gov/), then adjusted the given graph to 1 year to see its recordings on October 11th, 2023 (USGS, 2023).

3.3. Habitat Assessment

In Lab 7 (Coffman, 2023), for the Rapid Bioassessment Protocol (RBP), we analyzed the conditions visible to us upstream and downstream in an area roughly 100 - 150 meters wide consisting of both the left and right banks (facing downstream). We analyzed the North River's watershed and gave our assessments based on the 10 habitat metrics of the RBP provided by our instructor in 'Understanding the RBP Habitat Assessment' (Coffman, 2023). Those 10 metrics include: Epifaunal Substrate/Available Cover, Embeddedness, Velocity/Depth, Sediment Deposition, Channel Flow Status, Channel Alteration, Frequency of Riffles (or Bends), Bank Stability (one for each bank), Vegetative Protection (one for each bank), and Riparian Vegetative Zone Width (one for each bank). After conversing as a group, we decided on a single value for each metric we were each satisfied with and recorded them onto our data sheet with a Habitat Assessment Score of 123.

In Lab 8b, we followed the same steps as we did in Lab 7 (Coffman, 2023) and our Habitat Assessment Score for the Mossy Creek at Mossy Creek Road off Rt 42, Bridgewater was 100.

In Lab 9: North River Assessment IV - Water Quality, Periphyton, and Fish Survey (Coffman, 2023), we again followed the same steps as we did in the Lab 7 (Coffman, 2023) and our Habitat Assessment Score for Lab 9 (Coffman, 2023) equaled 130. However, in addition to conducting our assessment, we also compared our results to two other groups: S3G1 and S3G5, who had scores of 130 and 116 respectively. We took note of whether our scores were varied or similar, and provided justification to them by using the readings provided by our instructor. Those readings included: 'Stream Habitat', 'Rapid Bioassessment Protocols (RBP) for Use in Wadeable Streams and Rivers: Visual Habitat Assessment', and 'How Streamflow is Measured' (Coffman, 2023)

3.4. Water Quality Sampling

To perform the water quality sampling as outlined in Lab 7 (Coffman, 2023), the Hach field meter was used to gather temperature, pH, conductivity, and DO, and the Analite turbidity probe was used to measure turbidity (with both devices facing upstream in the North River). A 125-ml and a 500-ml bottle were filled with river water for later analysis of Total N, Total P, and major anions.

A YSI-EXO Continuous Water Quality Monitoring Device was deployed as described in Lab 8a (Coffman, 2023), to monitor the same parameters as the Hach meter, but this device takes a measurement every 15 minutes for a week. The Hach meter and Analite probe were also used to take the same measurements as Lab 7, but later in time.

In Lab 8b (Coffman, 2023), water quality tests were performed at the group's assigned tributary. Specifically, a 500-ml bottle of river water was collected for nitrogen, phosphorous, and major ions, and a 250-ml bottle was collected for fecal coliform and E. coli. The Hach meter was also used to collect the same measurements as Lab 7 and 8a.

Finally, in Lab 9, the Hach meter and Analite probe were once again used to collect temperature, pH, conductivity, DO, and turbidity.

3.5. Benthic Macroinvertebrate Assessment

To conduct the benthic macroinvertebrate assessment, we followed instructions outlined by the Virginia Save Our Streams (VASOS) organization, as well as Lab 8a (Coffman, 2023). We began by locating a section of river which contained riffles which were flowing over cobblestone sized rocks. Once an ideal site was visually identified, we approached from downstream to ensure the area was undisturbed prior to sampling. Then, two group members spread a seine net as widely as possible just below the riffles at a 45 degree angle so that the water was flowing into the nets center. While the net was in position, two other members rubbed the rocks that were immediately upstream of the net for twenty seconds. For the last five seconds they scratched the bottom with their fingers in order to collect any organisms living in the substrate. Next, the net was lifted from the water and any non-macroinvertebrates, such as minnows and crawfish were removed. Then, we took the net to the streamside and placed it on top of a plastic sheet so we could still count organisms which were able to pass through the net. Next, we used tweezers to pick up macroinvertebrates, and an ice cube tray to sort them. We gathered, sorted, and identified the organisms until we had reached an excess of 200 identified macroinvertebrates. We had to dip the net in the river a second time to meet the quota, and actually ended up exceeding the requirement by 75 organisms. Finally, with the individual counts of the organisms according to the categories on the VASOS identification sheet, we calculated the percentage of each metric for the multimetric index score, which will be further explained in part 4.5.

3.6. Fish Community Survey

Throughout the fish community assessment, we abided by the instructions given to us in Lab 9 (Coffman, 2023). To begin the assessment, one individual from each lab group tagged along with Kyle Snow and ventured deep into the North River. In order to catch the fish without causing a tremendous amount of harm to them, Kyle wore a backpack-mounted electrofishing unit while each student with him carried nets. The intention with this was to drive the fish closer to the electrode then temporarily stun and immobilize them long enough to give the people with nets time to collect them. Once the group collected a large enough sample size of fish, they returned to homebase and placed the fish into an aerated tank where students could identify and measure them using the "Pennsylvania Fishes" and other identification resources provided by our instructor. If a fish is unidentifiable, then its characteristics like its body shape, fin arrangement, mouth position and orientation, and tail shape were noted for later identification along with pictures. To determine the species diversity, once a species of fish was identified, its respective box on the datasheet was to be checked off to demonstrate its species presence in the stream. From there, the species richness of the sample could be calculated. Afterwards, the fish were to be released back into the stream (Coffman, 2023).

3.7. Periphyton Biomass Sampling

To sample the periphyton biomass in the North River we used the instructions outlined in Lab 9 (Coffman 2023). We began by collecting a relatively large and flat rock from the bottom of the stream. Before picking up the rocks, we tried our best to choose a rock which had algae growth that was representative of the surrounding area. Once we had picked a suitable rock to remove, we swished it back and forth under the water in order to remove any sand and silt that had settled in the periphyton layer. Then, we took the rock to the tables on land and placed a hollow metal tube (like a cookie cutter) on the flattest part of the rock. Next, we used a toothbrush to clean off the periphyton which surrounded the tube. Once the surrounding area was clean, we used a dull knife to scrape the periphyton which remained within the tube into a container. In addition, we used a squirt bottle with deionized water to remove and collect any periphyton material that remained from the area inside the tube. Following this, the container which held our periphyton sample was taken back to the JMU, where Lab Manager Kyle Snow poured the samples through a fiber filter. After the sample had been completely run through the filter, it was dried and weighed. Then it was placed into a muffle furnace and heated to 550^{0}C, "At this temperature, all organic matter is combusted into CO_2 and water"(Coffman, 2023). All that was left behind was inorganic ash. Therefore, by weighing the ash and subtracting it from the dry weight (recorded before the furnace), we found the Ash-free Dry Weight (AFDW) of our sample. Calculating the AFDW was important because it tells you the weight of the organic matter without the added mass of the inorganic material (the ash).

4. Results and Discussion

4.1. Water Delineation and Land Use Analysis

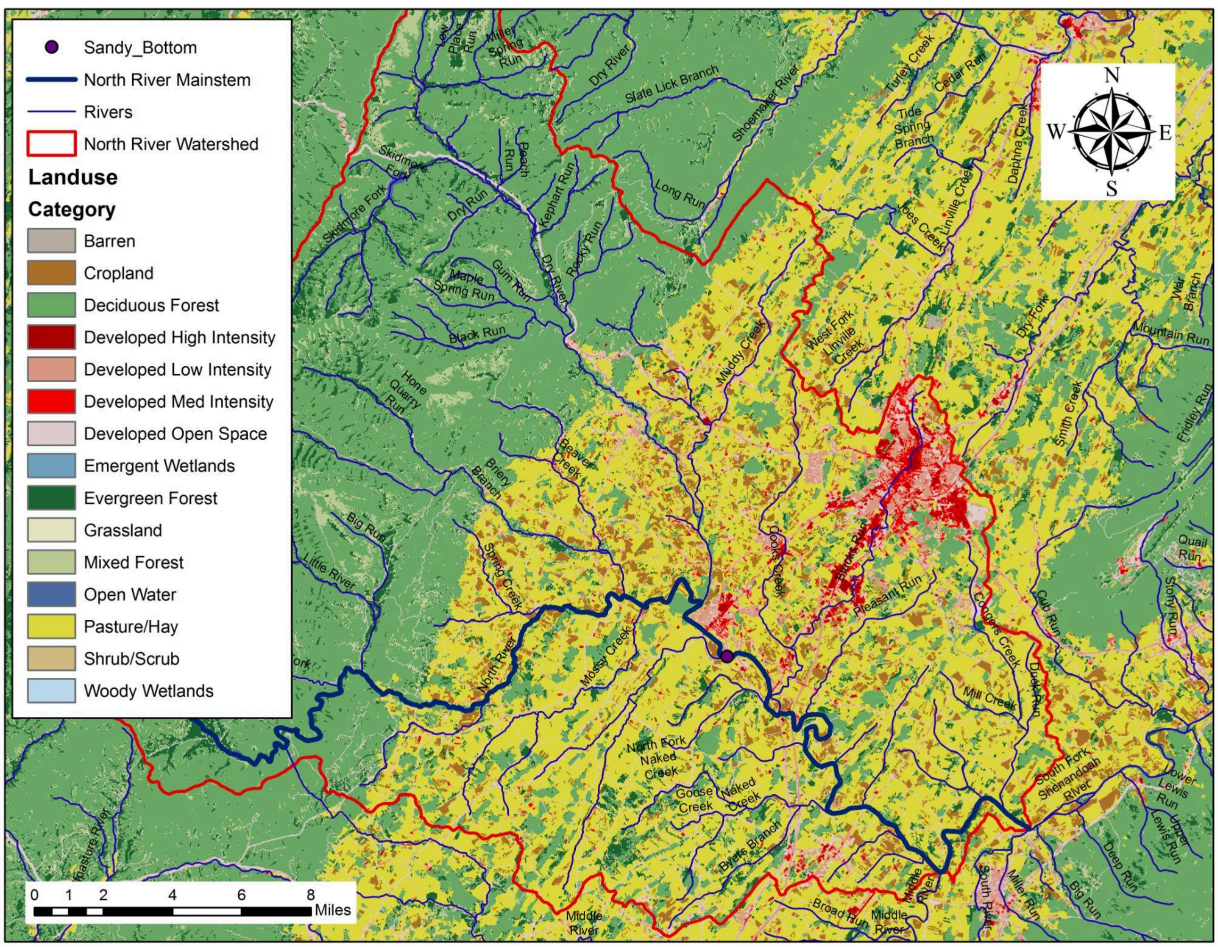


Figure 5: Land Use Patterns of the North River Watershed

Figure 5 shows a map of the different land use patterns of the North River Watershed. From the figure it can be seen that many of the smaller tributaries, near the headwaters, that join into the North River are dominated by forested lands, which is shown as greens in the map. As the North River goes further downstream and to our sampling location a lot of the land goes from being forested to being mostly pasture/hay and cropland, depicted as yellow and brown on the map, which was grouped as agricultural land. The other grouping that can be seen is urban areas which are a lower area than the agricultural and forested areas, but still have a vast effect because of the impervious surfaces. These can be seen in the eastern part of the watershed and some tributaries are more affected by urban land use, such as Cooks Creek, Blacks Run, and Pleasant Run. There is also the "Other" grouping which are areas not fitting under the previous 3 of forested, agricultural, and urban. This "Other" grouping is the smallest percentage and contains other less apparent land use patterns such as wetlands and grasslands, but this grouping also contains water, which includes the rivers.

Forested land use plays a critical role in maintaining the health of streams habitats and water quality through acting as a natural buffer, preventing soil erosion and filtering pollutants before they can reach the streams. Forested land use provides an excellent riparian corridor for a stream which can "reduce flood peaks, enhance base flows, slow erosive energy of floodwaters, filter sediments and nutrients, affect water temperature and dissolved oxygen levels and help stabilize stream banks, all of which affect habitat." (3) Through filtering of sediments and stabilizing stream banks the turbidity will also be lowered which will curb the dissolved oxygen levels and temperature levels. With less soil erosion and therefore sediment deposited the channel flow, pool variability, and velocity/depth regime will all be improved as well. Healthy water quality provides a more diverse stream community and influences which fish and macroinvertebrates could survive in the stream. Forests also provide food and habitat as "Most streams rely heavily on the input of leaves, twigs, and other food materials produced on land" (3) while also using vegetation to provide protection and cover for fish and other biodiversity. Forested land use also plays a large role in the hydrologic cycle as it reduces surface runoff by promoting infiltration and transpiration.

Agricultural land use significantly impacts in-stream habitats and water quality parameters, which in turn affect what aquatic communities can live in streams. Soil erosion and manure runoff are major factors of agricultural land use which lead to poor water quality. For example, "Agricultural areas that have not adopted "best management practices" to prevent soil erosion leaking sediment to local waterways" (2). Temperature, turbidity, and dissolved oxygen are all connected and the sediment leaked into waterways can increase the suspended solids in the water and with more particles it creates cloudy water which will absorb radiation from the sun, warming the water. Sediment leaking into waterways will also increase embeddedness and sediment disposition, which in turn will decrease channel flow, frequency of riffles, and bank stability, all of which will reduce available habitability (4). Agricultural land use is also a major influencer in the amount of E.coli, fecal coliform, nitrate, ammonia, and phosphorus in the waterways due to manure runoff and fertilizers. Manure contains nitrogen and phosphorus which is often deposited into waterways either directly or through runoff, which causes eutrophication, the addition of excessive nutrients such as nitrogen and phosphorus(Singer, chp20). Once deposited the nutrients often fertilize aquatic weeds and accelerate growth which reduces the available oxygen for other species and plants, potentially causing algae blooms. Manure and fertilizers can create these algae blooms which can cause the depletion of oxygen in surface waters, an unsightly murky green water, generate an unpleasant odor, and the possibility of pathogens. Pathogens are also often found in manure, such as e.coli and fecal coliform, and can contaminate drinking water supplies. (5) Fertilizer also has a huge effect and it can be sources of food for a stream, aquatic communities can change due to their food web being driven by fertilizers rather than sunlight, an example given could be that "Species like stoneflies, caddisflies and mayflies that cannot tolerate the conditions disappear. Pollution-tolerant species like leeches and aquatic worms become more abundant" (3) Agricultural land use near bodies of water is one of the biggest contributors and polluters to waterways. Bad management practices can often lead to soil erosion, manure runoff and fertilizer which can negatively affect the water quality, aquatic communities and in-stream habitats.

Urban land use patterns can have a significant impact on water quality which can further affect in-stream habitats. Temperature and dissolved oxygen are some of the most common effects from urban land use and that "Rain carries heat, salt, sediment, and other pollutants from impervious surfaces (streets, roofs, parking lots, etc.) into streams. This raises the water temperatures and total solids in the water reducing its capacity to hold DO." (2) Development, construction, quarries, mine operations, and other land disturbances can also result in soil erosion which will further the amount of total solids and sediment in the water which can smother habitats and further reduce the dissolved oxygen, potentially harming aquatic life and degrading conditions in the waterways. Urban land use patterns, such as storm drains and inadequately treated wastewater from sewage treatment plants, can cause excessive nitrogen, ammonia, and phosphorus in waterways (2). These extra nutrients can result in eutrophication which can lead to decreased oxygen levels, leading to algae blooms and dead zones which can lower the in-stream habitats and species richness. Urbanization can have a vast effect on the overall quality of a stream, but can be mitigated by proper land management practice and pollution control measures.

The Other land use patterns were the smallest percentage and will not have a vast effect on the overall ecosystem and watershed. However, as with all land use patterns waterways are unique and "Streams continuously adjust their individual physical conditions to surrounding watershed conditions, In turn, almost any change in a watershed directly or indirectly affects stream habitat. Increased runoff, forest fires, clearing of land, urbanization, channelization and changes in agricultural practices can alter stream habitat characteristics like depth, water quality, streambed quality, and flow." (3) Stream's are complex systems that give and take from a lot of different sources, and that the water quality and in-stream habitats are inextricably linked to the surrounding terrestrial land and how it is managed.

Table 1: Land Use Percentages for North River and 6 Focal Tributaries

Land Use	North River	Pleasant Run	Cooks Creek	Mossy Creek	Muddy Creek	Dry River	Blacks Run
Forested	71.53%	21.84%	16.15%	25.81%	40.70%	99.38%	20.13%
Agricultural	24.16%	61.95%	44.13%	67.78%	50.94%	0.04%	19.83%
Urban	2.17%	10.03%	26.99%	3.40%	4.78%	0.11%	44.56%
Other	2.14%	6.18%	12.73%	3.01%	3.59%	0.47%	15.48%

The different land use percentages across the North River and the 6 focal tributaries reveal distinct patterns of land use that can offer insight on the potential pollutants and water quality, as well as in-stream habitats and stream health. From Table 1, Pleasant Run, Mossy Creek, and Muddy Creek are all agriculturally dominant and over 50% of land use in the area is dictated to agriculture. Mossy Creek is the most dominant at 67.78% with Pleasant Run at 61.95% and Muddy Creek just over 50% at 50.94%. This prevalence in agriculture results in the tributaries most likely being more prone to soil erosion and manure and fertilizer runoff. These tributaries will most likely contain higher turbidity and temperature, with high levels of nutrients such as nitrogen and phosphorus, which can lead to eutrophication and decrease in the amount of dissolved oxygen. High sediment deposition from soil erosion will also reduce available habitat due to increased embeddedness in the stream. Muddy Creek compared to the 2 other tributaries most likely has more sustainable habitats and water quality as it is not as dominated by agriculture and has 40.70% forest, the second most of any tributary, which will filter sediment and nutrients, stabilize stream banks, and provide habitats for invertebrates and fish. Overall dominated agriculture land use can lead to higher sediment deposition and lower water quality, leading to less available in-stream habitats and aquatic communities.

Dry River is unique among the tributaries as it almost all forested land use at 99.38%. This vast amount of forest will be beneficial for maintaining water quality and providing lots of opportunities for in-stream habitats. This tributary will have very few pollutants as there is minimal anthropogenic influences so it should have stable and ecologically sound communities as it joins with other tributaries and streams. This would also be true for many of the non-focal small tributaries near the headwaters that are largely under forested land use.

Cooks Creek and Blacks Run both have the highest urban land use percentage, as well as other land use. Blacks Run has the highest for both at 44.56% urban and 15.48% other land use, while Cooks Creek has 26.99% urban and 12.73% other. The high percentage of urban land use will have more impervious surfaces leading to more runoff of sediments and pollutants into streams. Land disturbances associated with urban and other land use can also lead to soil erosion which will further the total amount of sediments in the water. This combination can greatly lower water quality, through higher water temperatures and lower dissolved oxygen, and damage in-stream habitats and aquatic communities. Storm drains and other urban land use patterns can lead to excessive nitrogen, ammonia, and phosphorus in waterways, leading to eutrophication.

Blacks Run will likely experience low water quality and a lot of runoff that deposits into the stream while Cooks Run will experience this, they also have a high percentage of agriculture at 44.13% leading to agricultural runoff influencing water quality and nutrients, which affect the available habitats and aquatic communities.

Different land use patterns have multiple effects on streams, making each stream and tributary unique in what materials are getting into it and how the aquatic communities and habitats are different because of it. Many of these tributaries have a range of land use patterns that will require a comprehensive approach for mitigation that addresses multiple land uses.

4.2. Stream Flow

The following table, "Table 2: Discharge Measurements for All 320 Groups & Statistics" displays all of the discharge measurements recorded by all but one ISAT 320 lab group while at Sandy Bottom in the North River, and the minimum, maximum, range, average, and standard deviation for both Discharge Measurement nt 1 and Discharge Measurement nt 2 (Coffman, 2023)

Table 2: Discharge Measurements for All 320 Groups & Statistics

Group	Location	Sampling Date	Sampling Time	Discharge Measurement nt 1 (cfs)	Discharge Measurement nt 2 (cfs)
Kyle	Sandy Bottom - North River	10/11/2023	11:00 AM	[redacted]	
S1G1	Sandy Bottom - North River	10/11/2023	9:40 AM	38	19
S1G2	Sandy Bottom - North River	10/11/2023	10:13 AM	27	23
S1G3	Sandy Bottom - North River	10/11/2023	10:24 AM	33	33
S1G4	Sandy Bottom - North River	10/11/2023	9:38 AM	20	24
S1G5	Sandy Bottom - North River	10/11/2023	9:45 AM	38	33
S1G6	Sandy Bottom - North River	10/11/2023	9:40 AM	24	23
S3G1	Sandy Bottom - North River	10/11/2023	11:05 AM	23	14
S3G2	Sandy Bottom - North River	10/11/2023	11:50 AM	[redacted]	
S3G3	Sandy Bottom - North River	10/11/2023	11:10 AM	27	32
S3G4	Sandy Bottom - North River	10/11/2023	11:30 AM	39	13
S3G5	Sandy Bottom - North River	10/11/2023	11:26 AM	45	30

S3G6	Sandy Bottom - North River	10/11/2023	11:34 AM	50	11
Minimum				19.86	11.00
Maximum				50.00	33.47
Range				30.14	22.47
Average				33.09	23.35
Standard Deviation				9.68	8.30

Table 3: ISAT 320 (Sandy Bottom, Bridgewater) vs. USGS (Burketown) Discharge Rates

Group	Location	Sampling Date	Sampling Time	Discharge Measurement (cfs)	
Kyle	Sandy Bottom, Bridgewater, Virgina	10/11/2023	11:00 AM	[redacted]	
S1G1	Sandy Bottom, Bridgewater, Virginia	10/11/2023	9:40 AM	37.70	19.30
S1G2	Sandy Bottom, Bridgewater, Virgina	10/11/2023	10:13 AM	26.87	23.36
S1G3	Sandy Bottom, Bridgewater, Virginia	10/11/2023	10:24 AM	33.22	33.47
S1G4	Sandy Bottom, Bridgewater, Virgina	10/11/2023	9:38 AM	19.86	24.23
S1G5	Sandy Bottom, Bridgewater, Virginia	10/11/2023	9:45 AM	37.97	33.47
S1G6	Sandy Bottom, Bridgewater, Virgina	10/11/2023	9:40 AM	24.36	23.07
S3G1	Sandy Bottom, Bridgewater, Virginia	10/11/2023	11:05 AM	23.00	14.00
S3G2	Sandy Bottom, Bridgewater, Virgina	10/11/2023	11:50 AM	[redacted]	
S3G3	Sandy Bottom, Bridgewater, Virginia	10/11/2023	11:10 AM	27.00	32.00
S3G4	Sandy Bottom, Bridgewater, Virgina	10/11/2023	11:30 AM	39.00	13.00
S3G5	Sandy Bottom, Bridgewater, Virginia	10/11/2023	11:26 AM	45.00	30.00
S3G6	Sandy Bottom, Bridgewater, Virgina	10/11/2023	11:34 AM	50.00	11.00
USGS	Burketown, Virginia	10/11/2023	9:00 AM	54.2	
USGS	Burketown, Virginia	10/11/2023	9:15 AM	54.2	
USGS	Burketown, Virginia	10/11/2023	9:30 AM	54.2	
USGS	Burketown, Virginia	10/11/2023	9:45 AM	54.1	
USGS	Burketown, Virginia	10/11/2023	10:00 AM	54.1	
USGS	Burketown, Virginia	10/11/2023	10:15 AM	54.1	
USGS	Burketown, Virginia	10/11/2023	10:30 AM	54.1	
USGS	Burketown, Virginia	10/11/2023	10:45 AM	55.4	
USGS	Burketown, Virginia	10/11/2023	11:00 AM	55.4	
USGS	Burketown, Virginiar	10/11/2023	11:15 AM	55.4	

USGS	Burketown, Virginia	10/11/2023	11:30 AM	58
USGS	Burketown, Virginia	10/11/2023	11:45 AM	58
USGS	Burketown, Virginia	10/11/2023	12:00 AM	58

Based on the Table 2: Discharge Measurements for All 320 Groups & Statistics, it is evident there are significant differences amongst the ISAT 320 discharge measurements. There are multiple attributable reasons to this.

One reason for the variation could be attributable to human error when it came to conducting specific measurements and calculating their monitoring points in their subsections within the stream. This is critical because the measurements collected by each group determines their locations for their monitoring points, which would affect their recordings for their streamflow.

Another possible reason could be human error when utilizing the equipment to measure the depth and velocity of the subsections. According to 'Stream Flow (Discharge) Measurement' in Lab 7 (Coffman, 2023), it was important to read the bank side of the meter stick, however, some students may have mistakenly read the upstream or downstream side, which would've given misleading readings due to the flow distortion. With the velocity, instructions from 'Stream Flow (Discharge) Measurement' in Lab 7 (Coffman, 2023) explicitly stated it was important to avoid standing directly upstream from the flow meter as it would distort the flow and velocity reading, though some students either in the same group or other groups may have mistakenly stood directly or indirectly upstream of the flow meter, thus disrupting the natural steam flow and consequently its readings.

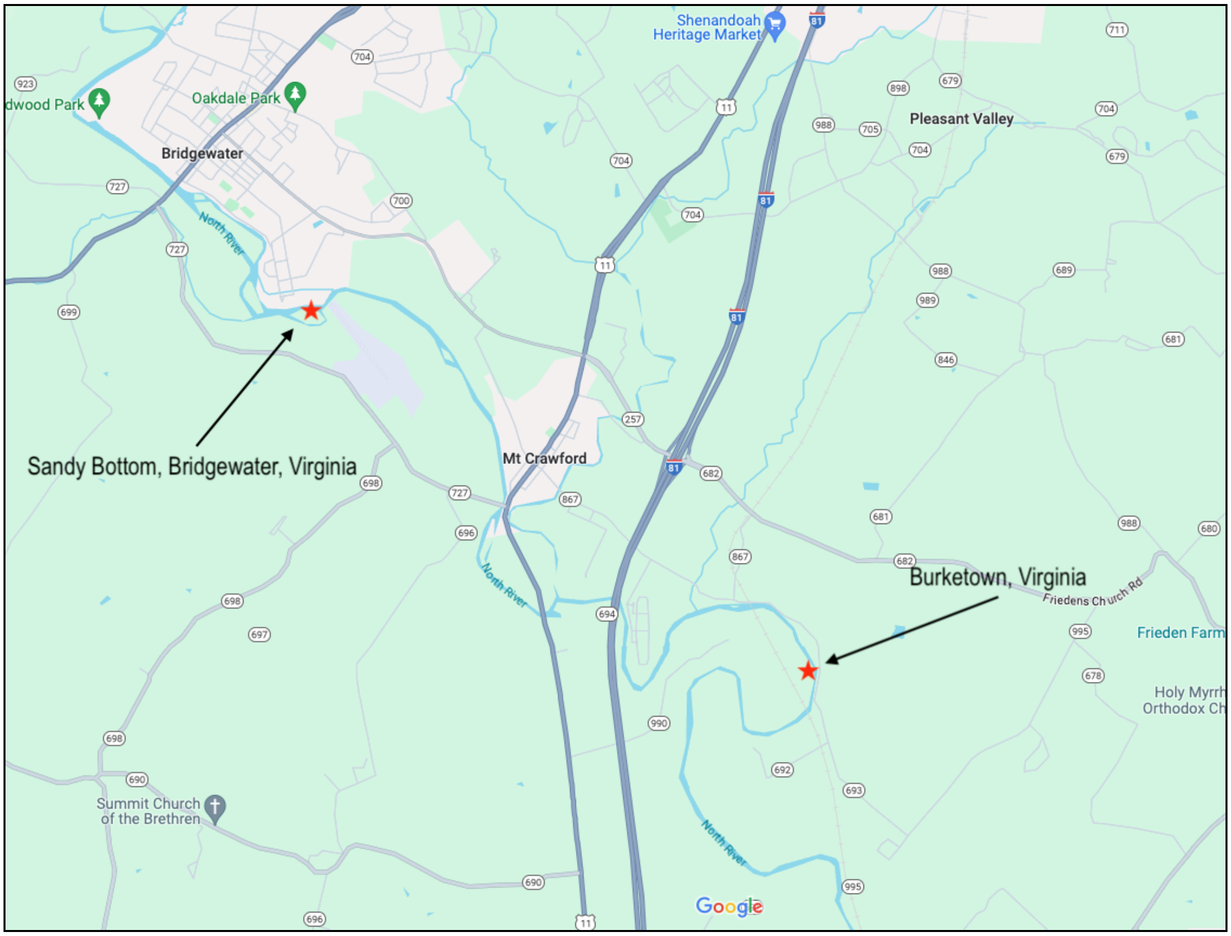


Figure 6: Geographic Location of ISAT 320 Testing Site and USGS Monitoring Site

4.3. Habitat Assessment

The following three tables present information regarding a more accurate habitat score of the North River (from Lab 9) per group along with its summary statistics, each group's assigned tributary and its respective habitat score, and the land use for each lab group's tributary.

Based on Table 4: ISAT 320 North River (Lab 9) Habitat Score (Coffman, 2023), it's clear there is a wide range of data, the lowest being S3G5 with 116, the highest being S1G3 with 178, and a range of 62 between them. That being said, there are multiple possible reasons for such variation. The first reason would be human error with the interpretation of the RBP. Per the instructions in Lab 7, accurate visual assessments could only be achieved with sufficient "skill and experience", which is something we lack given this was only our second attempt conducting this test (Coffman, 2023). Within each group there are four to five members with varying interpretations of the metrics within each category. It's very possible that not every member within each group took the time to assess each metric on their testing site and converse to find a group consensus, so while one individual may rate a metric very highly another individual may think less of it and give it a lower value, thus disregarding the directions of developing “a group consensus before recording each score” and producing a diverse score (Coffman, 2023).

Table 4: ISAT 320 North River (Lab 9) Habitat Score

Group	Habitat Score (North River - Week 3)
S1G1	132
S1G2	178
S1G3	178
S1G4	141
S1G5	123
S1G6	153
S3G1	130
S3G2	126
S3G3	122
S3G4	130
S3G5	116
S3G6	129
Minimum	116
Maximum	178
Range	62
Average	138.17
Standard Deviation	20.86

Another possible reason for the variation could be disregarding the entire testing area of the North River. Per the instructions in Lab 7 and 9, “Don’t merely focus on the one point where you collected your water quality information, but match your assessments to the predominant conditions that you see upstream and downstream” (Coffman, 2023). When groups were conducting their habitat assessments, it's very possible not everyone took the time and effort to analyze the large assessment area, and instead opted to look at a smaller area in close proximity to where they conducted their preliminary water quality tests. Doing this would skew the data since the quality of one area of a stream isn't representative of the entire stream, leading to inaccurate results.

Based on Table 5: we see additional variation between sections habitat assessment scores for Blacks Run , Muddy Creek, and Mossy Creek. These three locations possessed the highest range between sections one and three. The reasons for this are based on the same reasons as the North River habitat assessment (discussed previously) which includes the lack of experience and skill and the variation in the assessed area, and the land use with each tributary as presented in Table 5: ISAT 320 Tributary Land Use (Coffman, 2023).

Table 5: ISAT 320 Tributary Habitat Score

Group	Tributary	Tributary Habitat Score
S1G1	Blacks Run	132
S3G1	Blacks Run	91
S1G2	Cooks Creek	147
S3G2	Cooks Creek	92
S1G3	Muddy Creek	110
S3G3	Muddy Creek	73
S1G4	Mossy Creek	133
S3G4	Mossy Creek	100
S1G5	Pleasant Run	96
S3G5	Pleasant Run	109
S1G6	Upper Drive River	148
S3G6	Upper Drive River	157

The lack of experience and skill may have been a considerable factor given this was our third attempt at using the RBP, and our results could have been wildly inaccurate. Figure 7: ISAT 320 Tributary Locations presents the testing location for each tributary based on the addresses provided by our instructor. However, given the vastness of each tributary, it's likely both groups of each tributary studied different areas within their stream and produced varying results.

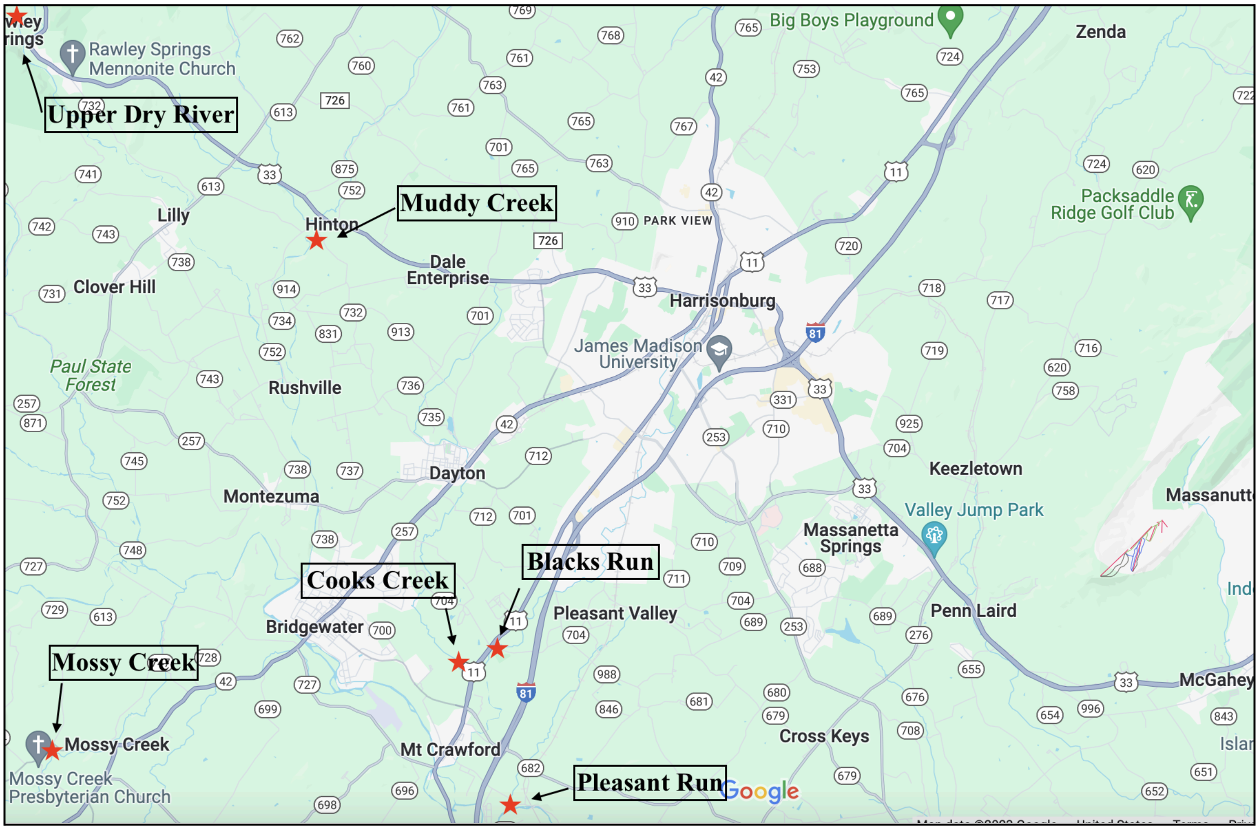
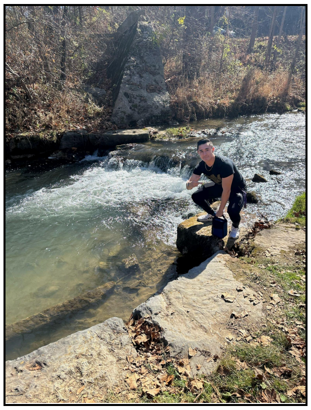
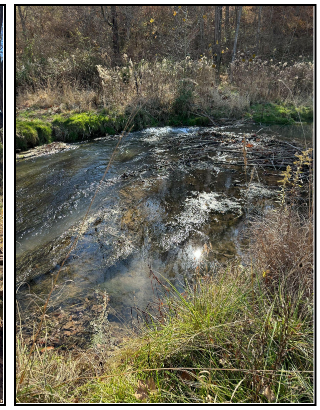


Figure 7: ISAT 320 Tributary Locations

For example, the area of Mossy Creek where we conducted our assessments could've been different from where the other group, S1G4, conducted their assessments. In addition, our results could've differed greatly had we done our tests a few meters downstream where we identified natural features that would have drastically changed our results and inaccurately represent the characteristics of the whole creek. Images 3, 4, 5, & 6 demonstrate the various natural features that could influence the water quality and RBP results.



Images 3, 4, 5, & 6: Natural Features of Mossy Creek

The significance of the land use in the surrounding tributary land is explained by the hydrological cycle, which according to Ecology in Action by Fred. D. Singer, is defined as the “basic patterns of water’s journey through the atmosphere, between the atmosphere and the surface (in both directions), and between different surface reservoirs” (Singer, Ecology in Action, pg. 43), and is visually presented as a systems model in Figure 8: Systems Model of the Hydrological Cycle (Coffman, 2023). This means that the treatment and transfer of water will have a significant impact on the overall quality of the environment, its habitats, and the life forms inhabiting it.

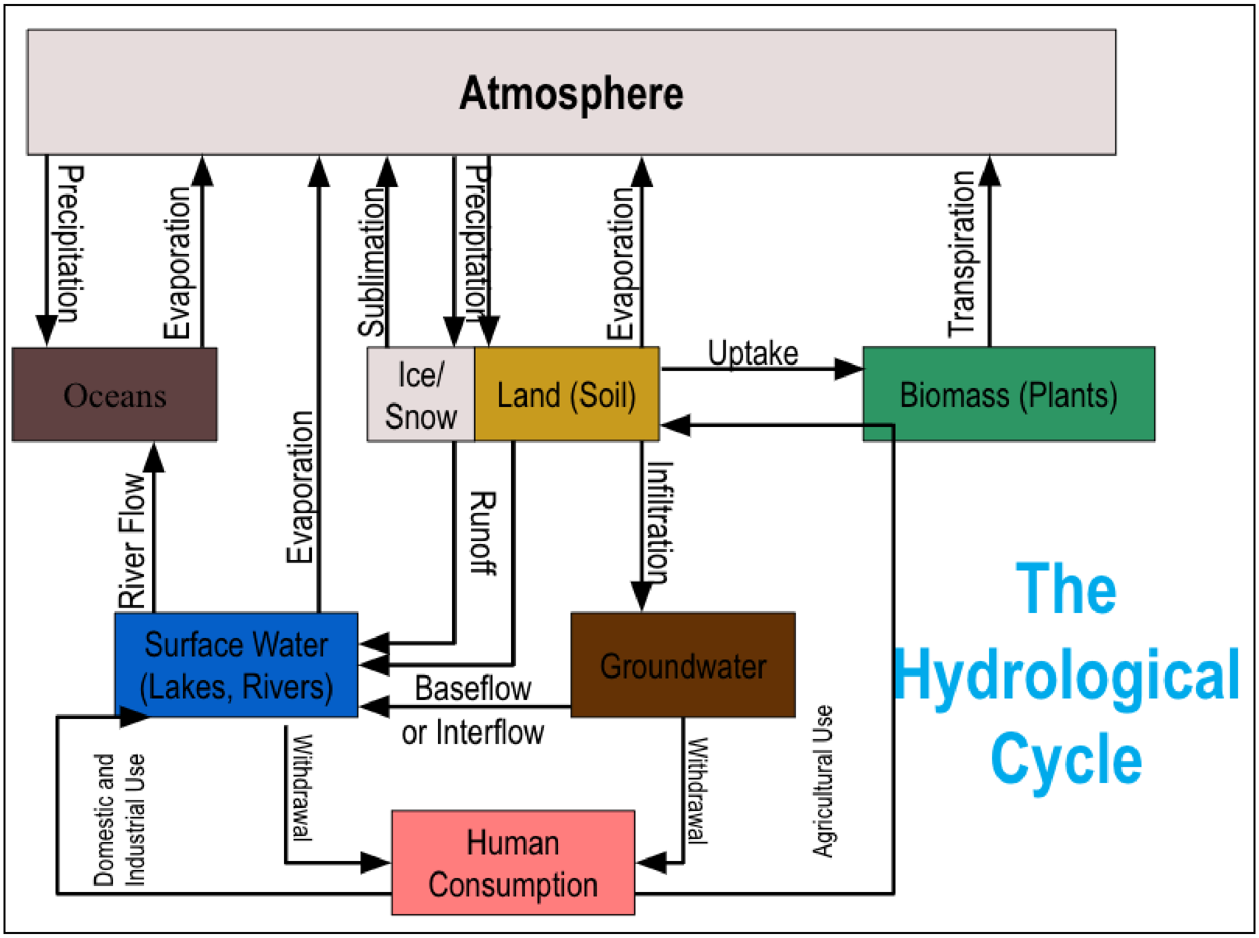


Figure 8: Systems Model of the Hydrological Cycle

Based on Table 6: ISAT 320 Tributary Land Use, there is a trend occurring with the tributary habitat score and its respective land use. The tributaries like the Dry River and the North River with predominantly ‘Forest’ land use have the highest habitat score. According to the Rapid Bioassessment Protocols for Use in Wadeable Stream and Rivers, this is because forests provide ecological services for the stream like minimizing sediment deposition through filtration which minimizes the stream embeddedness, ensures a stable bank by compacting the soil and minimizing soil erosion, and provides plenty of stream coverage. This consequently improves the channel flow, pool variability, and velocity/depth regime by minimizing the sediments entering the stream, therefore making the streams optimal for a diverse population (Coffman, 2023).

However, tributaries like Pleasant Run and Muddy Creek have the lowest habitat scores because they have a high percentage of ‘Cropland’ and ‘Pasture/Hay’ with a comparatively low ‘Forest’. These are three critical factors according to the Rapid Bioassessment Protocols for Use in Wadeable Stream and Rivers because the runoff with high concentrations of sediments from the agricultural treated land easily seeps into the stream without a sufficient amount of riparian vegetation (like trees) to absorb it. As a result, this leads to an increase in embeddedness and sediment deposition, which lowers the stream's depth (or makes it shallower) and reduces its channel flow status, stream velocity, and frequency of riffles (Coffman, 2023). Collectively, all of these effects will reduce the stream’s habitability.

Between the two extremes was Cooks Creek, Mossy Creek, and Blacks Run, all three which possessed a high and low score. Based solely on the statistics, it is assumed all three creeks would possess low habitat scores given their land use primarily consists of ‘Cropland’, ‘Pasture/Hay’, and impervious obstacles with very little in ‘Forest’ and ‘Pervious Developed’ areas. Runoff with extremely high concentration of nutrients and minerals from agriculture with obstacles that prevent adequate water runoff could lead to drastic changes in the steam’s habitat score similar to Pleasant Run and Muddy Creek. According to the Rapid Bioassessment Protocols for use in Wadeable Stream and Rivers, this is because the pollutants could accumulate in impervious areas where they eventually wash into the steam at large quantities and dramatically change the chemical makeup of the stream and drive out life. With that, there’s a possibility there are areas that aren’t affected as drastically as other areas, which could explain the variation in habitat scores (Coffman, 2023). Though, it's likely this variation is due to human error in making the correct judgment.

Table 6: ISAT 320 Tributary Land Use

Land Use	~~North River~~	~~Pleasant Run~~	Cooks Creek	Mossy Creek	~~Muddy Creek~~	~~Dry River~~	Blacks Run
Water	0.35%	0.29%	0.25%	0.18%	0.08%	0.46%	0.26%
Impervious Roads	0.63%	2.68%	6.74%	1.09%	1.09%	0.10%	10.69%
Impervious Structures	0.49%	1.42%	5.11%	0.83%	0.98%	0.00%	7.90%
Impervious, Other	0.76%	4.27%	10.86%	1.29%	1.59%	0.01%	18.33%
Tree Canopy over Impervious	0.41%	0.48%	1.00%	0.46%	0.51%	0.31%	1.41%

Turf Grass	1.69%	5.86%	12.18%	2.66%	3.37%	0.01%	14.69%
Pervious Developed, Other	0.29%	1.67%	4.28%	0.18%	1.11%	0.00%	7.64%
Tree Canopy over Turf Grass	0.71%	2.11%	4.91%	1.25%	1.39%	0.01%	7.70%
Forest	68.76%	15.15%	7.09%	19.79%	36.82%	98.16%	6.77%
Tree Canopy, Other	1.15%	3.61%	2.14%	3.90%	1.55%	0.05%	2.38%
Harvested Forest	0.04%	0.00%	0.06%	0.10%	0.07%	0.01%	0.09%
Natural Succession	0.51%	0.49%	1.00%	0.41%	0.43%	0.85%	1.86%
Cropland	11.28%	33.78%	26.52%	13.89%	29.06%	0.00%	6.98%
Pasture/Hay	12.88%	28.16%	17.61%	53.88%	21.88%	0.04%	12.85%
Extractive	0.00%	0.00%	0.17%	0.00%	0.00%	0.00%	0.39%
Wetlands, Riverine Non-forested	0.05%	0.03%	0.04%	0.06%	0.03%	0.00%	0.04%
Wetlands, Terrene Non-forested	0.01%	0.00%	0.02%	0.00%	0.03%	0.00%	0.00%
Habitat Score	138.17	96 106	147	133 100	110 73	148 157	132 91

4.4. Water Quality Sampling

Water quality is one of the most important sets of indicator characteristics when it comes to the health of a stream. Water doesn't need to be perfect to support life, but having the right quality characteristics can impact the amount of life supported. Table 7 displays the summary statistics for each water quality parameter collected on each day across all lab groups.

Table 7: North River Water Quality Parameters I

DAY 1	Temperature (°C)	Conductivity (us/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity (NTU)
AVG	13.3	378.6363636	9.808181818	8.24	1.5
STDEV	0.70124348	8.923920867	0.307211308	0.08095547	0.15275252
MIN	12.1	371	9.27	8.04	1.3
MAX	14.5	407	10.4	8.38	1.8
RANGE	2.4	36	1.13	0.34	0.52
DAY 2	Temperature	Conductivity	Dissolved Oxygen	pH	Turbidity
AVG	12.8909091	391.5	9.618181818	8.07727273	2.63636364
STDEV	1.15970216	21.58124185	0.259184034	0.08331757	1.5666989
MIN	11.5	364	9	8	0
MAX	15.4	429	10	8	0
RANGE	3.9	65	1.01	0.26	0
DAY 3	Temperature	Conductivity	Dissolved Oxygen	pH	Turbidity
AVG	11.2	397.4	8.6	7.9	2.0
STDEV	0.69580725	7.944409126	0.235659937	0.1539259	1.66354564
MIN	10.1	379.0	8.3	7.5	0.8
MAX	12.3	408.0	9.0	8.0	6.6
RANGE	2.2	29.0	0.7	0.5	5.8

The first trend that jumps out to me is a decrease in average temperature from week to week. Measurements were taken on 10/11, 10/25, and 11/1, 2023, on days 1, 2, and 3 respectively. There was some rainfall before the second and third day of data collection which could contribute to the lowering of the water temperature, as well as it just being later in the calendar year and therefore having colder air temperatures from measurement to measurement. It seems as though the conductivity increased as time went on. Conductivity can increase with turbidity, and the first week has the lowest turbidity reading out of the three. The Dissolved

Oxygen also decreased week-to-week - this is strange as colder water is supposed to hold more dissolved oxygen (Coffman, 2023). However, this can be explained when you remember that measurements were taken progressively, later-and-later into the fall season, meaning that each week there was more detritus as dead leaves accumulated in the river; decreasing the available DO. Table 8 displays the summary statistics for the parameters that remained constant across all lab groups from collection day to collection day.

Table 8: North River Water Quality Parameters II

	Minimum	Maximum	Range	Standard Deviation	Average
Total coliform MPN (cfu/100ml)	>2,419.6	>2,419.6	0	0	>2,419.6
E. coli MPN (cfu/100ml)	21.8	44.8	23	11.500	33.267
Total Coliform MPN (cfu/100ml) *by dilution 1:10	9,208	19,863	10,655	5,987.038	12,958.333
E. coli MPN (cfu/100ml) *by dilution 1:10	20	31	11	7.778	25.5
Total Nitrogen (mg/L - N)	4.167	6.25	2.083	1.042	5.208
Total Phosphorus (mg/L - P)	0.114	0.172	0.058	0.0286	0.143
IC - Fluoride (mg/L)	0.29	0.29	0	0	0.29
IC - Chloride (mg/L)	6.783	7.384	0.601	0.332	7.615
IC - Nitrate (mg/L)	5.1414	6.0383	0.8969	0.50076	5.7185
IC - Phosphate (mg/L)	0	0	0	0	0
IC - Sulfate (mg/L)	8.0833	9.1181	1.0348	0.539	8.688

The water quality parameters shown in Table 7 fell within the standards provided in Table 1 in the North River Assessment Template (Coffman, 2023), except for DO, which was consistently greater than the standard of >5.0mg/L, and the temperature, which when compared to the standard was much less than even the lower recommendation of 21 degrees Celsius for Trout. However, the water quality parameters in Table 8 showed much less similarity to the standards. The nitrate standard of less than 0.31 mg/L was smashed, with our groups' average being about 5.72 mg/L, more than 18 times higher than the standard. Runoff and wastewater containing fertilizer can increase nitrate levels in water - "*When farmers apply fertilizers to soil, on average about half of the reactive nitrogen is lost to the atmosphere and to runoff.*" (Singer's Ecology in Action, Ch. 20). Keeping in mind Harrisonburg's high-agriculture makeup, this parameter exceeding the standard makes sense. As all of the phosphorus were below the detectable level (reflected by a 0 in Table 8), and the phosphorus standard is less than 0.01 mg/L, I feel comfortable calling that in line with the standard. Our Total Coliform MPN also vastly exceeded the standard of less than 126 cfu/100 ml water, which can also be attributed to the high amounts of waste input to the water table from farm animals in the area surrounding Harrisonburg.

When trying to discern a river's water quality characteristics, it can be useful to take water quality measurements at a number of the river's tributaries. The following two tables display the water quality parameters across the six different tributaries:

Table 9: Tributary Water Quality Parameters I

Location (specific site where you collected sample)	Air temperature (°C)	Water Temperature (°C)	Conductivity (us/cm)	Dissolved Oxygen (mg/L)	pH	Habitat Score
Blacks Run	21.1	15.1	623	10.4	8.3	132
Blacks Run	13.9	12.3	589	10.6	8.3	91
Cooks Creek	5.6	12.9	395	7.4	7.8	147
Cooks Creek	21.7	13.9	533	6.8	7.8	
Muddy Creek	15.6	16.5	874	8.7	7.9	110
Muddy Creek	10.0	8.2	526	6.5	7.7	73
Mossy Creek	8.9	12.7	399	10.6	8.3	133
Mossy Creek	18.3	14.1	400	10.2	8.1	100
Pleasant Run	3.3	6.5	591	11.2	8.1	96
Pleasant Run	17.2	14.5	589	10.9	11.7	109
Upper Dry River	12.8	13.3	30.8	8.9	7.2	148
Upper Dry River	12.2	12.4	35	9.4	7.1	157

Table 10: Tributary Water Quality Parameters II

Location (specific site where you collected sample)	Total coliform MPN (cfu/100ml)	*E. coli* MPN (cfu/100ml)	Total Coliform MPN (cfu/100ml) *by dilution 1:10	*E. coli* MPN (cfu/100ml) *by dilution 1:10	Total Nitrogen (mg/L - N)	Total Phosphorus (mg/L - P)	IC - Flouride (mg/L)	IC - Chloride (mg/L)	IC - Nitrate (mg/L)	IC - Phosphate (mg/L)	IC - Sulfate (mg/L)
Blacks Run	>2419.6	26.2	10,462	20	2.81	0.08	BDL	49.37	2.79	BDL	23.02
Blacks Run	>2419.6	579.4	17,329	309	1.51	0.04	0.41	50.11	1.07	BDL	22.17
Cooks Creek	>2419.6	50.4	>24,196	31	10.21	0.28	0.51	43.53	16.84	BDL	61.16
Cooks Creek	>2419.6	46.4	12,997	41	3.44	0.09	BDL	37.27	5.08	BDL	20.03
Muddy Creek	>2419.6	79.8	17,329	41	18.44	0.51	0.63	83.30	29.03	10.79	112.28
Muddy Creek	>2419.6	435.2	9,804	794	1.41	0.04	BDL	24.12	1.74	BDL	19.55
Mossy Creek	>2419.6	193.5	9,804	160	4.32	0.12	BDL	7.01	6.23	BDL	6.90
Mossy Creek	>2419.6	648.8	19,863	457	0.52	0.14	BDL	6.87	6.14	BDL	6.96
Pleasant Run	>2419.6	157.6	24,196	295	13.13	0.36	0.41	54.19	33.39	1.69	54.56
Pleasant Run	>2419.6	77.1	24,196	86	12.19	0.33	BDL	20.83	19.58	BDL	16.16
Upper Dry River	816.4	1.0	1100	10	1.46	0.04	BDL	2.34	0.91	BDL	3.90
Upper Dry River	770.1	<1	2014	<1	0.63	0.02	BDL	2.38	0.85	BDL	3.86

This data can be analyzed such that one can infer certain tributaries are more impacted by agricultural runoff than others. For example, every tributary except the Upper Dry River had above measurable levels of E. coli, and Cook Creek and Pleasant Run had very high levels of Total Nitrogen compared to the other tributaries, suggesting these waters had especially high amounts of agricultural land influence. To infer more from the data, each water quality parameter will be presented graphically across all tributaries, starting with the temperature in Figure 9:

Figure 9: Air & Water Temperature Measurements

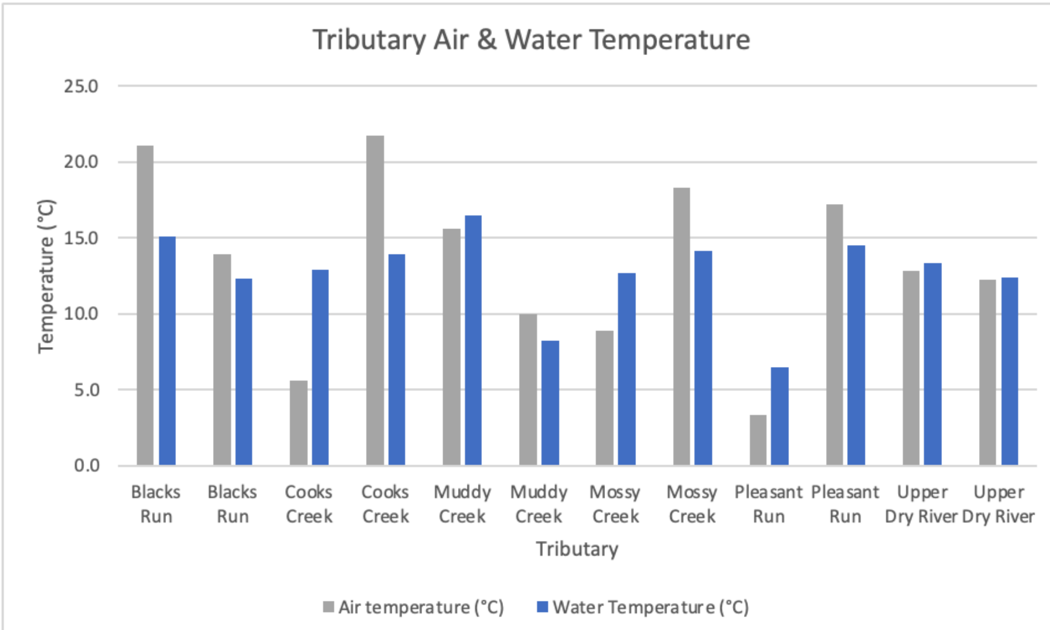


Figure 10: Conductivity Measurements

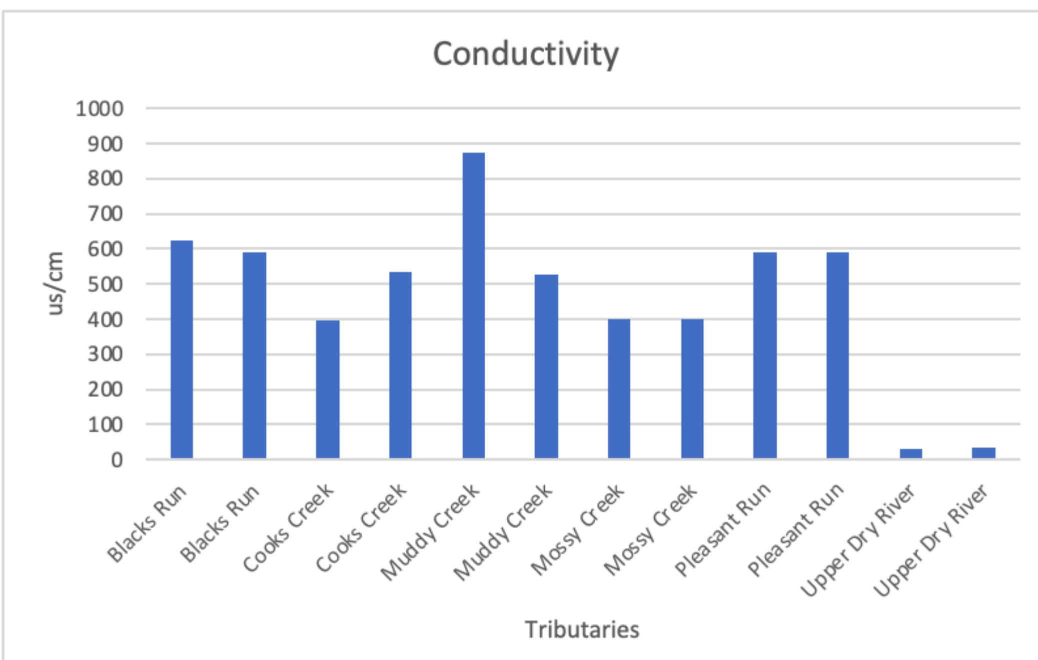


Figure 11: Dissolved Oxygen Measurements

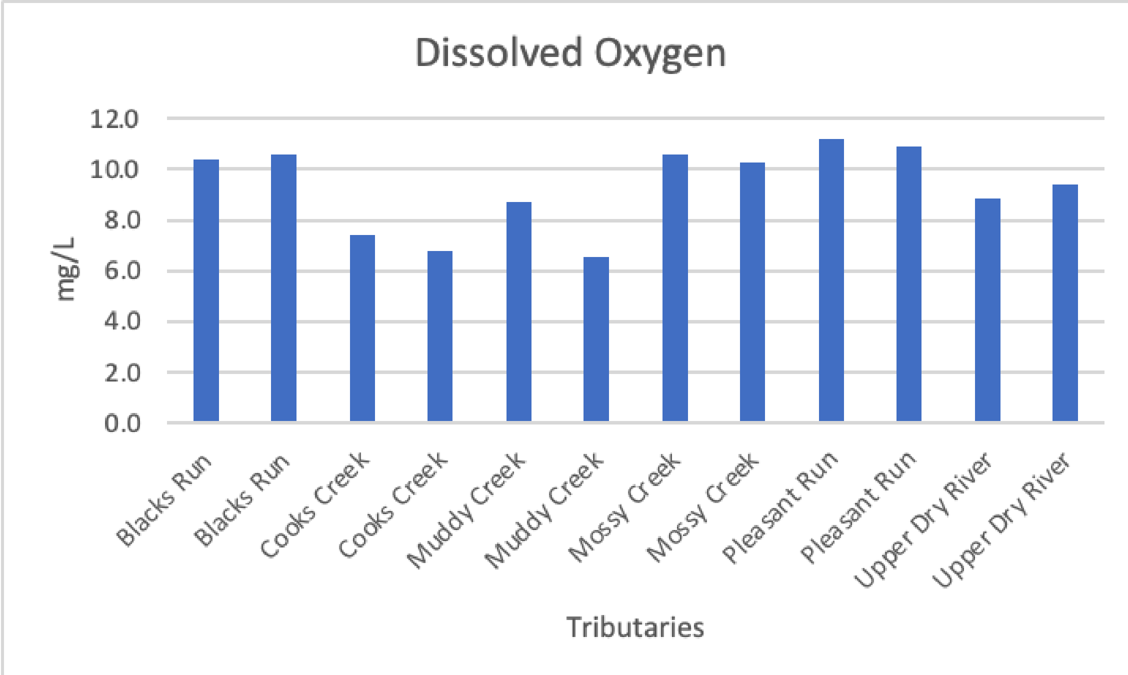


Figure 12: pH Measurements

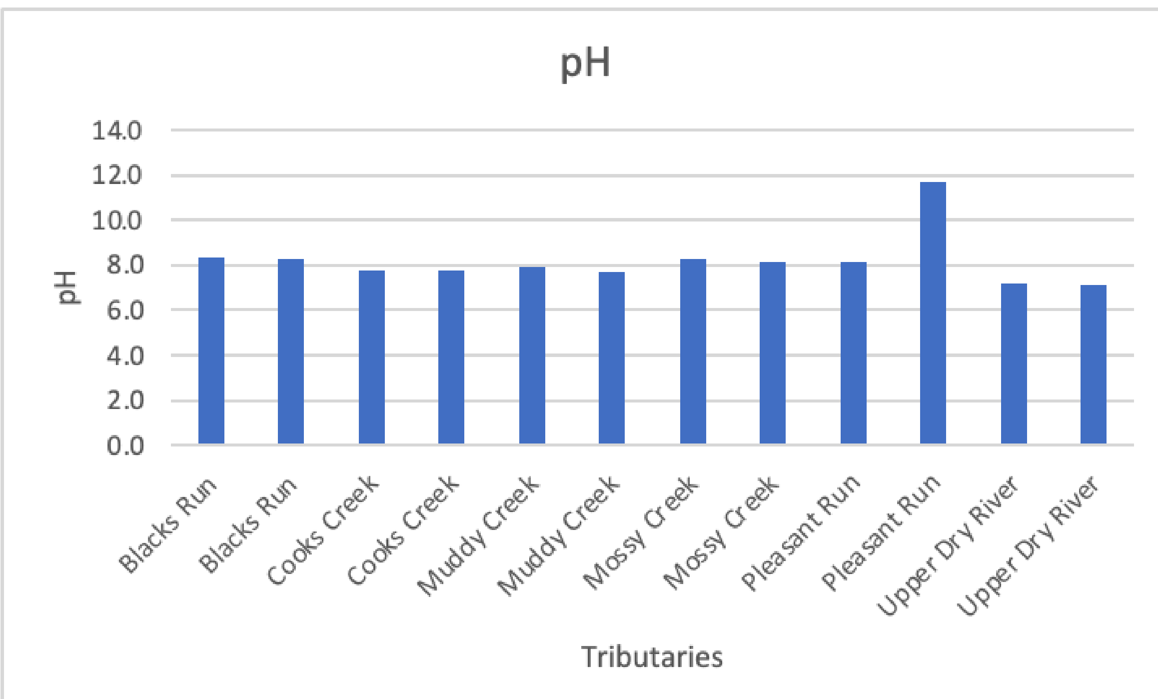
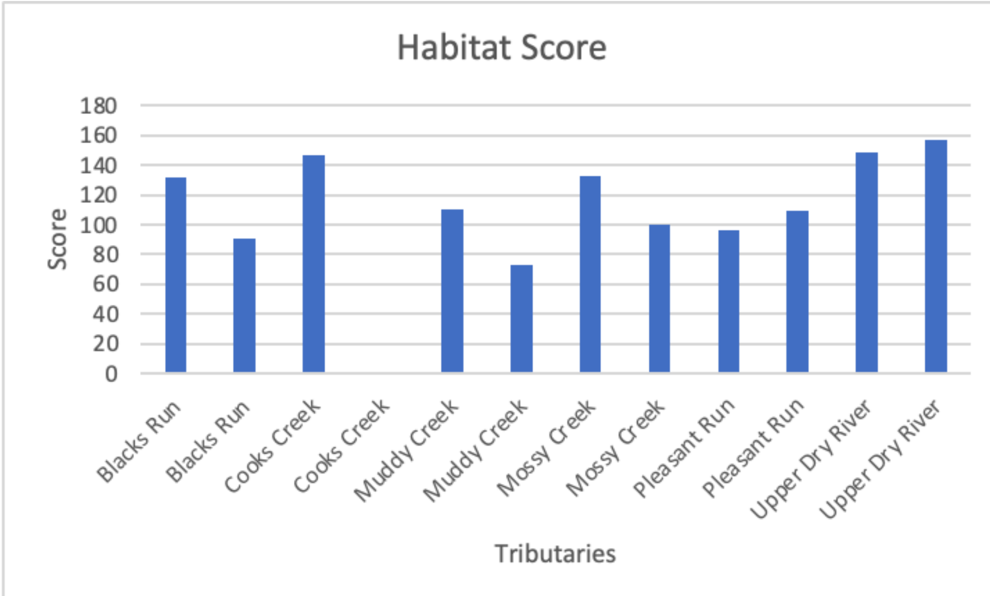
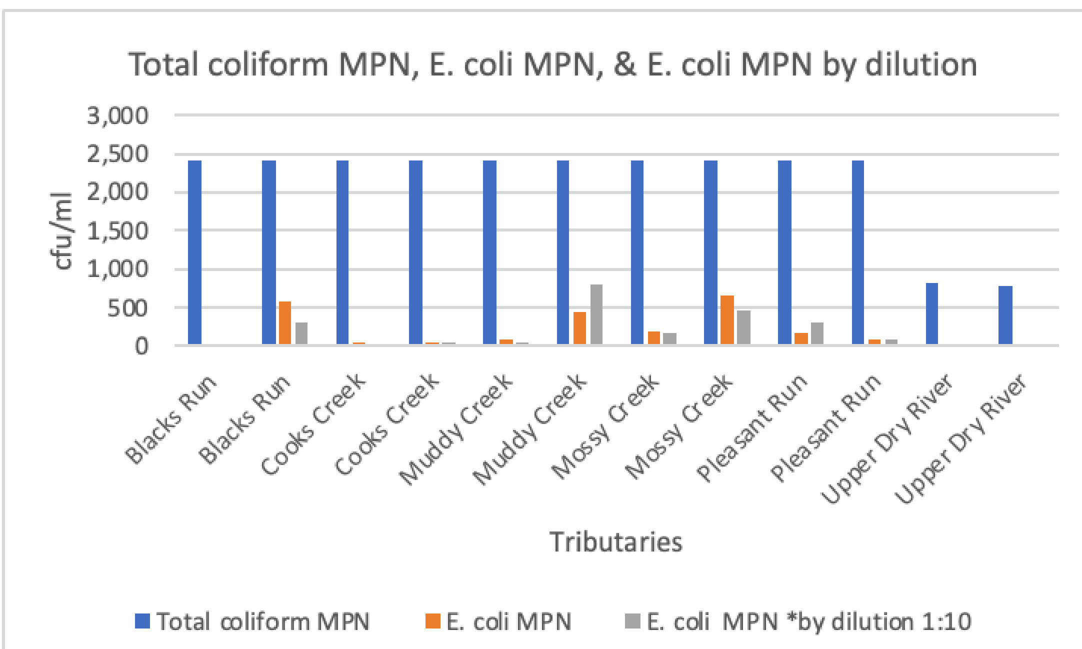


Figure 13: Habitat Score



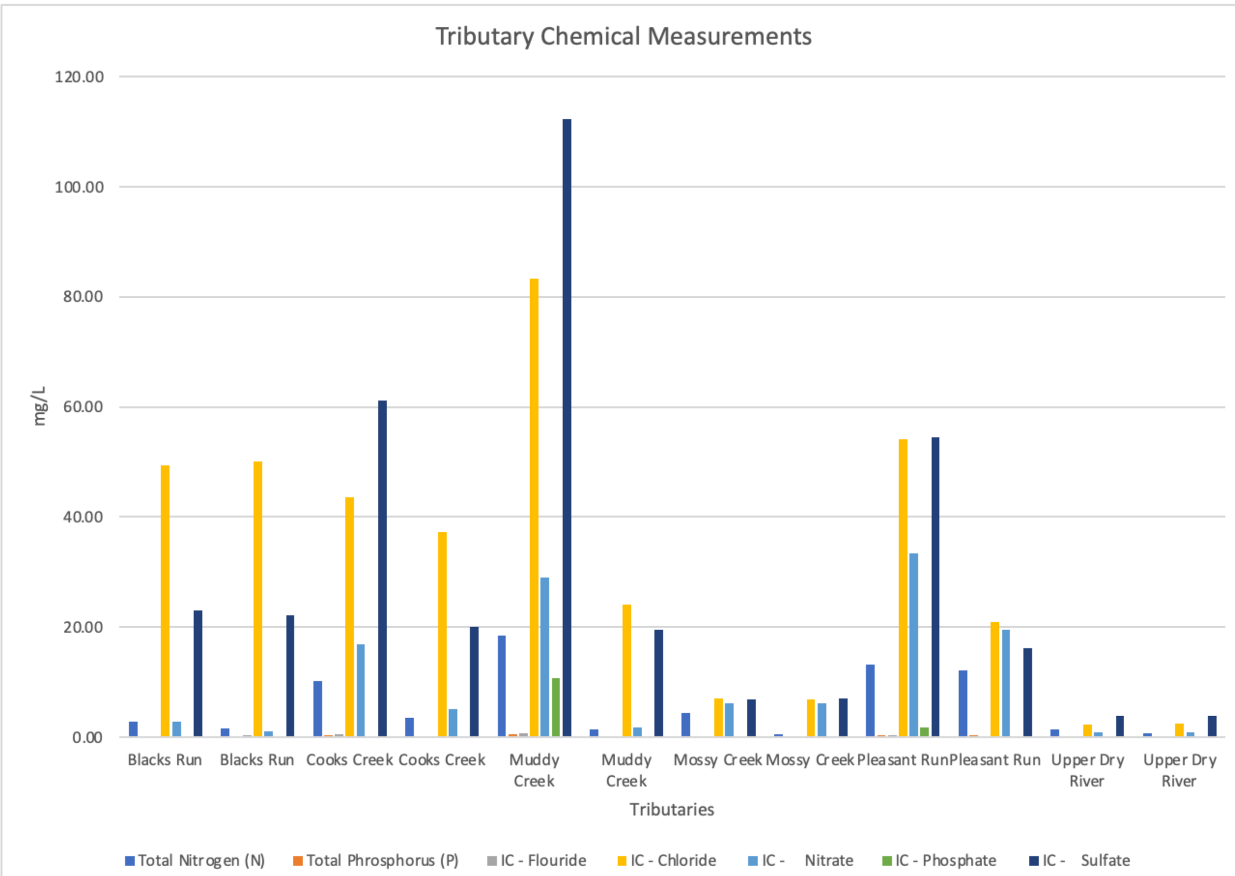
Interestingly, the Upper Dry River shows the highest habitat score out of any tributary. This might be due to it being impacted less by agricultural land in the area, as it displays lower levels of E. coli, total coliform, and lower chemical levels (nitrates and phosphates) than any other river.

Figure 14: Total Coliform, E. coli MPN, and E. coli MPN by Dilution Measurements



Again, Figure 14 shows the Upper Dry River has much less coliform and E. coli, suggesting it has less agricultural land use and animal life in general in its area, as E. coli is more likely to come from the intestinal tracts of farm animals. The data also shows that Cooks Creek had almost no E. coli across its two measurements while still maintaining the above measurable level of Total coliform MPN common across almost every other tributary.

Figure 15: Tributary Chemical Measurements



Muddy Creek had massive levels of sulfates, almost double any other tributary. For that reason, I think this can be considered an outlier and using the ~20 mg/L reading for Muddy Creek will have to do. In that case, Cooks Creek has the highest IC - Sulfate levels, suggesting facilities such as wastewater treatment plants are introducing waste to Cooks Creek and the surrounding atmosphere, or perhaps there is less basic rock in the area so as to neutralize acidic rain than other tributaries (Singer, Ecology in Action, pg. 104).

Figure 16: Conductivity & % Saturation Fluctuations

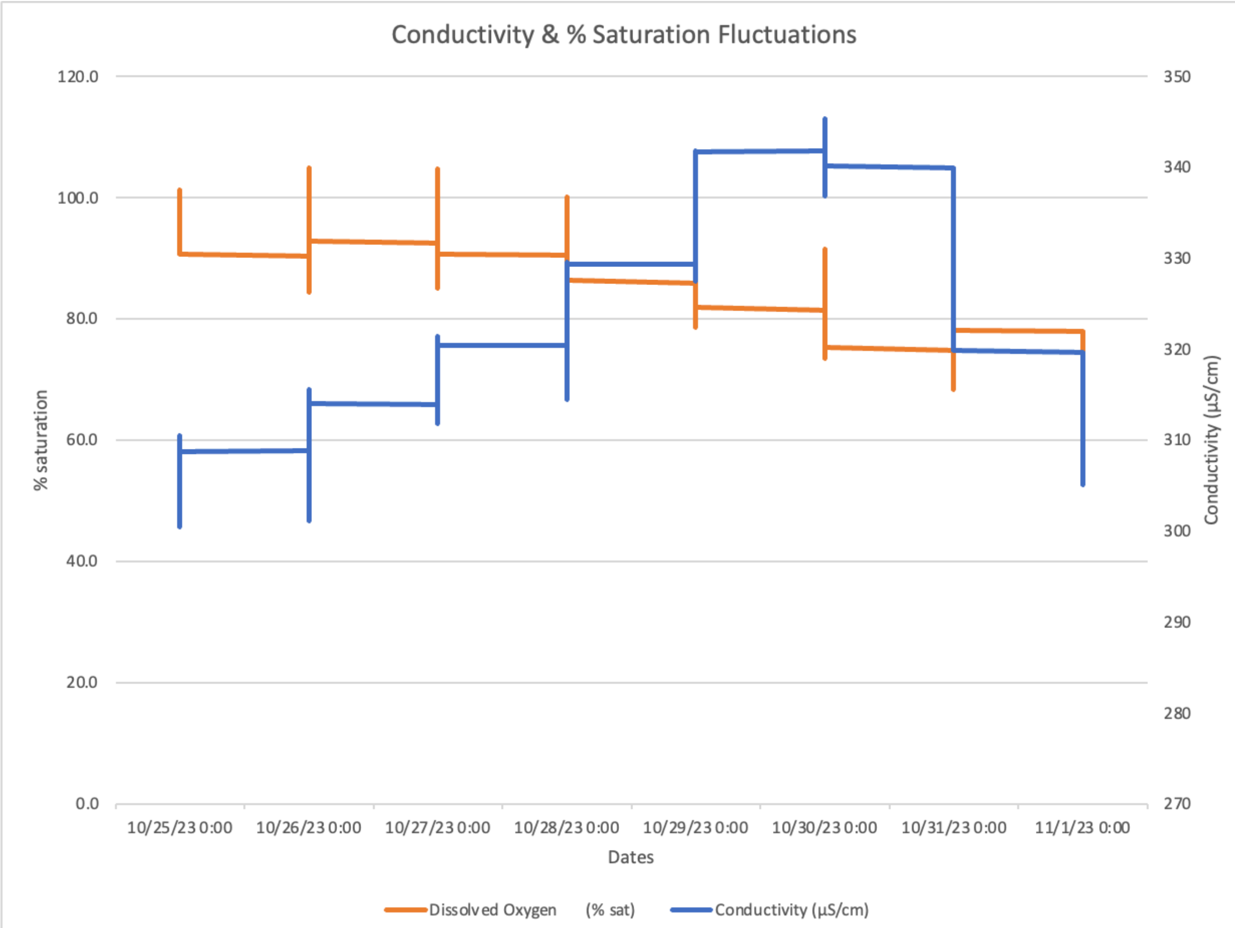


Figure 16 reveals how the percent saturation of Dissolved Oxygen steadily decreased over the monitoring period. This could be caused by temperatures lowering across the monitoring period, causing biological activity to lessen, or by more leaves falling into the river as time went on and decomposing, taking up oxygen.

Figure 17: Dissolved Oxygen, Turbidity FNU, pH, & Temperature Fluctuations

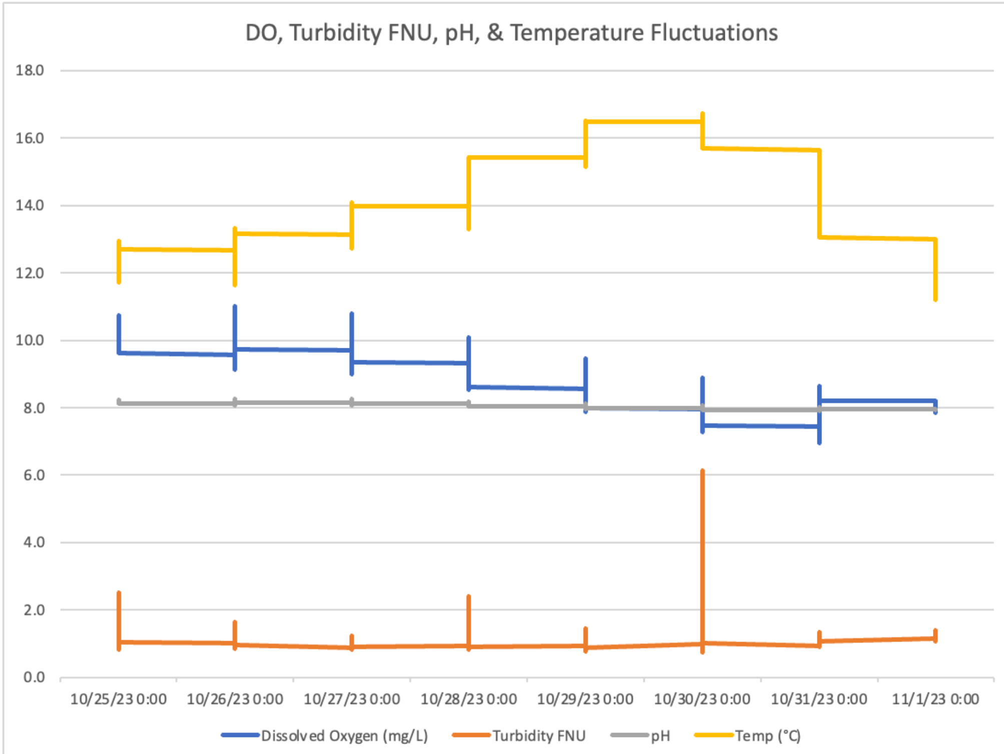


Figure 17 also shows the dissolved oxygen lowering, although in different units. The pH of the river stayed constant at just above 8, and the turbidity also stayed relatively constant. The temperature actually increased throughout the monitoring period before falling again, which makes the most likely cause of the lowered dissolved oxygen levels the refuse falling into the river and decomposing, rather than lessening biological activity as winter approaches.

The water quality of the North River and its tributaries has certainly been impacted by human activity. Above-standard levels of bacteria and chemicals that should be helpful to the quality of life in moderation, but at present, their excess could be hindering that quality. This effect can be seen in the low dissolved oxygen, the extremely high levels of sulfates and nitrates, and in our river displaying the lowest species richness possible for our level of habitat score and our assumed RBP range. Although it isn't the worst-case; these aren't dead streams with no biological activity, choked with pollutants, these streams could still be better suited, more productive, and healthier for the variety of life that call them home.

4.5. Benthic Macroinvertebrate Assessment

Table 11: Benthic Multi-metric Scores and Summary Statistics for All Groups

Group	Location	Benthic Multi-metric Score	Min Score	Max Score	Average Score	Standard Deviation	Range
S1G1	Sandy Bottom	7	4	10	6.54	1.81	6
S1G2	Sandy Bottom	7					
S1G3	Sandy Bottom	7					
S1G4	Sandy Bottom	6					
S1G5	Sandy Bottom	Not Provided					
S1G6	Sandy Bottom	8					
S3G1	Sandy Bottom	5					
S3G2	Sandy Bottom	10					
S3G3	Sandy Bottom	6					
S3G4	Sandy Bottom	8					
S3G5	Sandy Bottom	4					
S3G6	Sandy Bottom	4					

Our group sampled 275 benthic macroinvertebrates during Lab 8A. This data was broken down into six different metrics according to the organism groups listed on the VASOS identification sheet. For example, metric one consisted of Mayflies, Stoneflies, and most Caddisflies (not Common Net Spinning), while metric two examined common net spinning Caddisflies. The number of organisms which applied to a specific metric was then divided by the total sampled (275) and multiplied by 100 to determine the percentage of organisms from the total sample that fell under a particular metric.

By following the instructions on the VASOS identification sheet, the Multimetric index score was calculated by combining the six metric percentages into one value. The value for this score could range between 0-12, with 0-7 representing unacceptable ecological conditions, and 9-12 indicating acceptable conditions. Our group calculated a score of 8, which meant that the ecological condition of the site could not be determined based on the data we provided.

When comparing our Multimetric index score with the 11 other groups, we found that the average was 6.54. The highest score was 10, the lowest was 4, and the standard deviation was 1.81, which indicates a slightly high level of variability. Overall, 8 out of the 13 groups (61% of the groups) scored in the 0-7 range. Therefore, on paper this bioassessment data would indicate that the North River possesses unacceptable ecological conditions. However, the relatively high level of variance between group scores could be the result of simple collection and sampling errors, such as incorrect identification of organisms, miscounts, and improper gathering techniques. Further, because the average was 7.5, it is likely more appropriate to conclude that, by and large, the Multimetric scores across all groups are insufficient in determining an accurate score for the ecological conditions in the North River.

In relation to the water quality samples, we can infer that the health of the benthic macroinvertebrate ecosystem is being negatively impacted by the low levels of dissolved oxygen. Additionally, the variability in the habitat assessment scores also ties into the inconclusive multimetric index scores. There were many opportunities for error in both assessments due to, largely due to students being unfamiliar with the parameters on the habitat assessment field data sheet, as well as the process of identifying macroinvertebrates.

4.6. Fish Community Survey

The purpose of conducting the fish community assessment was to determine the species richness of the North River, then compare our results to other variables like the benthic mult-meter, habitat, and water quality scores (Coffman, 2023). Based on Table 12, the North River's final species richness equals to 14 with section 1 catching 7 fish and section 3 catching 13 fish, six of which are the same as section 1.

Table 12: Fish Species Identified by Section 1 & 3

Species	Section 1	Section 3	Species	Section 1	Section 3
Common Carp			Rock Bass	X	X
Shiners		X	Green Sunfish	X	X
Chubs	X	X	Redbreast SunFish		X
Daces	X		Pumpkinseed		
Fallfish		X	Bluegill		
Cultip Minnow		X	Smallmouth Bass	X	X
Blunt-Nosed Minnow			Largemouth Bass		
White sucker		X	Brook Trout		
Northern Hogsucker		X	Brown Trout		
Torrent Sucker			Rainbow Trout		
Margined Madtom		X	Darters		
Potomac Sculpin	X	X	American Eel		
Mottled Sculpin	X	X	Overall Species Richness	7	13

When we take the results of the benthic macroinvertebrate sampling in account with the relative abundance of fish species surveyed, we see evidence of general biodiversity in the surveyed portion of the North River. Though our macroinvertebrates survey largely had inconclusive results, we still found a fair level of evenness among the six metrics. Wherein, *evenness* refers to "..less variation in the distribution of abundances of each species within an ecosystem…"(Singer, 432). Further, as outlined in Singer's breakdown of species diversity indices, a riparian community with high evenness will have a higher Shannon Diversity Index (more biodiversity) than the average garden community with a higher species richness, but less evenness (Singer, 433).



Images 7, 8, & 9: Harrison McQuillan and his Largemouth Bass

With the habitat assessments, despite assessing the same area of the North River, section 1 had a larger deal of variation while section 3 had smaller variation. That being said, it's reasonable to assume the North River’s actual RBP is likely around the 120 - 140 range given the majority of the scores fell between that range with a couple outliers, which was likely due to misjudgement of the RBP metrics. In comparison to the species richness, it’s reasonable to assume that the North River is likely holding at the minimum 14 fish species within the assumed RBP range.

According to the ‘Chapter 7: Water Chemistry’ reading, the water quality scores are a good indicator of a stream’s health and capability of sustaining a variety of life. In addition, it provides a much deeper analysis beyond a RBP assessment. Based on the water quality results, the pH remained consistent throughout the two sections. This is ideal for the fish given their limited survival tolerance range (Coffman, 2023). This lack of pH fluctuation could likely be due to the recent drought in the region, similar to what we experienced with the Hillside Assessment Report and how it impacted our soil samples and results (Chizmadia, Lisco, Sizemore, Carroll, & McQuillan, 2023, p.1). The time when the assessments were conducted also played a major role with section 1 reporting slightly lower temperatures than section 3 who conducted assessments around two hours later in the morning. The effects of this time difference was shown in the dissolved oxygen results with section 1 reporting lower numbers than section 3, thus demonstrating the diel oxygen fluctuation explained in 'Chapter 7: Water Chemistry' reading (Coffman, 2023). The balance in dissolved oxygen levels correlates with the species richness reported as it shows how life forms like fish and plants gradually became more active as the morning progressed (Coffman, 2023). This increase in plant activity correlates to more photosynthesis and higher dissolved oxygen levels in stream ecosystems (Coffman, 2023). In addition, this increase in life form activity could partly explain the rise in turbidity levels as fish begin to release organic waste and plankton undergo rapid reproduction by decomposing organic matter that have fallen into the stream, both of which increase the suspended matter content (Coffman, 2023). Lastly, conductivity remained consistent in a typical stream range between both groups, meaning the micro-ions content remained the same, providing a healthy environment for fish and other organisms.

Table 13: ISAT 320 Species Richness vs. Benthic, Habitat, & Water Quality

	Species Richness	Benthic Multi-metric Score	Habitat Score (Lab 9)	Temp (°F)	Conductivity (us/cm)	Dissolved Oxygen (mg/L)	pH	Turbidity
S1G1	7	7	132	11.2	387	8.3	7.7	1.5
S1G2	6	7	178	10.7	405	8.5	7.8	0.9
S1G3	7	7	178	10.5	408	8.4	8.0	1.5
S1G4	6	6	141	11.2	402	8.7	7.7	0.8
S1G5	5	[redacted]	123	11.0	402	8.7	7.9	1.6
S1G6	7	8	153	10.1	402	8.3	8.0	0.9
S3G1	7	5	130	11.3	397	8.8	7.9	1.1
S3G2	13	10	126	11.6	399	9.0	8.0	6.6
S3G3	13	6	122	11.4	400	8.6	7.9	0.9
S3G4	13	8	130	10.2	379	8.9	8.0	3.2
S3G5	13	4	116	12.3	395	8.6	7.5	2.7

S3G6	13	4	129	12.2	397	9.0	8.0	2.7

4.7. Periphyton Biomass Sampling

Table 14: Periphyton Ash Free Dry Weight Values and Summary Statistics For all Groups

Group	**Periphyton Biomass (Ash Free Dry Weight in g/m²)**	Standard Deviation	Min	Max	Range	Average
S1G1	26.1	12.96 g/m²	4.6 g/m²	45.8 g/m²	41.2 g/m²	25.7 g/m²
S1G2	43.5					
S1G3	7.8					
S1G4	28.7					
S1G5	11.9					
S1G6	31					
S3G1	35.9					
S3G2	4.6					
S3G3	20.6					
S3G4	26					
S3G5	45.8					
S3G6	26.7					

According to Lab 9, “Periphyton is the complex mixture of algae, fungi, bacteria, diatoms, and protozoans that cover the rocks in a shallow stream”(Coffman, 2023). This collection of organisms form the base of the food web in freshwater ecosystems, and the importance of this will be explained in further detail below.

To determine the average periphyton biomass in each mile of the North river, we used the two different (relatively representative) cross sectional width measurements obtained in Lab 7. After taking the average of these widths (104 ft.), we multiplied it by 1 mile (5,280 ft.) to get the average surface area for every mile portion of the river (5.4×10^5 ft.^{2} or 5.1×10^4 m^2). Finally, the average surface area was multiplied by the average periphyton ash free dry weight for all groups (25.7 g/m^2). This operation provided us with average mass of periphyton growing in every mile of the North River (1.3×10^6g).

Finding the average mass of periphyton per mile is important to understanding the significance of trophic pyramids and food chains within aquatic ecosystems. Trophic levels form a top-down biomass pyramid, the base of which is occupied by bacteria, algae, phytoplankton, and other microscopic organisms which form the layer of periphyton on the rivers’ bottom. Therefore, a healthy layer of periphyton influences the health of every trophic level above it, such as benthic invertebrates and fish. This is further supported by the fundamental rule that the amount of energy available to one trophic level is only a small fraction of the total energy available to the trophic level which precedes it (Singer, 487).

Finally, by examining the mix, max, and range in Table 14, we see considerable variation and unevenness among the ash-free dry weight values across all groups. This is due to random sampling errors, as some groups happened to use rocks which had low levels of periphyton, and thus were likely not representative of the entire substrate. Further, some groups might have used rocks which had lost periphyton from other people walking around and disturbing the bottom. This can be prevented in the future by coordinating what area each group will sample from prior to entering the river.

5. Conclusions

The data collected over the North River labs seems to point towards agricultural land use and runoff from urban zones as primary factors impacting the health of the North River. The high levels of nitrates and phosphates measured in the majority of tributaries and the North River contribute to this line of reasoning. One potential reason that there were relatively high species richness and diversity scores in the fish communities despite the above-standard levels of nitrates and phosphates could be the lack of rainfall in the weeks where data was taken. The lack of rainfall could explain the mostly stable pH levels seen across the tributaries and North River, as drought means less acidic rain and runoff from urban areas entering the watershed. However, it's important to note human error likely played a significant part in some areas of measurement, especially the benthic macroinvertebrate assessment and measurements taken after other groups had been in the river already.

Based on the data collected, some recommendations for improving the health of the North River would be to increase the riparian buffer along the banks of the North River and its tributaries, which could decrease soil erosion as more root systems take hold on the bank's soil. This along with increasing the epifaunal substrate present would help prevent increases in embeddedness and stream deposition, preventing the river from getting shallower, holding the stream flow velocity constant, and protecting existing riffles. Additional root systems would also help with filtration of runoff water containing chemicals. As another added benefit, decreasing erosion might hold the river's temperature more constant, as less particulate in the water means less heat being absorbed by the water. Additional shade provided by fortifying the riparian buffer can also contribute to stabilizing temperatures. All of these changes could make the North River a better environment for supporting life.

6. References

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