Baxter Creek Benthos Survey

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1.0 INTRODUCTION

In collaboration with the Baxter Creek Watershed Alliance (BCWA), the Baxter Creek Benthos Survey is a Capstone Project focused on understanding the water quality and ecosystem health of the Baxter Creek watershed. The data collected from this project will establish a baseline benthic data set as it is the first year of collection. In addition to collecting benthic macroinvertebrates, field observations and water chemistry parameters will be recorded to provide comparable quantitative measurements between the sites and for future research. Founded in 2021, The Baxter Creek Watershed Alliance (BCWA) is a non-profit environmental non-government organization (ENGO) passionate about conserving and enhancing the local watershed health for future generations of humans and wildlife (Baxter Creek Watershed Alliance, 2021). Based out of the Cavan-Monaghan and Baxter Creek area, the community-based citizen science organization prioritizes education and engagement within the community to protect and care for a clean, healthy watershed (Baxter Creek Watershed Alliance, 2021).

1.1 Baxter Creek Watershed History

The Baxter Creek watershed is one of twelve sub-watersheds that stem from the Otonabee River basin (Pethick et al., 2023). The Otonabee River basin flows through the city of Peterborough and covers 806 km^2 (Figure 1). The Baxter Creek watershed occupies a much smaller area and spans four municipalities. This includes the City of Kawartha Lakes, the Municipality of Clarington, and the Township of Otonabee-South Monaghan (Pethick et al., 2023). Baxter Creek is located within the traditional territories of the Hiawatha, Curve Lake, Alderville, and Missisaugas of Scugog Island First Nations (Pethick et al., 2023). As seen in Figure 1. Baxter Creek is a sub-watershed in a large river basin system. A sub-watershed is the area of land that water flows through to drain into a larger body of water.

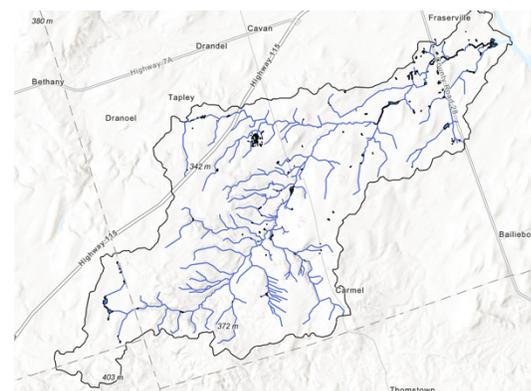Figure 1. Otonabee River basin (Pethick et al., 2023).

Figure 2. Hydrology within Baxter Creek watershed (MacLean et al., 2022).

As a sub-watershed, Baxter creek has a large impact on all the other waterbodies in the region. Watersheds provide critical ecosystem services such as drinking water and outdoor recreation. Although watersheds support our economies, environment, and quality of life, they are particularly vulnerable to the effects of surrounding land use. As seen in Figure 3. The dominant land use is Agricultural + Rural areas with 54%, followed by a mix of Green Space (Mixed Trees, Deciduous, Swamp) with 30%,
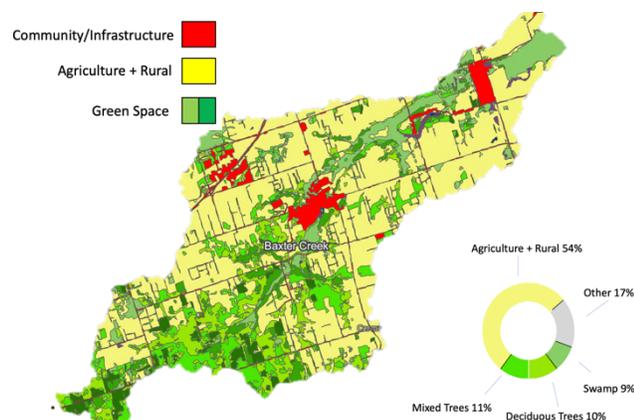

Figure 3. Baxter Creek watershed surrounding land uses (BCWA, 2022).

and the rest of the land use is composed of Other (community/infrastructure etc.). It is extremely helpful to determine the different land uses of the watershed and possible reasons for the water quality in different areas of the creek. For instance, anthropogenic land-use change causing agricultural run-off of pesticides and fertilizers into the watershed upstream will directly impact vulnerable ecosystems downstream. The residents, businesses, and communities rely on the Baxter Creek watershed for a variety of uses. Understanding the history of these communities and local watersheds plays a significant role in conserving and protecting Baxter Creek watershed. The implementation of conservation measures and management plans is important in ensuring the health of the other watersheds and the river basin system.

1.2 Benthic Macroinvertebrates as Bioindicators of Water Quality

Benthic macroinvertebrates are excellent indicators of ecosystem health in freshwater environments as they are present in most aquatic habitats (Reynoldson &Metcalfe-Smith, 1992). Benthic macroinvertebrates were collected as part of the Baxter Creek Benthos Survey and will serve to inform water quality assessments. Benthic macroinvertebrate communities integrate exposure over time which allows for assessment from a variety of sources of stress (Jones et al. 2007).

Figure 4. *Decapoda* (Crayfish) found at site BXCR-01-R2.

They are easy to sample quantitatively compared to other groups such as phytoplankton, zooplankton, and fish; they have recognized community responses to water quality changes depending on taxonomic order (Reynoldson &Metcalfe-Smith, 1992; Hilsenhoff, 1987, 1988). Additionally, benthic macroinvertebrates are non-mobile, allowing them to represent the location being sampled (Reynoldson &Metcalfe-Smith, 1992). The early response to environmental stress makes these macroinvertebrate communities a great effects-based measure of ecosystem condition.

Freshwater benthic macroinvertebrates are composed of many insect orders in addition to crustaceans, gastropods, bivalves, and oligochaetes. Many bioassessment approaches focus on a reduced assemblage, which includes a combination of specific species that are indicative of certain types of pollution. Benthic invertebrates exhibit a range of tolerance values which can be used to indicate the water quality (Reynoldson & Metcalfe-Smith, 1992). Indicator species are species that have requirements regarding a known set of physical or chemical variables (Rosenberg & Resh, 1993). Variations in the presence/absence, numbers, morphology, physiology, or behaviour of that species indicate that the given physical or chemical variables are beyond its preferred threshold (Rosenberg & Resh, 1993). The factors that make up the benthic population may act at any stage of the life cycle and may be abiotic (e.g., chemical variables: elemental oxygen (O_2), hydrogen ion (H^+)or metal concentration; physical variables: sedimentation) or biotic (competition, predation, or parasitism) (Rosenberg & Resh, 1993).

2.0 PURPOSE

The purpose of this project is to gather data to obtain baseline knowledge for understanding the stream health of the Baxter Creek watershed. Identifying current trends in stream health is significant for addressing potential concerns, understanding long-term environmental changes of the watershed, and implementing natural resource management strategies to mitigate risks to conserve and protect the Baxter Creek watershed. The Baxter Creek Benthos Survey aims answer three main research questions:

1. What is the baseline composition of benthic macroinvertebrate communities of the Baxter Creek watershed?

2. What insights do benthic macroinvertebrate communities provide about water quality in the Baxter Creek watershed?

3. What are the external factors influencing stream quality?

With further research and continued monitoring of the Baxter Creek watershed, it may be beneficial to investigate land uses and potential causes of water quality outside of the stream. This will provide insight to better protect the watershed and make the community aware of the importance as watersheds provide critical ecological services that support our quality of life (Baxter Creek Watershed Alliance, 2021). What prompted this study is the lack of knowledge regarding the ecological conditions of the Baxter Creek Watershed. However, breaking through this barrier by carrying out the Baxter Creek Benthos Survey for at least 5 years will establish a baseline inventory of the stream for future comparisons and to further guide stream rehabilitation management strategies.

2.1 Community Concerns

The Baxter Creek Watershed Alliance (BCWA) prioritizes conservation of the watershed. To implement conservation measures, BCWA will focus on conducting future research to continue assessing benthic macroinvertebrates in the watershed. This first year is essential in terms of creating a baseline for the entire watershed and comparing data to assess trends from previous years. There is particular concern of how anthropogenic activities and local land developments may be having a negative impact on the health of Baxter Creek. There are a variety of anthropogenic activities surrounding the Baxter Creek watershed that could be contaminating the freshwater ecosystem. This includes but is not limited to, agricultural fields, the Millbrook wastewater treatment plant, Baxter Creek Golf course, and subdivision expansions. There is specific concern from the BCWA on the urban expansion occurring in Millbrook. In recent years, Millbrook has been undergoing large housing developments to house its increasing population. With plans to double their population in the next few years, it is essential to conduct a bioassessment of the Baxter Creek watershed to assess water quality before further development occurs. This study will provide evidence to determine if these external factors are negatively impacting the stream which further provides direction to create a stream rehabilitation action plan.

2.2 Establishing a Baseline

The Baxter Creek Watershed Alliance along with Trent University and Trent Community Research Center (TCRC) are in collaboration to begin a long-term benthos biomonitoring program to understand the health of the watershed ecosystem and establish a baseline dataset for future comparisons. In scientific studies, establishing a baseline dataset is a crucial process to compare future research. By comparing new data to the baseline, researchers can indicate any significant changes in the health of an ecosystem. For this project, this is the first year of collecting benthic macroinvertebrates. To establish a baseline inventory of benthic macroinvertebrates, a minimum of five years is required.

3.0 METHODS

All sampling was conducted by an undergraduate student at Trent University following Ontario Benthos Biomonitoring Network (OBBN) protocols under the supervision of Assistant Professor with Trent School of the Environment, Dr. Kaitlyn Fleming.

3.1 Site Description

In collaboration with Dr. Fleming and Craig Onafrychuk from BCWA, 4 sites were chosen to be sampled in the Baxter Creek watershed (BXCR-01, BXCR-02, BXCR-03, BXCR-04). At each location 3 sub samples were taken, for a total of 12 samples across 4 sites (See Figure 5). Sites were selected based on current OBBN sites and monitoring stations from Otonabee Regional Conservation Authority (ORCA) (See Figure 5). Sites were also selected based on accessibility and possible stressors that could have an impact on benthic macroinvertebrate communities.
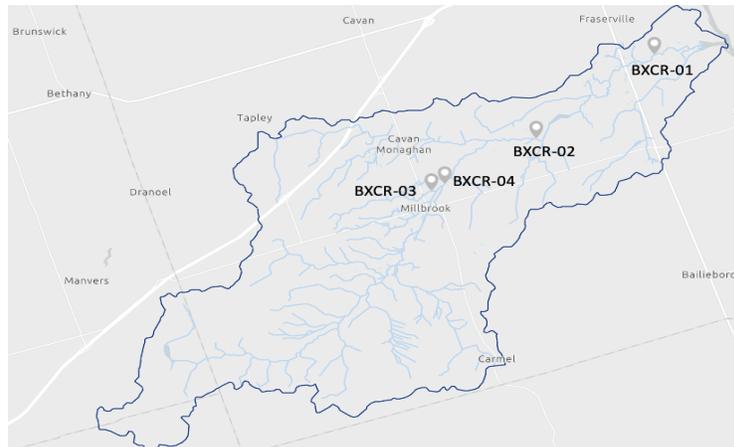

Figure 5. Map indicating the location of the four sample sites, with 3 sub samples per site, studied on Baxter Creek watershed.

3.2 Field Sampling

The field methods used in this study were based on the Ontario Benthos Biomonitoring Network Protocols (Jones et al. 2007). Sampling took place on October 23, 2023, and November 5, 2023, at four sites along Baxter Creek (Figure 5). At each of the four reference sites, qualitative habitat metrics are recorded on field sheets (Jones et al. 2007). Mandatory features include using a GPS to determine Location (latitude and longitude), using a ruler to measure Maximum Depth (m) and Maximum hydraulic head (mm) at the thalweg-transect intersection of the stream, using a measuring tape to record wetted width and bank full width of the stream (m), using a classification system and pebble count to determine the dominant substrate class,

Figure 6. Researcher performing the Traveling Kick and Sweep method with a 500micron D-net at site BXCR-03.

using a classification system to observe the organic matter and arial coverage, recording the riparian vegetation at three distances (1.5-10 m, 10-30 m, 30 –100 m), estimating the percent tree canopy cover, using a classification system to indicate dominant aquatic macrophytes and algae, and indicate flow permanence if known. These habitat characterizations may offer a better understanding of Ontario reference conditions and the environmental factors that determine benthos-assemblage types (Jones et al. 2007). Included on the field sheets are optional water chemistry parameters (water temperature, pH and conductivity).

These quantitative water chemistry metrics were collected by submerging an Oakton meter at mid depth in the flow of the stream. Using standard Ontario Benthos Biomonitoring Network (OBBN) protocols we collected 3 subsamples (2 riffles and 1 pool) from each of the four sampling sites. Benthic macroinvertebrates were sampled with a traveling kick-and-sweep transect method using a 500-micron mesh D-Net. Each sampling location was sampled once during the fall of 2023 (BXCR-01, BXCR-02 on October 23 & BXCR-03, BXCR-04 on November 5) with each sample consisting of three 10 m transects of 3-minute sampling time using a good kick to stir up substate and sweeping motion across to the opposite bank. Collected samples are sieved and transferred to containers for identification in the lab.
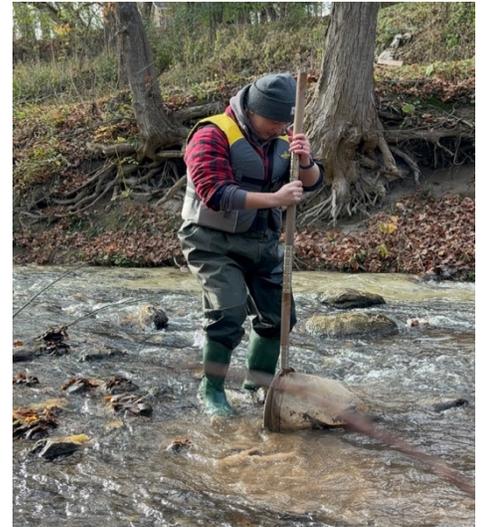
3.3 Lab Analysis

Laboratory methods based on OBBN protocols (Jones et al. 2007) were conducted in the lab at Trent University. The teaspoon-bucket method was followed. This method involves scooping the sample into a separate container to further use a microscope to identify and tally organisms until 100 organisms are sorted (Jones et al. 2007). According to OBBN protocols, all invertebrates from a sample should be tallied, with a minimum of 100 animals required for a sufficient sample. Samples were preserved in non-toxic antifreeze and were stored in a fridge until they were processed and tallied using a microscope and a standard tally sheet with identification to the coarse 27-group level (Jones et al. 2007). Once a sample is completed, the contents are transferred to a labeled vile and preserved in 95% ethanol.

Figure 7. A researcher using a microscope to identify and process samples in the lab.

3.4 Data Analysis

Once all samples had been identified and tallied with a minimum of 100 invertebrates for each sample, all the data was transferred to Microsoft Excel. Microsoft Excel was the only software used for data analysis. By using a Benthic Indices Calculator in Excel provided by Dr.Kaitlyn Fleming, there were four indices chosen to analyze this data. This included:

1. The *Modified Hilsenhoff's Family Biotic Index* (mHBI)
2. The *Simpsons Diversity Index*
3. The *%EPT Index*
4. *Hill numbers*

The *Modified Hilsenhoff's Family Biotic Index* (mHBI) is used to estimate the average tolerance of benthic communities at a given site (Hilsenhoff, 1987). As this is a modified Hilsenhoff Biotic Index, mHBI uses the family level taxonomy to assign tolerance values to each of the 27 taxonomic groups. Tolerance values range from 0-10 and are based on the response of a taxonomic group to water pollutants (Table 9) (Hilsenhoff, 1987). To calculate mHBI, the average of the tolerance values at each site was calculated using abundance in one of the 27 taxonomic groups. This can be calculated using the following equation:

$$mHBI = 1\frac{\Sigma \text{Tn}}{N}$$

Where T is the tolerance value of the taxonomic group, n is the total number of individuals per taxonomic group, and N is the total number of individuals in all taxonomic groups (Hilsenhoff, 1987).

The *Simpsons Diversity Index* is a measures species diversity of a site. This biotic index considers both the number of species and the amount of each species present at a given site (Simpson, 1949). Simpsons Diversity values range from 0 to 1, where a value closer to zero represents less diversity and a value closer to one represents infinite diversity (Simpson, 1949). In terms of bioassessments on benthic macroinvertebrates, Simpsons Diversity can be measured to determine the diversity of OBBN taxonomic groups for each site using the following equation:

$$D = 1\frac{(\Sigma n - 1)}{N(N-1)}$$

Where n is the total number of individuals in a taxonomic group and N is the total number of individuals of all taxonomic groups (Simpson, 1949).

The *%EPT Index* is a biotic index commonly used in stream health. It refers to the relative abundance of three major orders of pollution sensitive invertebrates: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (Jones et al., 2007). A large percentage of EPT taxa indicates high water quality and a low percentage of EPT taxa indicates poor water quality. The EPT Index can be calculated using the following equation:

$$\%EPT = \frac{(\#\text{Mayflies} + \#\text{Caddisflies} + \#\text{Stoneflies})}{\text{Total \# of Invertebrates}} \times 100$$

Where the sum mayflies, caddisflies, and stone flies (numerator) get divided by the total number of invertebrates in a sample (denominator), multiplied by 100.

Hill numbers provide a framework for the three most popular groups of diversity measures. The first order, q= 0 (species richness), q=1 (exponential of Shannon's entropy index), q=2 (Simpson's concentration index). Hill numbers are the 'effective number of species' or 'species equivalents' (Hill, 1973). Hill numbers can be calculated using the following equations:

$$q D = \left(\sum_{i=1}^{S} p_i^q \right)^{1/(1-q)}$$

Hill 0: $0D$ =S   Hill 1: $1D = e^H$ Hill 2: 2D= $\frac{1}{D}$

Where *S* in the number of species, p_i is the relative abundance of the *i*th species and *q* is the order of the diversity measure, as it determines its sensitivity to the frequency of species (Chao et al., 2014).

4.0 RESULTS AND DISCUSSION

4.1 Benthic Community Composition

In total, our benthos sample consisted of 2634 benthos across the 27 taxonomic groups. Figure 8 below displays the number of individuals from each taxonomic group from all four sampling locations.
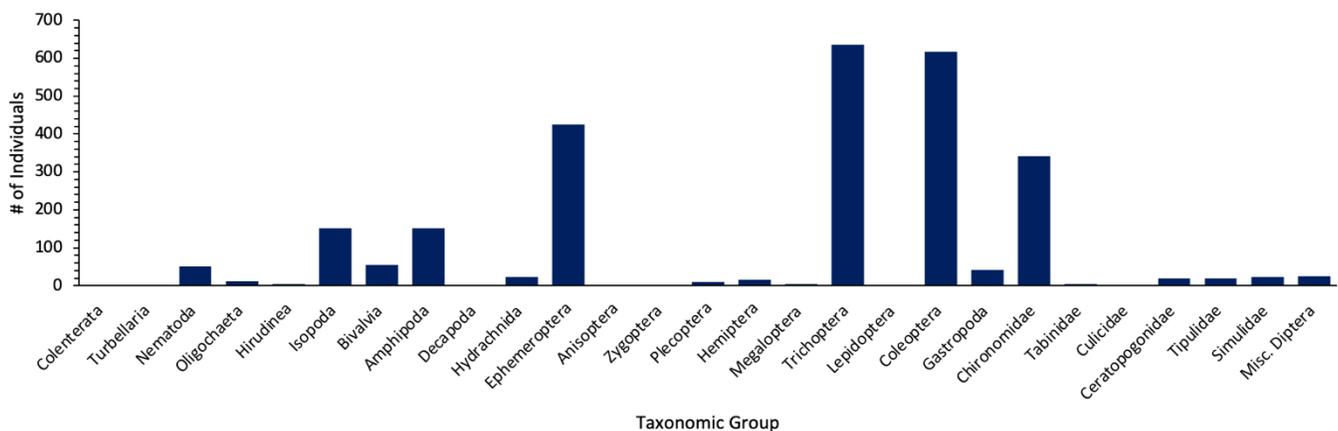
Figure 8. Total composition of benthic macroinvertebrates across all sites in Baxter Creek.

The most abundant groups across four sites were Trichoptera (caddisflies) and Coleoptera (beetles), tallying 635 and 617 individuals respectively (Figure 8). The next most abundant taxa were Ephemeroptera (mayflies) with 425 individuals, Chironomidae (midges) with 342 individuals, Isopoda (sowbugs) with 152 individuals, and Amphipoda (scuds) with a total of 151 individuals (Figure 8). Other taxonomic groups that were present included Colenterata (hydras), Nematoda (roundworms), Oligochaeta (aquatic earthworms), Hirudinea (leeches), Bivalvia (clams and mussels), Decapoda (crayfish), Hydrachnida (mites), Zygoptera (damselflies), Plecoptera (stoneflies), Hemiptera (true bugs), Megaloptera (fishflies, alderflies), Gastropoda (snails, limpets), Tabinidae (horse, deerflies), Culicidae (mosquitos), Ceratopogonidae (no-see-ums), Tipulidae (crane flies), Simulidae (black flies), Misc.Diptera (true flies). The taxonomic groups that were not present included Turbellaria (flatworms), Anisoptera (dragon flies), Lepidoptera (aquatic moths). Out of the 27 taxonomic groups, 24 groups were present in Baxter Creek.

4.2 Water Chemistry

A variety of water parameters were measured at each sampling location to provide a comprehensive understanding of water quality and aquatic conditions. To determine the water chemistry at each site, we used an Oakton meter to measure temperature, pH and conductivity.

Table 1.Temperature, pH and conductivity measurements and corresponding mean values across all sites sampled in Baxter Creek.

Water Parameter	Site Code				Mean Value
	BXCR- 01	BXCR- 02	BXCR- 03	BXCR- 04	
Temperature (°C)	4.9	5.8	7.4	7.6	6.4
pH	9.1	8.9	9.2	9.2	9.1
Conductivity ($\mu S/cm$)	395	388	370	373	381.5

The average pH for the sites was 9.1, with the highest pH at BXCR-03 and BXCR-04 of 9.2 and the lowest pH at BXCR-02 at 8.9. The average temperature for the sites was 6.4°C, with the highest temperature of 7.6°C at BXCR-04 and the lowest temperature of BXCR-01 at 4.9°C. The average conductivity measured for the sites was 381.5 with the highest conductivity measured at BXCR-01 of 395μs/cm and the lowest conductivity measured at BXCR-03 of 370μs/cm.

4.3 Biotic Indices

Biotic indices were calculated to determine the baseline health and ecological integrity of the stream. Different indices summarize different components of biological condition. This is why it's important to choose an appropriate set of indices to characterize the specific biological community of Baxter Creek. Compositional indices such %EPTs were used to determine ratios of taxa to total number of individuals. Diversity indices such as Simpsons Diversity Index and Hill numbers were used since this considers both the number of species and proportion of each species present to determine diversity of each site. Pollution-tolerant Indices such as Modified Hilsenhoff Family Biotic Index (mHBI) were used to determine the average tolerance in a community of benthos in each sample site.

Table 2. Summary of values calculated for biotic indices based on data from four reference streams in the Baxter Creek watershed.

Metric	BXCR-01	BXCR-02	BXCR-03	BXCR-04	Mean Value
Modified Hilsenhoff Family Biotic Index	5.037	5.784	4.922	4.580	5.081
%EPT	29.808	8.086	42.636	54.116	33.661
Simpson's Diversity Index	0.877	0.676	0.828	0.715	0.774
Hill 0	23	15	15	16	17.250
Hill 1	10.729	5.401	7.106	4.094	6.832
Hill 2	8.150	3.088	5.823	3.509	5.143

This table allows for direct comparison between the four sites sampled at Baxter Creek to determine ecological condition between sites and of the Baxter Creek watershed altogether. mHBI ranged from 4.580 (BXCR-04) – 5.784 (BXCR-02), with a mean value of 5.081. %EPT ranged from 8.086 (BXCR-02) – 54.116 (BXCR-04), with a mean value of 33.661. Simpson's Diversity Index ranged from 0.676 (BXCR-02) – 0.877 (BXCR-01), with a mean value of 0.774. Hills 0 ranged from 15 (BXCR-02, BXCR-03) – 23 (BXCR-01), with a mean value of 17.250. Hills 1 ranged from 4.094 (BXCR-04) – 10.729 (BXCR- 01), with a mean value of 6.832. Hills 2 ranged from 3.088 (BXCR-02) – 8.150 (BXCR-01), with a mean value of 5.143.

To evaluate potential environmental stress, %EPT was calculated and displayed in the figure below (Figure 9). The site that had the highest %EPT was BXCR-04 with 54.116%, falling into the Excellent category. The site that had the lowest %EPT was BXCR-02 with 8.086%, falling into the Fair Category. Across all the sites in the watershed there was an average of 33.661% EPT which falls into the Excellent Category.
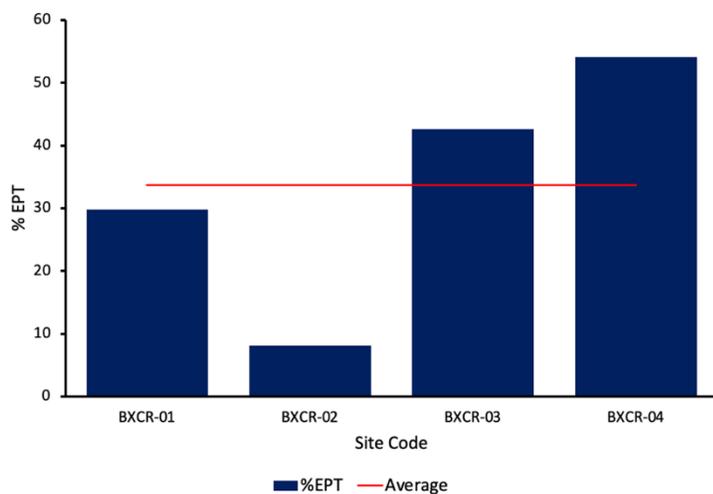
Figure 9. % EPT Index plotted for each of the four sites selected. The red line indicates the average percent EPT of Baxter Creek across the sites.

To evaluate diversity, Simpsons Diversity Index was calculated and displayed in the figure below (Figure 10). The average Simpsons Diversity Index of Baxter Creek was 0.774, indicating a moderately high degree of diversity/heterogeneity. The highest value was calculated at BXCR-01 with a value of 0.877, indicating a high degree of diversity/heterogeneity. The lowest value was calculated at BXCR-02 with a value of 0.676, indicating a moderately high degree of diversity/heterogeneity.
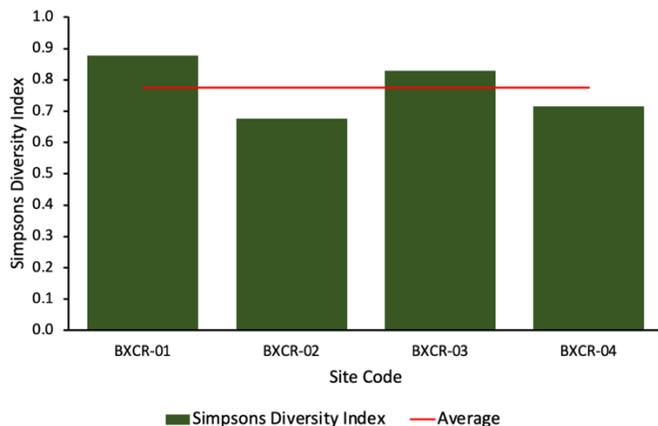
Figure 10. Average Simpsons Diversity plotted for each of the four sites selected. The red line indicates the average Simpsons Diversity Index across the sites.

To detect possible organic pollution, the Modified Hilsenhoff Biotic Index was calculated and displayed in the figure below (Figure 10). The mHBI values range from 1-10 are developed to be a direct indication of stream health, 1 being healthy and 10 being unhealthy (Hilsenhoff, 1987). The average mHBI value was 5.081, indicating good water quality. The site with the highest value was BXCR-02 with a value of 5.784, indicating fair water quality. The site with the lowest value was BXCR-04 with a value of 4.580, indicating good water quality .
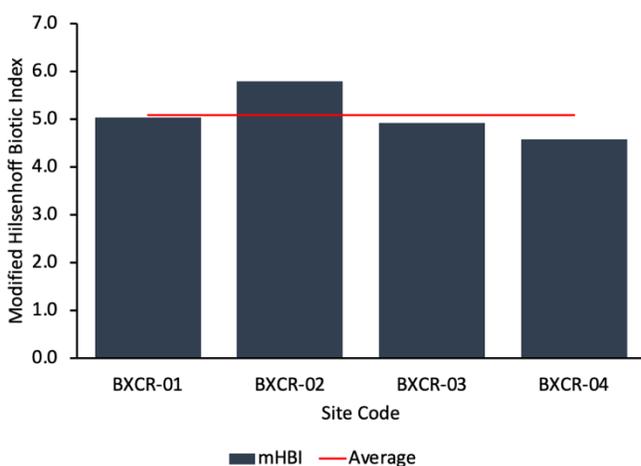
Figure 11. Modified Hilsenhoff Biotic Index plotted for each of the four sites selected. The red line indicates the average mHBI across all sites.

To measure species richness and species relative abundance, Hill numbers were calculated and displayed in the figure below (Figure 11).The highest diversity was calculated for BXCR-01, Hill 0 = 23, Hill 1 = 10.729, Hill 2 = 8.150. The lowest diversity was calculated for BXCR-02, Hill 0 = 15, Hill 1 = 5.401, Hill 2 = 3.088. The average Hill 0 value calculated across the four sites was 17.250. The average Hill 1 value calculated across the four sites was 6.832. The average Hill 2 value calculated across the four sites was 5.143.
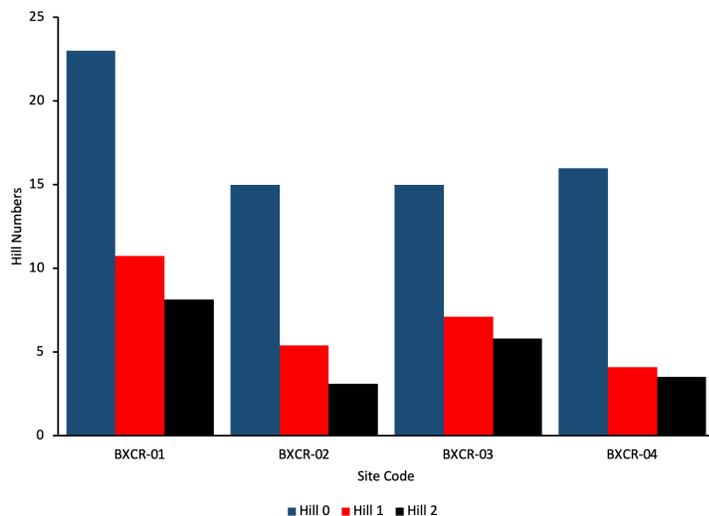
Figure 12. Hill numbers (Hill 0, Hill 1, Hill 2) plotted for each of the four sites selected. Bar colours correspond to each of the diversity measures.

5.0 DISCUSSION

5.1 Water Chemistry

Various water chemistry parameters were taken from each site at Baxter Creek. Temperature ranged from 4.9°C (BXCR-01)- 7.6°C (BXCR-04). There was a large variation in water temperature since sampling of sites took place across the months of October and November. The colder temperatures measured at BXCR-01 and BXCR-02, as well as the warmer temperatures measured at BXCR-03 and BXCR-04 align with when sampling occurred. Sampling of BXCR-01 and BXCR-02 occurred in October 2023 while sampling of BXCR-03 and BXCR-04 occurred in November 2023. Temperate differences across the different sampling locations could be due to a cold/warm spell or possibly due to the location (i.e. canopy cover, water level etc.). Samples even taken on the same day varied since sites were sampled at different times of the day. For instance, BXCR-01 was sampled in the morning and BXCR-02 was sampled in the afternoon after the sun had come out. The average temperature across the sites was 6.4°C. The pH of the stream did not vary as much as temperature. pH ranged from 8.9 (BXCR-02) – 9.2 (BXCR-03, BXCR-04), and the average pH was 9.1. The pH was relatively consistent across the four sites. The average conductivity was 381.5μs/cm. Lower conductivity values of 370 μs/cm and 373 μs/cm were measured at BXCR-03 and BXCR-04 respectively. Higher conductivity values of 395 μs/cm and 388 μs/cm were measured at BXCR-01 and BXCR-02. Conductivity is a

measure of the ability of water to pass an electrical current (EPA, 2023). It is a useful measure of water quality since significant changes in values could be an indicator that a discharge or source of pollution has entered the ecosystem.

5.2 Benthic Data Analysis

It is crucial to understand that this project was implemented and designed to provide data in the establishment of a baseline of health for the Baxter Creek watershed. Any conclusions drawn from this first year do not give an immediate or accurate health assessment. A minimum of five years of data is required to establish an accurate baseline. Once that is completed, the health of the stream can be assessed through comparing future results to the baseline. However, the data obtained from this study can still be used to infer the perceived condition of the stream. That way, we can determine if conservation approaches should be implemented to protect the Baxter Creek watershed.

The mHBI measurements calculated for each site gave insight to the levels of tolerance of taxonomic groups found in the watershed. Based on values derived from Hill (1973), high values are given to groups that are tolerant to pollution and can survive in lower water quality (Table 9). Low values are given to groups that are non-tolerant to pollution and cannot survive in lower water quality (Table 9). The average mHBI value was 5.081, indicating good water quality. The site with the highest value was BXCR-02 with a value of 5.784. This site was mostly composed of midges (Chironomidae) and scuds (Amphipoda). This makes sense since midges have a tolerance value of 6 and scuds have a tolerance value of 4 (Table 9). After reviewing literature and observing the surrounding land use and dominant substrates/ sediments. The pollution tolerant groups inhabiting this site was consistent with literature. For instance, this was a site that had a dominant substate of sand, this type of sediment is a difficult environment to live in and it is not fit for a wide diversity of taxonomic groups. Additionally, the surrounding land use could also be a factor. There were agricultural fields, neighbourhoods, and roads near the site. The site with the lowest value was BXCR-04 with a value of 4.580. This site was downstream of the Millbrook wastewater treatment plant and had majority pollution intolerant groups such as mayflies (Ephemeroptera), caddisflies (trichoptera), and beetles (coleoptera). Ideally the sites sampled

would have mHBI values of less than 5 which would indicate excellent health, but this is dependent on a variety of factors. With having the site downstream of the wastewater treatment plant and closest to the urbanization, these are interesting measurements. It had been predicted that BXCR-02 would have groups with high tolerance values due to possible effluent and run off from the urbanization of Millbrook.

In terms of %EPT across each site, it was observed that BXCR-04 had the highest value with 54.116%, falling into the excellent category (Figure 8). The site that had the lowest %EPT was BXCR-02 with 8.086%, falling into the fair category (Figure 8). BXCR-02 had far less %EPT than the other sites sampled, which brought the average %EPT down to 33.661% EPT which falls into the excellent category (Figure 8). Although a significant biotic index, in the first year of this project, %EPT alone was not an effective summary of the water quality of Baxter Creek. For instance, out of all sites, there were only 9 stone flies (Plecoptera) identified. Compared to 635 caddisflies (Trichoptera) and 425 mayflies (Ephemeroptera). The absence of stone flies skewed the data slightly, but overall calculating EPT index followed a similar trend against other biotic indices.

Simpsons Diversity Index is significant to measure as the sites with values closer to 1, have higher diversity than sites with values closer to 0. These are known as Simpson Scores as seen in Table 10. According to Simpson (1949), each Simpson Score gives an interpretation of diversity The highest value was calculated at BXCR-01 with a value of 0.877, indicating a high degree of diversity/heterogeneity (Figure 9). The lowest value was calculated at BXCR-02 with a value of 0.676, indicating a moderately high degree of diversity/heterogeneity (Figure 9). Across all sites the average Simpsons Diversity Index of Baxter Creek was 0.774, indicating a moderately high degree of diversity/heterogeneity (Figure 9). This is a high mean value that indicates that the stream is in good health since it can sustain a variety of species within the aquatic ecosystem. This is consistent across all sites, out of 27 taxonomic groups, 24 taxonomic groups were present.

The Hill numbers calculated for Baxter Creek give insight into three popular groups of diversity measures, The first order, q= 0, is species richness, which entails counting all species equally without considering their relative abundance. The second order, q=1, is the exponential of Shannon's entropy index, this involves counting each individual equally and weighing each species in proportion to its abundance, focusing on common and abundant species. The third order, q=2, is the inverse of Simpson's concentration index, which disproportionately favours individuals of abundant species and represents the number of very abundant species (Chao et al., 2014). The site with the highest values measured was at BXCR-01 with Hill 0=23, Hill 1=10.7, Hill 2= 8.2. The site with the lowest values measured was at BXCR-02 with Hill 0= 15, Hill 1= 5.4, Hill 2=3.1.

6.0 CONCLUSION

Based on the data collected in this study, it is recommended that benthic bioassessments should occur annually in the spring for at least 5 years to establish a baseline. Sampling in the spring is essential so comparisons can be made with previous spring bioassessments conducted by Otonabee Region Conservation Area (ORCA) on Baxter Creek. Future bioassessments should occur at a variety of sites in the Watershed in addition to the four sites in this study. Future efforts may prioritize comparing this data to different local watersheds (Squirrel creek, Cavan creek) in the area as further analysis between watersheds can occur. While majority of the sites do indicate great results in terms of stream health, this data alone is not definitive of the health of the Baxter Creek Watershed. It is important that this project continue as it was intended to for Trent Community Research Center in collaboration with the Baxter Creek Watershed to establish an accurate baseline for the health of the stream.

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APPENDICES

Appendix A- Excel Spreadsheet Data

Table 3. Site information data.

Site Information												
Site Code	BXCR-01-R1	BXCR-01-R2	BXCR-01-P1	BXCR-02-R1	BXCR-02-R2	BXCR-02-P1	BXCR-03-R1	BXCR-03-R2	BXCR-03-P1	BXCR-04-R1	BXCR-04-R2	BXCR-04-P1
Site Description	Down stream from Baxter Creek Golf Course			Upstream from Baxter Creek Golfcourse			Downstream from Millbrook Wastewater Treatment Plant			Upstream from Millbrook Wastewater Treatment Plant		
Latitude	44.19449			44.1699			44.15362			44.15791		
Longitude	78.37189			78.46951			78.4458			78.4412		
Sampling Event Date	23-10-2023			23-10-2023			05-11-2023			05-11-2023		
Left Riparian 1.5-10m	meadow			meadow			scrubland			meadow		
Left Riparian 10-30m	cropland			meadow			lawn			meadow		
Left Riparian 30-100m	cropland			meadow			none			scrubland		
Right Riparian 1.5-10m	scrubland			meadow			scrubland			forest		
Right Riparian 10-30m	scrubland			scrubland			scrubland			forest		
Right Riparian 30-100m	forest			cropland			none			forest		

Table 4. Water quality field parameter data.

Water Quality												
Site Code	BXCR-01-R1	BXCR-01-R2	BXCR-01-P1	BXCR-02-R1	BXCR-02-R2	BXCR-02-P1	BXCR-03-R1	BXCR-03-R2	BXCR-03-P1	BXCR-04-R1	BXCR-04-R2	BXCR-04-P1
Water Temperature (℃)	4.9			5.8			7.4			7.6		
Conductivity ($\mu S/cm$)	395			388			370			373		
pH	9.1			8.9			9.2			9.2		

Table 5. Sampling information data.

Sampling Information												
Site Code	BXCR-01-R1	BXCR-01-R2	BXCR-01-P1	BXCR-02-R1	BXCR-02-R2	BXCR-02-P1	BXCR-03-R1	BXCR-03-R2	BXCR-03-P1	BXCR-04-R1	BXCR-04-R2	BXCR-04-P1
Sampling Distance (m)	10			10			10			10		
Wetted Width (m)	9	8.2	8.6	7.3	7.1	9.2	5.4	6.8	4.8	4.4	4.7	5
Sampling Time (mins)	3			3			3			3		
Max Depth (cm)	23	31	26	36	45	58	57	28	61	27	23	40
Max Hydraulic Head (mm)	30	25	20	0	5	0	58	105	15	110	85	35

Table 6. Site features data.

Site Features												
Site Code	BXCR-01-R1	BXCR-01-R2	BXCR-01-P1	BXCR-02-R1	BXCR-02-R2	BXCR-02-P1	BXCR-03-R1	BXCR-03-R2	BXCR-03-P1	BXCR-04-R1	BXCR-04-R2	BXCR-04-P1
Dominant Substrate	4-Gravel	4-Gravel	4-Gravel	3- Sand	1-Clay	1-Clay	1-Clay	4-Gravel	1-Clay	4- Gravel	4- Gravel	4- Gravel
Second Dominant Substrate	2-Silt	2-Silt	2-Silt	2-Silt	2-Silt	2-Silt	2-Silt	1-Clay	2-Silt	5- Cobble	5- Cobble	1-Clay
Woody Debris	1-present	0-absent	0-absent	0-absent	1-present	0-absent	1-present	1-present	1-present	1-present	1-present	1-present
Detritus	1-present	1-present	1-present	0-absent	1-present	0-absent	0-absent	1-present	1-present	0-absent	1-present	1-present
Macrophytes - Emergent	0-absent	1-present	0-absent	1-present	0-absent	1-present	0-absent	0-absent	0-absent	1-present	0-absent	0-absent
Macrophytes- Rooted Floating	0-absent	1-present	1-present	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent
Macrophytes - Submergent	1-present	1-present	1-present	1-present	1-present	1-present	0-absent	0-absent	0-absent	0-absent	1-present	0-absent
Macrophytes- Free Floating	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	1-present	1-present	1-present	1-present	0-absent	0-absent
Algae -Floating	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent
Algae- Filamentous	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent
Algae- Attached	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	0-absent	2-abundant	1-present	2-abundant
Pebble Count (mm)	15, 19, 11, 16, 10, 10, 14, 15, 25, 19	15, 50, 24, 45, 105, 15, 70, 1111, 30, 50	40, 10, 30, 28, 16, 8, 5, 28, 10, 17	0.1, 0.1, 0.1, 0.1, 0.1,0.1, 4, 0.01, 0.01, 0.01	0.01, 0.1, 1111, 0.01, 0.1, 0.01, 78, 0.01, 0.01, 0.01	0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01	40, 10, 0.0011, 5, 35, 0.011, 34, 0.011, 55, 0.1	40, 35, 20, 27, 41, 11, 19, 85, 70, 25	5, 30, 31, 15, 13, 60, 36, 10, 16, 3	19, 30, 19, 20, 60, 31, 27, 65, 53, 42	57, 9, 41, 26, 21, 31, 22, 32, 31, 73	40, 11, 20, 70, 39, 32, 25, 22, 26, 32
Comments				Very sandy, hard to sample								

Table 7. Benthic tally data.

Benthic Tally											
Site Code	BXCR-01-R1	BXCR-01-R2	BXCR-01-P1	BXCR-02-R1	BXCR-02-R2	BXCR-02-P1	BXCR-03-R1	BXCR-03-R2	BXCR-03-P1	BXCR-04-R1	BXCR-04-R2	BXCR-04-P1
Colenterata	0	0	1	0	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	0	1	0	0	18	2	3	13	12	1	0	1
Oligochaeta	0	5	1	0	0	2	1	1	1	0	0	0
Hirudinea	1	0	0	1	0	0	0	0	0	1	2	0
Isopoda	0	1	1	7	7	7	10	18	4	39	45	13
Bivalvia	3	37	5	4	2	0	1	1	0	0	2	0
Amphipoda	13	53	26	20	10	12	6	3	4	0	0	4
Decapoda	0	1	0	0	0	0	0	0	0	1	0	0
Hydrachnida	22	0	1	0	0	0	0	0	0	0	0	0
Ephemeroptera	5	19	6	10	11	9	40	55	8	89	74	99
Anisoptera	0	0	0	0	0	0	0	0	0	0	0	0
Zygoptera	1	0	1	0	0	0	0	0	0	0	0	0
Plecoptera	4	3	1	0	0	0	0	0	0	0	0	1
Hemiptera	0	0	3	5	4	2	0	1	0	1	0	0
Megaloptera	0	1	0	0	0	0	0	3	0	0	0	0
Trichoptera	47	48	22	0	0	0	67	42	8	80	148	173
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera	10	30	13	8	0	0	29	66	24	164	170	103
Gastropoda	5	13	3	14	1	0	0	2	0	0	2	1
Chironomidae	30	15	17	75	62	65	12	18	44	1	2	1
Tabinidae	1	0	0	1	1	1	0	0	0	0	0	0
Culicidae	0	0	0	0	0	1	0	0	0	0	0	0
Ceratopogonidae	0	3	8	0	0	7	0	1	0	0	1	0
Tipulidae	6	5	7	0	0	0	0	0	0	1	0	0
Simulidae	1	1	0	0	0	0	5	9	0	0	4	3
Misc. Diptera	12	2	5	0	0	2	2	1	1	0	0	0
Total Number Entered	161	238	121	145	116	110	176	234	106	378	450	399

Table 8. Benthic indices data.

Benthic Indices				
Site Code	BXCR-01	BXCR-02	BXCR-03	BXCR-04
Modified Hilsenhoff Family Biotic Index	5.037	5.784	4.922	4.580
% EPT	29.808	8.086	42.636	54.116
Simpson's Diversity Index	0.877	0.676	0.828	0.715
Hills 0	23	15	15	16
Hills 1	10.729	5.401	7.106	4.094
Hills 2	8.150	3.088	5.823	3.509

Table 9. Taxonomic group tolerance values.

HBI Tolerance Values		
Scientific Name	**Common Name**	**Tolerance Value**
Colenterata	Hydras	5
Turbellaria	Flatworms	4
Nematoda	Roundworms	5
Oligochaeta	Aquatic Earthworms	8
Hirudinea	Leeches	10
Isopoda	Sow Bugs	8
Bivalvia	Clams + Mussels	8
Amphipoda	Scuds	4
Decapoda	Crayfish	8
Hydrachnida	Mites	6
Ephemeroptera	Mayflies	5
Anisoptera	Dragonflies	5
Zygoptera	Damselflies	7
Plecoptera	Stoneflies	1
Hemiptera	True Bugs	5
Megaloptera	Fishflies,Alderflies	4
Trichoptera	Caddisflies	4
Lepidoptera	Aquatic Moths	6
Coleoptera	Beetles	4
Gastropoda	Snails, Limpets	7
Chironomidae	Midges	6
Tabinidae	Horse + Deer Flies	6
Culicidae	Mosquitos	8
Ceratopogonidae	No-see-ums	6
Tipulidae	Crane Flies	3
Simulidae	Black Flies	6
Misc. Diptera	Misc. True Flies	7

Table 10. Simpson scores and interpretations.

Simpson Score	Interpretation
0.00	Absence of diversity (homogeneity)
0.01- 0.40	A low degree of diversity/heterogeneity
0.41- 0.60	A moderate degree of diversity/heterogeneity
0.61- 0.80	A moderately high degree of diversity/heterogeneity
0.81- 0.99	A high degree of diversity/heterogeneity
1.00	Absolute (perfect) diversity/heterogeneity

Appendix B- Field Sheets

Figure 11. Field sheets for BXCR-01 sampling site.

Figure 12. Field sheets for BXCR-02 sampling site.

Figure 13. Field sheets for BXCR-03 sampling site.

Figure 14. Field sheets for BXCR-04 sampling site.