Scientific Report: 2019-2023 Macroinvertebrate Survey of the Quittapahilla Creek Watershed

Charles Katona, Megan Bisco, and Dr. Rebecca Urban

Lebanon Valley College

April 4th, 2025

Abstract:

Pollution levels are a critical concern for watershed health, particularly in systems that provide sustainable drinking water to their surrounding communities. Freshwater benthic macroinvertebrates serve as bioindicators of stream water quality due to their varying pollution tolerances. The Quittapahilla Creek Watershed Association conducts annual assessments at six stream sites as part of a long-term monitoring protocol to evaluate the success of restoration efforts. Historically being considered unrecoverable, the watershed has shown notable improvements in water quality in recent years. This study examines macroinvertebrate composition from fall 2019 to fall 2023, utilizing the Shannon-Weiner Index (SWI), EPT Index, and Family Biotic Index (FBI) to quantify water quality trends across sites. We plan to use these metrics to assess improvements in the stream's health and the effectiveness of restoration initiatives conducted by the Watershed Association.

Introduction:

Watersheds are areas of land where all forms of water move or fall into common areas, like a river or lake. Watersheds not only provide habitats and water for animals and plants, but they also supply humans with water that can be used for agriculture, proper sustainable drinking sources, and other daily needs (Burkholder et al. 2007). Water used for daily needs like showering, washing dishes and clothes, and flushing toilets all use a tremendous amount of water on a daily basis. According to the Environmental Protection Agency, “the average American family uses more than 300 gallons of water per day at home” (US EPA 2017). Of the household water use, the greatest percentage used was the toilet at 24%, followed by showers at 20% (US EPA 2017). Irrigation for agriculture was the second highest usage of water, right after thermoelectric Power (US EPA 2017). The multitude of purposes that water serves us in a single day is enormous, and yet watersheds are under constant threat due to water pollution

Pollution is one of the biggest threats not just to the watersheds themselves but the wildlife that inhabits and uses that water that water. This damage to the water can lower biodiversity and cause the remaining species to become overpopulated. Unnoticed pollution of watersheds also creates drinking hazards for humans. The culprits of these pollution sources can be traced back to runoff water from the surrounding land. Agriculture and stormwater runoffs play major roles in damaging the quality of these watersheds (Ghane et al. 2016). Pesticides, fertilizers, and herbicides

Waste from agricultural livestock also presents a major concern to the quality of surrounding water sources. The position of farms and livestock is detrimental to the prevention of waste pollutants. If the livestock are located on an upper surface of a stream, then their waste will travel downward with rainwater and accumulate in the streams at the bottom (Burkholder et al. 2007). Erosion also amplifies the impact of pollution on waterways. Sediment pollution occurs when the eroded sediment contains phosphate and heavy metals or other synthetic chemicals that could pollute the water (Cohen et al. 1993). Sediment pollution can decrease the biodiversity in the aquatic communities (Cohen et al. 1993). Disturbed sites have less species richness compared to undisturbed sites.

Lebanon County, Pennsylvania (USA), consists of a mixture of urban and rural areas. There are over one thousand farms throughout Lebanon County (Pennsylvania: Farm Numbers, Land in Farms & Average Size 2004). With a surplus in farms also comes an increase in agricultural runoff from fertilizers, pesticides, and livestock waste (Szocs et al. 2017). The city of Lebanon and other small urban development’s create another source of pollution for the neighboring bodies of water. Runoff water in these areas carries chemicals from vehicles, fuel, and garbage that pollute streams. With these aggressive factors, water pollution prevention and rehabilitation of watersheds are critical for all of life.

To keep track of pollution levels, benthic macroinvertebrates can be used to indirectly determine the water quality of streams and their tributaries. These aquatic organisms live in the sediment at the bottom of streams (Wallace and Webster 1996). Using macroinvertebrates is cheaper compared to using digital monitors to determine water quality. Determining water quality with monitors requires several measurements to be taken, such as temperature, dissolved oxygen, phosphorus, and nitrate concentration. Macroinvertebrates are also abundant and easy to collect. They are excellent bioindicator organisms as these organisms cannot escape water until they have gone through metamorphosis (Wallace and Webster 1996).

Another benefit to using macroinvertebrates is that each family has unique tolerance levels to pollution (Wallace and Webster 1996). A higher number signifies a greater tolerance to pollution where a smaller number means the macroinvertebrate is highly susceptible to pollution. If most benthic macroinvertebrates are from families with high tolerance levels, then the stream where they were inhabiting are likely to contain pollutants. For example, two species commonly found in the Quittaphilla Creek watershed are from different families—Gammaridae (Gammarus roeseli) and flatworm (Dugesia subtentaculata). Gammaridae has a tolerance level of four, and flatworm has a tolerance level of nine. The flatworm come from a family with high tolerance to pollution.

In this report, we compare the macroinvertebrate communities across six sites throughout Lebanon County. Four sites were located along tributaries of the Quittapahilla Creek (Snitz Creek, Beck Creek, Bachman Run, Killinger Creek), and two sites are within Quittapahilla Creek itself. To indirectly determine the water quality of the streams, we calculated the Family Biotic Index, EPT index, and species diversity via the Shannon-Wiener Index. The objective of this study was to compare the differences between the sites' water qualities from fall 2019 to fall 2023 by identifying the species, their families, and using their tolerance levels for the formulas.

Methods:

Study Sites:

The six study sites were located along five streams that flowed all throughout Lebanon County, PA, USA. The first site was Quittapahilla Upstream (Q1; Fig. 1). This specific sampling area (indicated by the circle) ran alongside fields of farmland and in between residential areas. There was more farmland than houses, but the sampling area still can be impacted by both agricultural runoff and runoff from the communities nearby. There are also baseball fields located directly by the stream, which shows that there will be an abundant amount of recreational use. More recreational use means a higher population of people, and with people comes trash that does not make it into the proper containment.

The next site was Quittapahilla Downstream (Q2; Fig. 2). Not as much farmland, and instead, there was more open space that was residents' yards. It was not as populated as the previous study site, but some roads intersect, running alongside the stream and going over it. Quittapahilla Downstream runs through Quittie Creek Nature Park, which can minimize pollutants, but agricultural runoff is still a concern due to Quittapahilla Upstream flowing down into it. Annville, PA, also contributes by adding fuel and oil from cars. The third study site was Snitz Creek (SC; Fig. 3). Part of the stream, indicated as the sampling area, runs between farmland and along a parking lot. Pesticides and animal waste could damage the quality of this stream, and oil leaks from cars.

The fourth study site was Beck Creek (BK) (Fig. 4), and this sampling area had the greatest coverage of farmland surrounding it out of all six sites. There were minimal housing developments, and only one was near the sampling area. The main pollution causes would be agricultural runoff due to the farmland surrounding both sides of the stream. Site number five was Bachman Run (BR; Fig. 5) and has farmland on one side of it and then housing developments and forests on the other side. It is a more populated area than site four, but it has less farmland surrounding it. Agricultural runoff and garbage pollution from the community can cause contamination concerns for this site.

The last study site was Killinger Creek (K1; Fig. 6) and had the widest range of impacts among all the study sites. The creek is on a lower slope than the farmland running along it. A road travels over it, and there is a house next to the creek. Fuel or oil chemicals could leak from vehicles on the road and drip into the creek. The location of the farmland on the higher slope makes it easier for the agricultural runoff to run downward into the creek.

Macroinvertebrate Survey

Quittapahilla Upstream (Q1)

Quittapahilla Downstream (Q2)

Snitz Creek (S1)

Beck Creek (BK)

Macroinvertebrate Survey

Bachman Run (BR)

Killinger Creek (K1)

Protocols

Members of the Quittapahilla Watershed Association collected macroinvertebrates from the six different sample sites with D-nets (Fig. 7). The flat side of the net was placed into the substrate, and hands were used to disturb the substrate upstream from the net, so the macroinvertebrates could flow into the net with the moving water. The disruption of the substrate lasted one minute each time the macroinvertebrates were collected.

Figure 7: D net used for the collection of macroinvertebrates

The macroinvertebrates were then removed from the net using dissecting forceps and placed into jars containing 70% ethanol. The jars were labeled with the date of collection, site location, and the notation that they contained 70% ethanol. They were taken back to the lab, and the macroinvertebrates were placed on petri dishes with ethanol in them and were identified by their families under dissecting microscopes. Dissecting forceps were used to manipulate them.

Data Analyses

Family Biotic Index:

FBI = $(\sum n_i \times t_i)/N$

n_i = Number of individuals of species i

t_i = Tolerance

N = Total number of individuals across all species

Biotic Index	Water Quality Rating		Degree of Organic Pollution
0.00 - 3.75	Excellent		Organic Pollution unlikely
3.76 - 4.25	Very Good		Slight Organic Pollution possible
4.26 - 5.00	Good		Some Organic Pollution probable
5.01 - 5.75	Fair		Fairly Substantial Pollution likely
5.76 - 6.50	Fairly Poor		Substantial Pollution likely
6.51 - 7.25	Poor		Very Substantial Pollution likely
7.26 - 10.0	Very Poor		Severe Organic Pollution likely

Figure 8: Family biotic index chart showing the index values with their corresponding water quality rating and degree of organic pollution

Shannon-Weiner Index:

$H' = -\sum p_i \ln p_i$

p_i = proportion of species = # of individuals of species I / total # of individuals sampled

Macroinvertebrate Survey

The Shannon-Weiner Index measures the community's diversity, which combines the species richness and their relative abundances. If the diversity is low, predicting what species will be picked at random is easier than when the diversity is high. This equation was used to compare the diversity between the six sites

Results:

Table 1: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for SC in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI.

Year	Total # Individuals	Species Richness	SWI	FBI
2023	231	11	1.85	5.03
2022	26	8	1.96	5.00
2021	56	14	2.36	4.75
2020	52	12	2.22	5.25
2019	227	11	1.60	6.88

Table 2: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for BK in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI.

Year	Total # Individuals	Species Richness	SWI	FBI
2023	768	9	0.186	4.19
2022	38	9	1.76	6.97
2021	256	15	1.74	5.31
2020	291	12	1.67	5.70
2019	708	13	1.51	4.65

Table 3: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for K1 in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI.

Macroinvertebrate Survey

Year	Total # Individuals	Species Richness	SWI	FBI
2023	X	X	X	X
2022	275	19	1.12	2.63
2021	640	6	1.78	6.39
2020	626	15	1.70	7.12
2019	X	x	X	X

Table 4: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for BR in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI

Year	Total # Individuals	Species Richness	SWI	FBI
2023	515	20	0.10	4.16
2022	98	6	1.05	5.65
2021	215	9	1.64	4.75
2020	217	10	1.70	5.91
2019	1128	10	0.96	4.16

Table 5: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for Q1 in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI

Year	Total # Individuals	Species Richness	SWI	FBI
2023	50	11	0.93	5.44
2022	65	6	1.40	4.77
2021	40	9	1.92	5.58
2020	40	9	1.92	6.02
2019	128	11	1.32	4.46

Table 6: Summary of the total number of macroinvertebrates found throughout 2019 to 2023 for Q2 in Lebanon County. It includes the total number of individuals, species richness, SWI, and FBI

Macroinvertebrate Survey

Year	Total # Individuals	Species Richness	SWI	FBI
2023	259	21	0.28	4.49
2022	259	8	1.80	5.09
2021	180	9	1.49	4.29
2020	184	11	1.60	4.32
2019	653	12	1.33	4.28

The total number of individuals of all the sites in 2019 and 2023 was higher than in the years 2020, 2021, and 2022. The primary feeding group for these individuals was shredders and collectors, and they stayed relatively consistent throughout the years of sampling. Gammaridae, Chiromidae, and Elmidae were the most abundant species throughout the period. There were no substantial predators other than an invasive Bivalvia, the Asian clam.

The Shannon Wiener index from our most important years (2019 and 2023) increased in one of the sampling sites. SC increased its value from 1.60 to 1.85. The remaining five saw a decrease. BK's SWI value went from 1.51 to 0.18. K1 in the notable years was dried up/ did not have access to the land. BRs value went from 0.96 to 0.10. Q1 went from 1.32 to 0.93. Lastly, Q2 went from 1.33 to 0.28 (Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7).

The Family Biotic Index values for 2019 and 2023 had two sites that improved, two sites stayed the same, and two sites that did not improve. SC decreased its value from 6.88 in 2019 to 5.03 in 2023, and BK decreased its value from 4.65 to 4.19. On the other hand, no values were collected for K1 in 2019 and 2023, and BR also maintained its value at 4.16 for both years. Q1 increased its value from 4.46 to 5.44, and Q2 increased its value from 4.28 to 4.49 (Table 1, Table 2, Table 3, Table 4, Table 5, Table 6, Table 7).

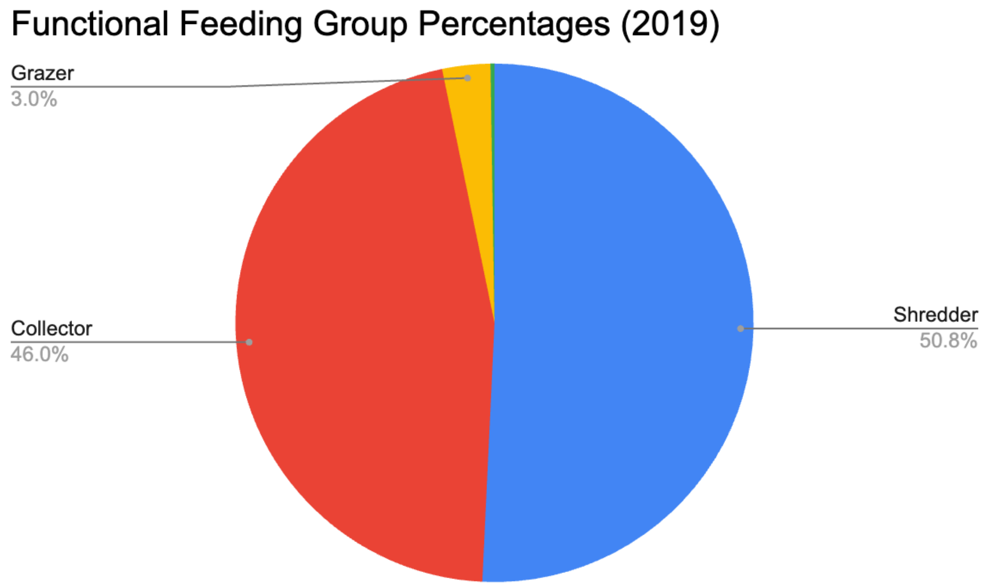

Figure 9: Comparison of the percentages of the functional feeding groups of macroinvertebrates among the six sites in Lebanon County in 2019.

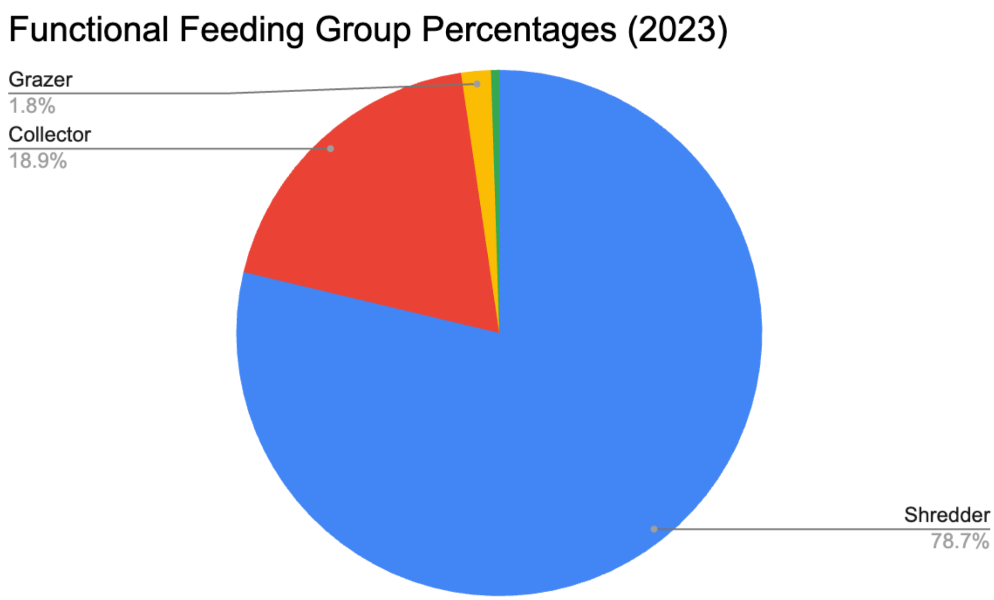

Figure 10: Comparison of the percentages of the functional feeding groups of macroinvertebrates among the six sites in Lebanon County in 2023.

Figures 9 and 10 show the overall feeding group percentages in both 2019 and 2023. In 2019, the percentage of shredders was 50.8%, and the percentage of collectors was 46.0%. These were our most abundant feeding groups (Figure 9). In 2023, there was a shift in shredder and collector family populations, shredders making up 78.7% of the feeding group population while Collectors dropped massively to 18.9% (Figure 10). Grazers and predators make up virtually nothing on the pie chart.

Discussion:

The total number of individuals of all the sites in 2019 and 2023 was higher than in the years 2020, 2021, and 2022. The other three years have fewer individuals because this type of science is known as civilian science. Volunteers come out to assist the QWA and the conservation district when needed, and assist with projects like macroinvertebrate sampling, water quality monitoring, and other projects unrelated to stream health when needed. Our most accurate numbers are 2019 and 2023, due to the assistance and expertise of the sampling teams in those years. In 2019, Dr. Rebecca Urban conducted the sampling, and she is proficient in macroinvertebrate sampling, teaching it in labs and having done it in previous years with the QWA, only stopping due to COVID-19. In 2023, Tony Shaw, a former Pennsylvania DEP specialist, was on the team, who helped collect the macroinvertebrates in the field.

To restore waterways, it is important to identify which ones have the greatest pollution levels. Overall, there seems to have been a negative shift in Shannon Weiner, meaning that there is a decrease in the number of species in the streams. This is due to an increase in pollution. Since each family of macroinvertebrate has a tolerance value, anything below what the stream’s pollution rating currently is will die. There are only a handful of species with higher tolerances, so the poorer water quality directly correlates with the diversity of species left in the stream.

The Family Biotic index overall has shown us that streams are all over the place, in a 2,2,2 split over the course of 2019 to 2023. This is due to the amount of pollution still being dumped into the streams. This includes runoff, excess nutrients, pesticides, trash, cattle or other animal droppings, and their presence in streams. However, we are seeing a little improvement in two of the streams, being SC and BK. This is a sign that the restoration efforts from the QWA and the conservation district have worked in some capacity in terms of stream health.

There was no data collected at the K1 site in 2019 because to property owners did not want us to sample at the time. 2020, 2021, and 2022 all had successful collections with their SWI value not changing much. However, in 2023, the stream had dried up. Upon arrival, there was nothing even remotely to sample. This is likely due to the drought we were in for the majority of last year and the extreme heat of the year. In 2024, the stream returned, and sampling continued that year.

Site Q1 had the highest Family Biotic Index and lowest SWI, indicating the lowest water quality. This is due to the large number of Chiromidae. This family is a collecting feeding group species, eating primarily small particles of organic matter. These particles can consist of dead organic material, like leaf fragments and bacteria, and can also include waste products from other organisms. These particles are present in streams due to the population of shredders, which break down larger particles of wood and leaves for food (Wallace and Webster, 1998). Gammaridae is another well-abundant family of shredders in the stream. We recommend restoration efforts upstream of this sampling location to allow there to be a healthier surrounding area downstream as well.

Quittapahilla Downstream had lower pollution than the upstream is the location where the stream flows. Before the sampling site for Quittapahilla Upstream, the water traveled down from the city of Lebanon, where pollution can accumulate from vehicles and stormwater runoff from the urban landscapes (Ghane et al. 2016). Quittapahilla Downstream traveled through Quittie Creek Nature Park in Annville, PA, where numerous volunteer groups, such as college students, collect litter for water quality projects to make sure the surrounding areas do not contribute to the pollution.

There are some negatives for the community itself when it comes to low biodiversity. Biodiversity leads to a healthier ecosystem because it increases food sources and decomposition throughout it (Tornwall et al. 2015). A low biodiversity could prevent some species from living there because of a lack of food sources and could overall lower the quality of the ecosystem’s productivity. Bachman Run had the best water quality with this Shannon-Wiener Index because of the low tolerance level of Gammaridae at 4. If it were a macroinvertebrate with a higher tolerance level, then that would be the result of greater pollution.

The different feeding groups of macroinvertebrates are shredders, collectors, scrapers, and predators (Uwadiae, 2010). With the example of Bachman Run, Gammaridae are shredders, so that could suggest that there are few predators and a lot of leaf litter accumulating here. If predators were more abundant than the shredders, then that could negatively affect the ecosystem because there would be no macroinvertebrates that could decompose the leaf litter. There needs to be a balance of organisms to fulfill ecosystem services.

Macroinvertebrate Survey

The streams throughout Lebanon County, PA, have a pollution concern. There has been little to no progress within a year to alter these damaging results. Some ways to prevent further pollution would be to clean up all litter in and surrounding the sites, put barriers along the waterway to reduce the amount of agricultural runoff, and if there is an oil spill from a vehicle, then you should soak it up with a towel instead of hosing it off into the water. (Rai et al. 2020). The main focus for restoration efforts should be Killinger Creek. Its consecutive low water quality results have shown that it has a constant pollution issue. This problem will not be fixed overnight, but these simple prevention ideas can help improve the water quality in the site

References:

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P. S., Wichman, M. (2007). Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. *Environmental Health Perspectives*, *115*(2), 308–312. https://doi.org/10.1289/ehp.8839

Cohen, A., Bills, R., Cocquyt, C., Caljon, A. G. (1993). *Conservation Biology, 7*(3), 667-677. https://www.geo.arizona.edu/sites/www.geo.arizona.edu/files/web/Cohen/pdf/25%20Cohen%20et%20al%201993%20Conservation%09Biology.pdf

Ghane, E., Ranaivoson, A. Z., Feyereisen, G. W., Rosen, C. J., Moncrief, J. F. (2016). Comparison of Contaminant Transport in Agricultural Drainage Water and Urban Stormwater Runoff. PLoS ONE, 11(12), e0167834. https://doi.org/10.1371/journal.pone.0167834

"Pennsylvania: Farm Numbers, Land In Farms & Average Size." (2010). https://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2010_2011/farm_number%20and%20land%20in.pdf

Rai, R., Sharma, S., Gurung, D. B., Sitaula, B. K., Shah, R. D. T. (2020). Assessing the impacts of vehicle wash wastewater on surface water quality through physico-chemical and benthic macroinvertebrates analyses. *Water Science*, *34*(1), 39–49. https://doi.org/10.1080/11104929.2020.1731136

Macroinvertebrate Survey

Szöcs, E., Brinke, M., Karaoglan, B., Schäfer, R. B. (2017). Large Scale Risks from Agricultural Pesticides in Small Streams. *Environmental Science & Technology*, *51*(13), 7378–7385. https://doi.org/10.1021/acs.est.7b00933

Tornwall, B., Sokol, E., Skelton, J., Brown, B. L. (2015). Trends in Stream Biodiversity Research since the River Continuum Concept. *Diversity*, *7*(1), 16–35. https://doi.org/10.3390/d7010016

US EPA. (2017). *How We Use Water* [Overviews and Factsheets]. https://www.epa.gov/watersense/how-we-use-water

Uwadiae, R. (2010). Macroinvertebrates' functional feeding groups as indices of biological assessment in a tropical aquatic ecosystem: Implications for ecosystem functions. *New York Science Journal, 3*(8).

Wallace, J. B., & Webster, J. R. (1996). The role of macroinvertebrates in stream ecosystem function. *Annual review of entomology*, *41*(1), 115-139.