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Using Macroinvertebrates To Assess The Effects Of Tropical Storm Helene In The Swannanoa River Watershed

Olivia Williams

Department of Environmental Science
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Mentor(s):
David Gillette
Casey King

Abstract

Flooding can have negative effects on stream health by increasing pollution and sediment, disturbing the natural flow regime, and removing vegetation. On September 27th, 2024, Tropical Storm Helene delivered large amounts of rainfall across Western North Carolina, causing major flooding and riparian damage. This project evaluated the health of streams in the Swannanoa River watershed before and after Helene using macroinvertebrates and water temperature data. Macroinvertebrates are commonly used as biological indicators because they are abundant, easy to sample, and sensitive to stream quality. Macroinvertebrate samples were collected from four forested and four non-forested streams using a Surber sampler at eight randomized points from riffles and pools, and water temperature was measured from May through September. To assess stream health, macroinvertebrates were identified to family, and a Family-Based Index of

Biotic Integrity (FBIBI) and percent of insects belonging to the orders Ephemeroptera, Trichoptera, and Plecoptera (EPT) were calculated. Of the eight stream sites, two were significantly affected by Helene as mean FBIBI increased significantly at Burgin Cove and Flat Creek, and mean %EPT decreased significantly, indicating a decline in water quality. These two sites were both in the forested stream category. Stream health did not differ significantly at the six other sites. After controlling for air temperature, it was seen that there was a significant increase in water temperature, possibly due to loss of riparian vegetation. This study showed evidence that some forested streams in the Swannanoa watershed were negatively affected by the impacts of Tropical Storm Helene, which may help focus recovery efforts.

1. Introduction

Rivers and streams are among the most threatened habitats. They only take up 2.5% of the water on Earth, but are important for maintaining the health and well-being of all species (Mishra, 2023). Rivers and streams support high levels of biodiversity, but extinction rates in these systems are higher than those in terrestrial areas, despite the numerous conservation efforts around the world (Reid et al., 2019; Vörösmarty et al., 2010). Disturbances can provide a spectrum of short- and long-term consequences that will affect the overall ecology of the stream (Strickland et al., 2024). Natural disasters such as hurricanes can be a severe disturbance for stream communities. High winds and rain can strip riparian vegetation which changes light conditions, displaces sediment, and increases the input of pollution and debris into water (Strickland et al., 2024). Predictable floods are an important part of lotic ecosystems, however unpredictable major flooding can be highly destructive (Dolloff et al., 1994). In coastal ecosystems, hurricanes critically impact water systems by affecting biogeochemical cycling and water quality (Schafer et al., 2020). Flow disturbances are frequently studied in stream ecosystems, however few studies have examined hurricane impacts on stream communities (Strickland et al., 2024).

Aquatic macroinvertebrates can be used as indicators of stream water quality to assess ecosystem response to disturbances such as hurricanes. Macroinvertebrates exhibit a wide range of pollution tolerance, with some especially sensitive groups and others that can tolerate highly contaminated water. When a stream changes drastically due to an environmental disturbance, macroinvertebrate communities will change as a result (López-López & Sedeño-Díaz, 2015). Therefore, we can look at the macroinvertebrate community after a disturbance in order to determine the health of a stream. A study based in West Virginia described the macroinvertebrate response to two floods in a forested headwater stream (Angradi, 1997). After the first flood in February, taxa abundance decreased by 70-90%, but recovered rather quickly before the second flood in May, in only 42 days (Angradi, 1997). In response to a severe flood in the Staunton River, Virginia, the macroinvertebrate community was stable again after 3 years (Snyder & Johnson, 2006). However, there were significant differences in total macroinvertebrate density and trophic structure that were attributed to the flood (Snyder & Johnson, 2006). Both of these studies show that macroinvertebrates can have different recovery periods after disturbance due to their rapid lifecycles and recolonization mechanisms.

Changing water temperature is another way that Helene could have long-term effects on stream health. Changes in the thermal regime of streams play a large role in stream health (Caissie, 2006). Globally, rivers are already undergoing warming temperatures due to atmospheric warming (Barbarossa et al., 2021). Loss of trees and other vegetation reduces shading effects, allowing more solar radiation to reach streams (Johnson et al., 2024). A review by Bowler et al., (2012), concluded that streams with more trees in the riparian zone had overall cooler temperatures compared to streams without trees. Rising water temperatures have many direct and indirect impacts on aquatic life (Johnson et al., 2024). Water temperature affects the physiology of aquatic animals, as it affects the growth rate and distribution of aquatic organisms, and most species have a specific range of temperatures that they can tolerate (Johnson et al., 2024). Rising water temperatures also cause an increase in eutrophication and disease spread in streams (Johnson et al., 2024). There is little research known about the effects of hurricanes on water temperature in stream systems.

Tropical Storm Helene hit the Southern Appalachians on September 27th, 2024. There were detrimental effects on the freshwater systems across Western North Carolina, due to the distribution of large amounts of debris and run-off into the water systems. The riparian zone was also heavily damaged due to the high winds and destructive flooding. However, specific impacts on water quality are still unknown. This research project provides valuable information for stream recovery after Tropical Storm Helene. A local non-profit, RiverLink, is currently working with the Friends and Neighbors of Swannanoa in developing a watershed restoration plan for a six-mile section of the Swannanoa River impacted by Helene. The streams that I studied in this project are various tributaries that flow into the Swannanoa River. This will provide information to RiverLink from the smaller streams in order to identify which areas need the most help with recovery. RiverLink's restoration plan is important because streambank restoration is recognized by the EPA as a climate mitigation strategy (*Stream Restorations* | *Riverlink*, n.d.). The upkeep and restoration of streambanks and floodplains benefit the ecosystem and humans because they help protect communities from climate change impacts, such as major flooding (*Stream Restorations* | *Riverlink*, n.d.). It is important for studies such as these to expand because due to climate change, extreme weather events that affect river habitats have increased and will continue to (Intergovernmental Panel On Climate Change (Ipcc), 2023).

There are few studies that have concentrated on the benthic fauna of streams in the Appalachian mountains after flood events due to limited data availability (Angradi, 1997). In this research project, I will be examining the effects of Tropical Storm Helene on stream health in the Swannanoa River Watershed by collecting data on macroinvertebrates, and comparing it to data from previous years. This study also examines how the opening of the canopy affects water temperature. The findings of this study may be used to help focus ongoing recovery efforts post-Helene.

2. Methods

2.1 Study Area

The study area is located in the Swannanoa River Watershed in Buncombe County, NC. The Swannanoa River is a 22 mile long major tributary to the French Broad River. The upstream area of the Swannanoa Watershed is forested, and the lower is non-forested, or more urban. Eight stream sites were selected along the watershed. Three of the sites are non-forested streams: Grassy Branch, Haw Creek, and Sweeten Creek (*Figure 1*). The other five streams are in more forested areas: Beetree Creek, North Fork Swannanoa River, Burgin Cove, Camp Branch, and Flat Creek. When a stream is more urbanized, water floods faster, and water levels drop quicker during drought, causing more pollution and warmer temperatures. In contrast, in a forested stream the water level is more stable and has less pollution (Walsh et al., 2005). This greatly affects the types of macroinvertebrates found in the streams, and is why representation from both forested and non-forested stream environments are needed to properly assess the impacts of Tropical Storm Helene.

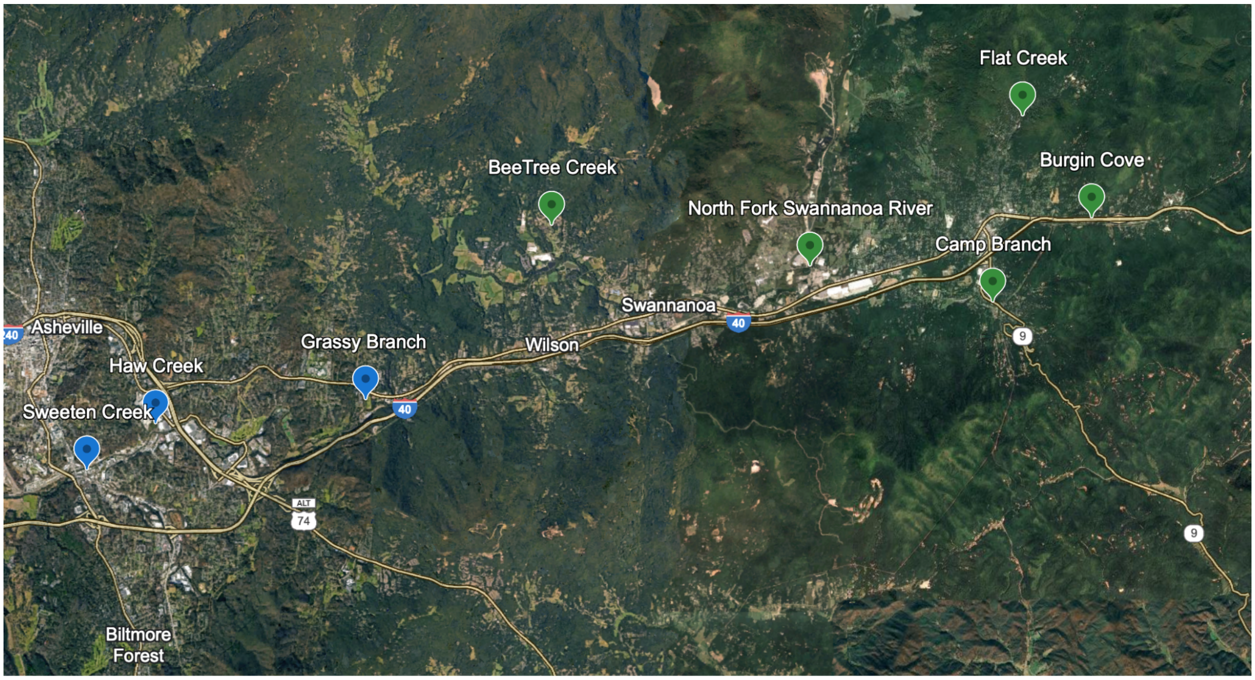

Figure 1. Eight stream site locations along the Swannanoa River Watershed. Non-forested streams are represented by blue pins, and forested streams are represented by green pins.

2.2 Macroinvertebrate Sampling

At each of the eight stream sites, eight macroinvertebrate samples were collected. Four were collected from pools, and four from riffles at each stream. A riffle is the shallow, fast moving part of the stream and a pool is the deep, slow moving part of the stream. Samples were collected using a Surber sampler ($0.10m^2$) at randomly selected locations along each measured riffle and pool. The random points were chosen by measuring each riffle and pool, and then a random number generator was used to select the sample points. The Surber sampler is held down in the stream and the substrate in the streambed is completely disturbed by hand for at least 60 seconds. The organisms flow into the net during this process. Everything collected in the net was poured through a sieve, to remove sediment and organic debris. The sample was transferred into a jar containing 70% ethanol to preserve the species. The samples were analyzed at the lab at UNCA for macroinvertebrate identification. All samples were collected between June 29th and July 13th, 2025.

Every macroinvertebrate was identified to family following McCafferty, (1998). Using Hilsenhoff, (1988), macroinvertebrates were given a tolerance value. Once all of these values were averaged together, the mean Family Based Index of Biotic Integrity (FBIBI) was determined for each site. An FBIBI analysis shows an overview of what the water quality is like at a site, based on a scale from zero to ten with higher values indicating worse water coquality. A %EPT analysis was also performed. These three insect orders, Ephemeroptera, Plecoptera, and Trichoptera, are considered to be intolerant to pollution. To find the mean %EPT of a site, I divided the total number of individuals in the EPT order by the total number of macroinvertebrates in the sample, and multiplied it by 100. A higher mean %EPT indicates better water quality.

A previous research student sampled the same sites, during the same months, in 2023 (pre-Helene). The post-Helene mean FBIBI and mean %EPT from each site was compared to the site's data from 2023 using a paired t-test, to find if the pre- and post- sites were significantly different from each other. A p-value less than 0.05 tells that there is a significant difference between the data from pre- and post-Helene, meaning that there was a real effect at the sites.

2.3 Water Temperature

I used HOBOware Pendant Water Temperature Dataloggers to measure temperatures every two hours. The data collected by the HOBOware pendants were transferred to a smartphone via Bluetooth. Protective casings for the pendants were hand built and installed into the stream in locations that were not in the heavy stream flow or direct sight. Datalogger locations were hard and rocky, so the modules would not sink into the mud. The rebar was hammered into the streambed, and the loop of the cable on the casing was attached to the rebar. Large rocks were placed on and around the module to prevent the module from being pulled out when water gets rough, and it allowed the modules to be more out of sight to prevent vandalism. The data loggers were installed between the dates of May 13th-22nd, 2025 and were picked back up on September 11th, 2025 to ensure that the full range of temperatures, as well as the highest maximum temperature, was captured.

For the water temperature data analyses, the mean daily temperature was found from each day to form a line graph to be compared to the temperatures from the previous years. To correct for annual variation in air temperature, I performed a linear regression of daily mean air temperature and daily mean water temperature from 2025 data and the data from previous years, with daily mean water temperature as the dependent variable, and daily mean air temperature as the independent variable. A paired t-test was then performed on the residuals from the linear regression in order to determine if there was a significant difference in mean residual values between pre- and post-Helene. This allowed me to discover if the water temperature was warmer just based on the air temperature, or if it was based on another variable such as Helene.

3.Results

3.1 Macroinvertebrates

Over summer 2025, an average of 49 macroinvertebrates were counted from each sample from the eight stream sites, and 24 different families were identified. In 2023, an average of 50 macroinvertebrates were counted from the sites, with 28 different families identified. Of the eight stream sites, only two had a significant difference in mean FBIBI after the hurricane, and only one had a significant difference in mean %EPT *(Table 1)*. Flat Creek had a significant difference in mean FBIBI (p-value= 0.003) and mean %EPT (p-value=0.03) *(Figure 2, 3)*. Burgin Cove had a significant difference in mean FBIBI (p-value=0.007) *(Figure 4)*. Flat Creek went from excellent to fair water quality, and Burgin Cove went from good to fair.

Table 1. Mean FBIBI and Mean %EPT per site with standard deviation for both pre and post-Helene. (FBIBI<3.75= excellent water quality; 3.75<FBIBI<4.25= very good water quality; 4.26<FBIBI< 5.00= good water quality; 5.01<FBIBI<5.75=Fair water quality). Bold = significant.

Site	Pre-Helene FBIBI	Post-Helene FBIBI	Pre-Helene %EPT	Post-Helene %EPT
Sweeten Creek	5.09 ± 0.58	5.29 ± 0.48	38% ± 26	35% ± 24
Haw Creek	4.61 ± 0.24	4.84 ± 0.70	61% ± 41	41% ± 33
Grassy Branch	5.63 ± 0.75	5.45 ± 0.46	20% ± 41	23% ± 19
Beetree Creek	4.60 ± 0.55	5.05 ± 0.62	28% ± 33	45% ± 31
North Fork	4.60 ± 0.40	4.81 ± 0.64	56% ± 14	51% ± 37
Camp Branch	4.52 ± 0.95	4.35 ± 1.26	33% ± 17	44% ± 31
Flat Creek	3.43 ± 0.94	**5.46 ± 0.82**	73% ± 24	**26% ± 34**
Burgin Cove	4.34 ± 0.80	**5.53 ± 0.52**	30% ± 14	20% ± 17

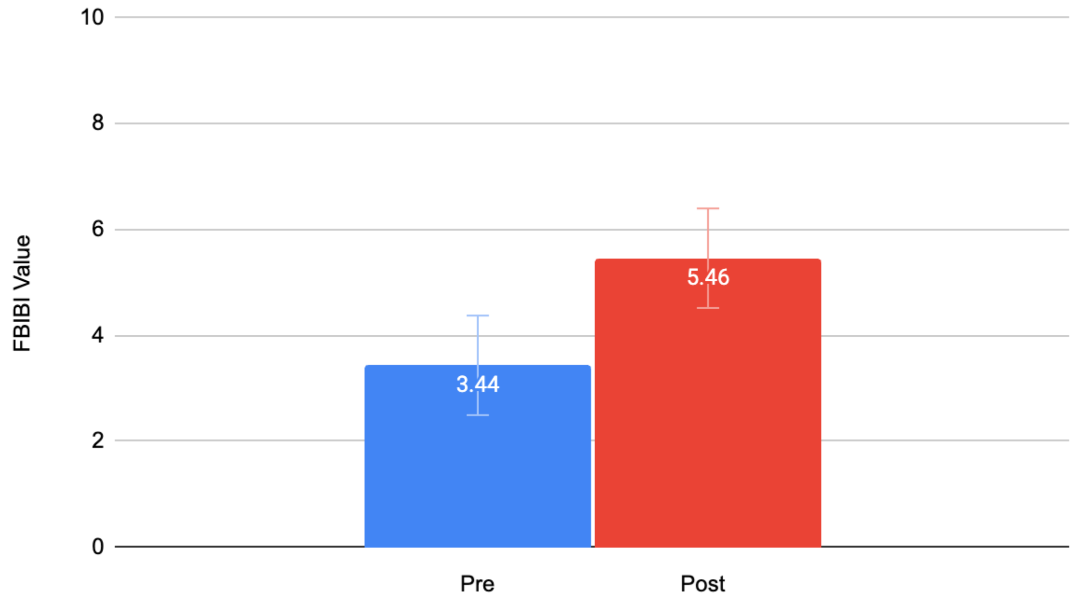

Figure 2. Flat Creek mean FBIBI with standard deviation pre- vs post-Helene. Means differed significantly (p=0.003).

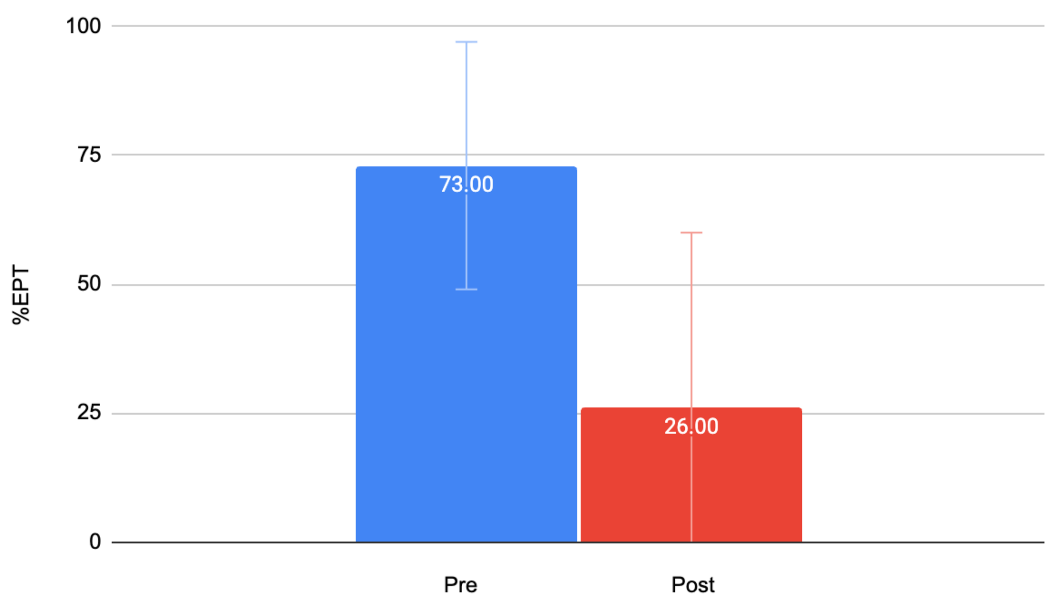

Figure 3. Flat Creek mean %EPT with standard deviation pre- and post-Helene. Means differed significantly (p=0.033).

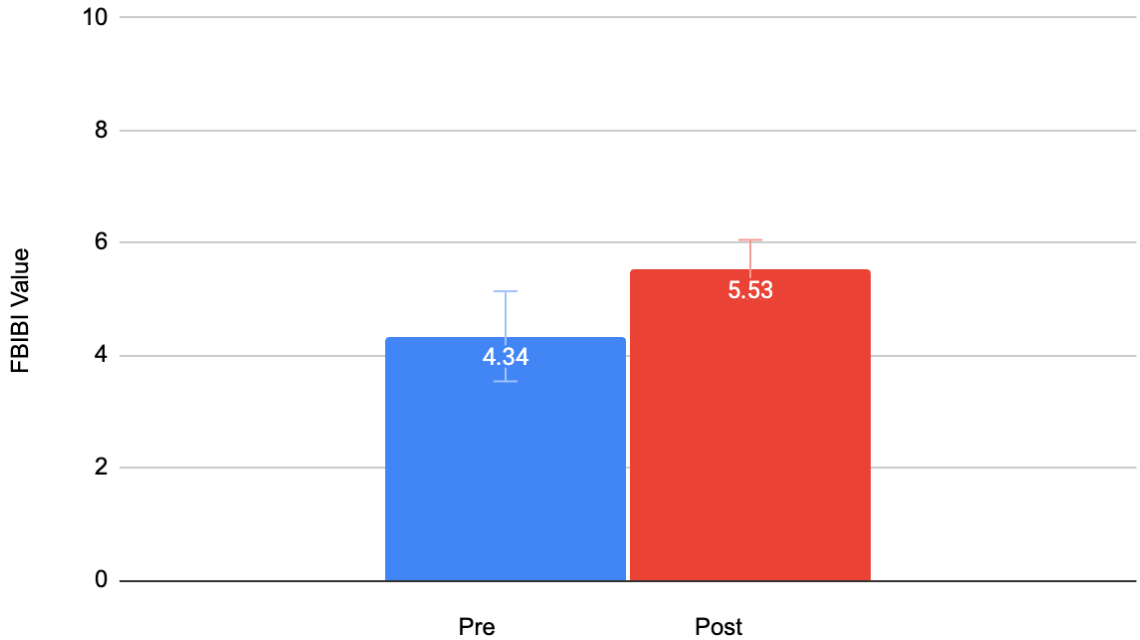

Figure 4. Burgin Cove mean FBIBI with standard deviation pre- vs post-Helene. Means differed significantly (p=0.007).

When looking at the macroinvertebrate communities of the two sites that had a significant difference, there are some noteworthy findings *(Table 2)*. Flat Creek had an increase in the families Chironomidae and Baetidae, and a large decrease in Plecoptera families, including Perlodidae, Perlidae, and Chloroperlidae, and Diptera family Tabanidae. When looking at Burgin Cove, there were similar findings such as an increase in Baetidae and a large decrease in Perlidae and Chloroperlidae

Table 2. Abundance of macroinvertebrate families at Burgin Cove and Flat Creek before and after Helene. Bold = importance based on large differences post-Helene.

		Burgin Cove			Flat Creek	
Order	Family	Pre	Post	Family	Pre	Post
Diptera	Chironomidae	95	96	**Chironomidae**	38	186
Diptera	Chironomidae (Red)	0	1	**Chironomidae (Red)**	0	25
Diptera	Simuliidae	10	4	Simuliidae	2	2
Diptera	Tipulidae	3	3	Tipulidae	3	0
Diptera	Tabanidae	0	0	Tabanidae	52	0
Ephemeroptera	Baetidae	3	20	**Baetidae**	0	21
Ephemeroptera	Heptageniidae	0	0	Heptageniidae	0	6
Ephemeroptera	Leptophlebiidae	0	0	Leptophlebiidae	9	0
Trichoptera	Hydropsychidae	3	3	Hydropsychidae	0	3
Trichoptera	Philopotamidae	0	0	Philopotamidae	4	1
Trichoptera	Rhyacophilidae	3	0	Rhyacophilidae	0	0
Trichoptera	Glossosomatidae	3	0	Glossosomatidae	0	0
Plecoptera	Ple: Leuctridae	1	5	Ple: Leuctridae	0	13
Plecoptera	**Perlodidae**	12	0	**Perlodidae**	31	0
Plecoptera	**Chloroperlidae**	14	0	**Chloroperlidae**	35	0
Plecoptera	Perlidae	0	0	**Perlidae**	4	0
Plecoptera	Unknown	0	0	Unknown	0	2
Odonata	Aeshnidae	1	0	Aeshnidae	0	0
Coleoptera	Psphenidae	0	0	Psphenidae	2	0
Coleoptera	Elmidae	13	0	Elmidae	0	0
Totals		161	132	Totals	180	259

3.2 Temperature

After comparing water temperatures for pre- and post-Helene, results varied by site. Sweeten Creek showed an increase in temperatures post-Helene in June, July, and part of August *(Figure 5)*. Haw Creek and Grassy Branch showed an increase in temperature throughout the summer, except for a short period in August *(Figure 6, 7)*. Beetree Creek showed an increase in temperature in June and July, but the data from 2022 stopped mid-July *(Figure 8)*. Flat Creek showed an increase in temperature in June and July, and a decrease in August *(Figure 9)*. Burgin Cove has limited data from pre-Helene, 2022, however post-Helene temperatures increased in July and stayed similar to previous temperatures in August *(Figure 10)*. I was unable to compare data from the remaining two sites, North Fork and Camp Branch. At North Fork, the only pre-Helene data available was from 12 days in October 2020, and this past summer the data logger was out of the water when we went to retrieve it in September. At Camp Branch, the only pre-Helene data available was from May to mid-June in 2022, and this summer the data logger was lost around mid-July. The maximum temperature post-Helene was higher than the maximum temperature pre-Helene at 4 sites; Sweeten Creek, Haw Creek, Burgin Cove, and Beetree Creek. At the remaining sites with data, Flat Creek and Grassy Branch, the maximum temperature was the same pre- and post-Helene, although the timing of the maximum temperature differed.

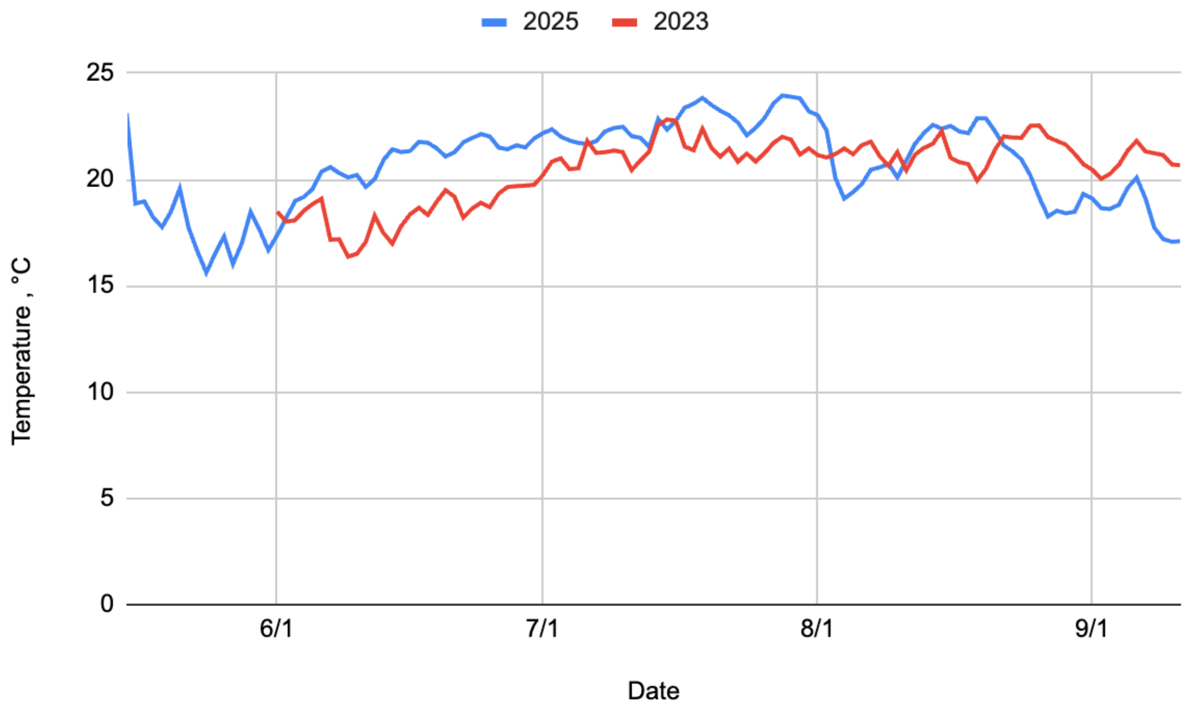

Figure 5. Mean daily temperature at Sweeten Creek from summer 2025 and 2023.

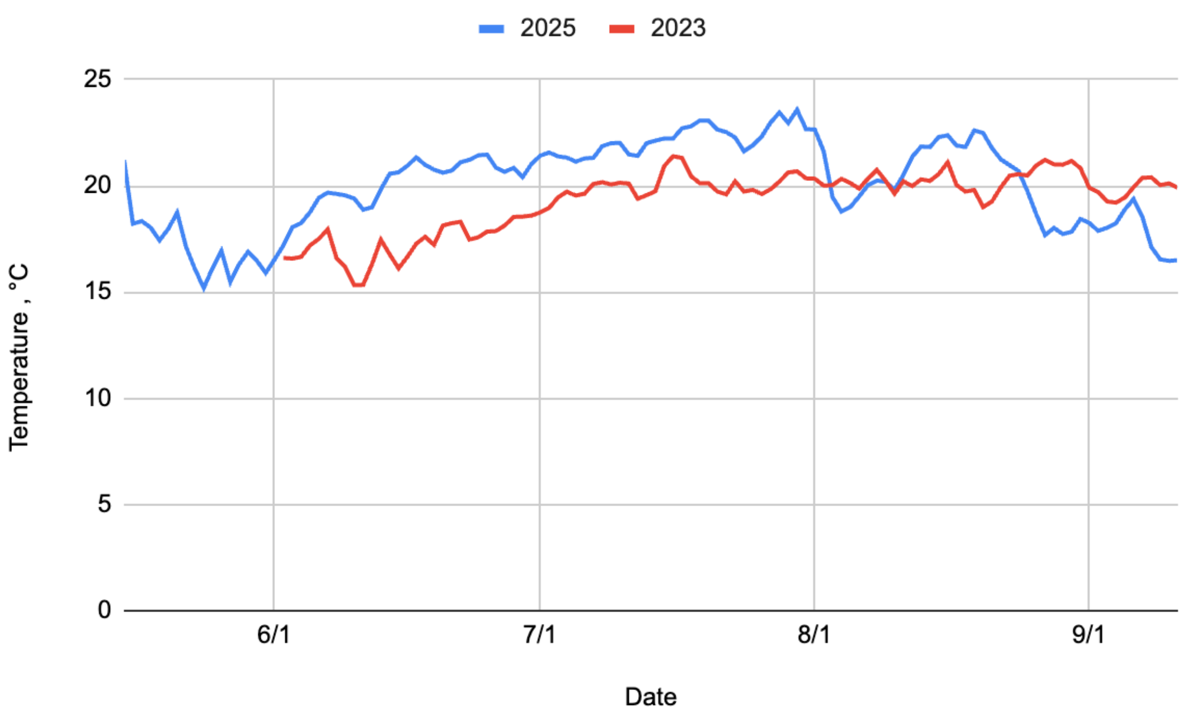

Figure 6. Mean daily temperature at Haw Creek from summer 2025 and 2023.

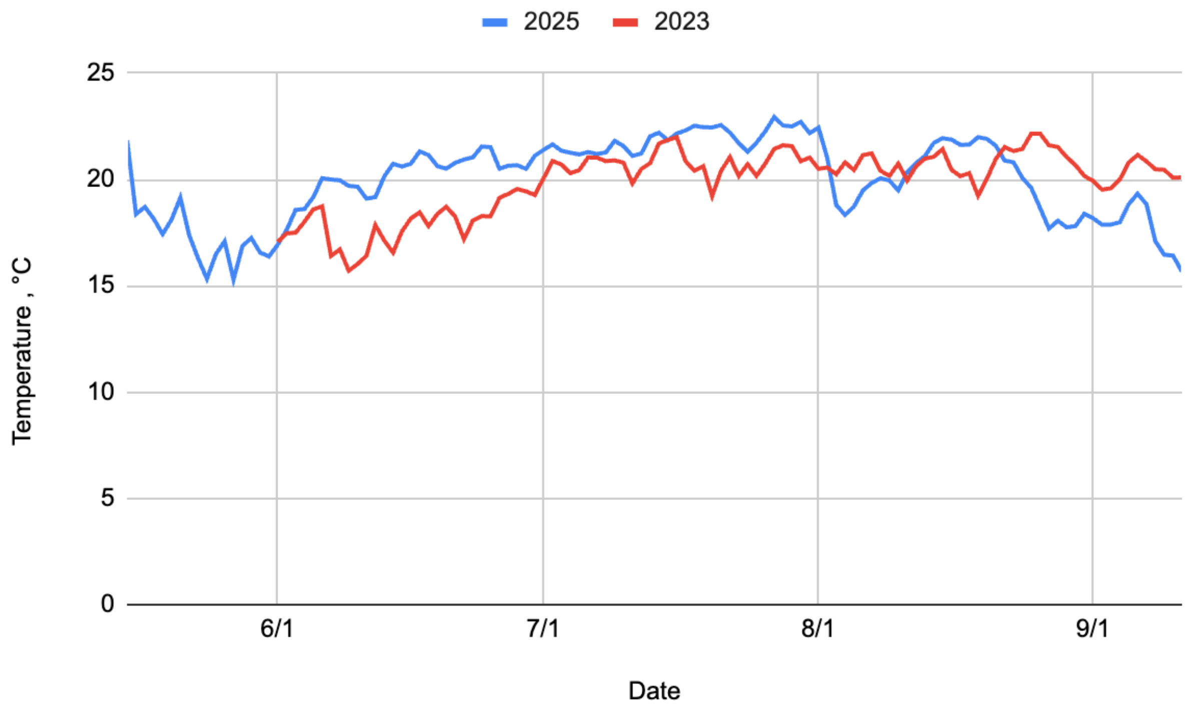

Figure 7. Mean daily temperature at Grassy Branch from summer 2025 and 2023.

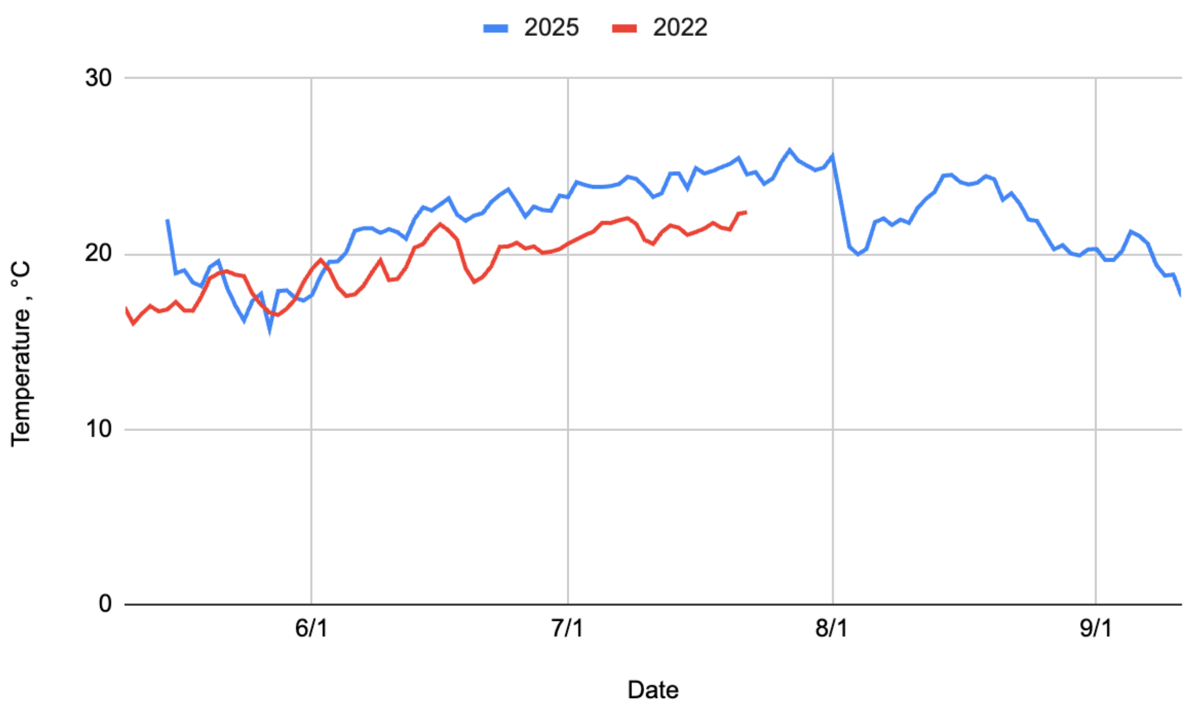

Figure 8. Mean daily temperature at Beetree Creek from summer 2025 and 2023.

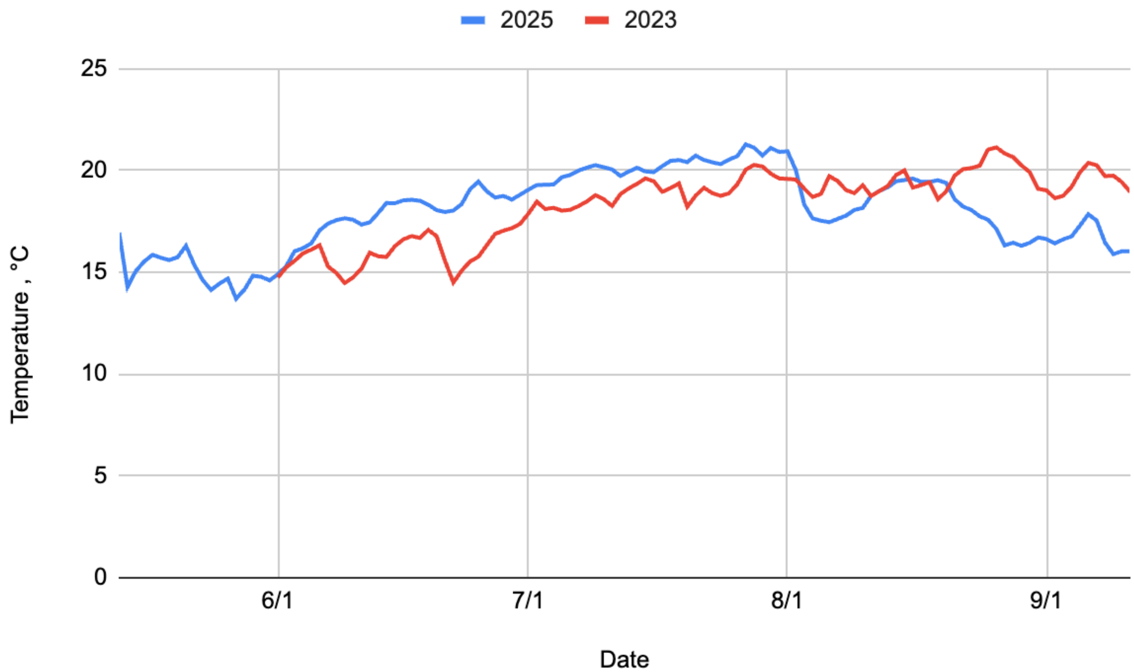

Figure 9. Mean daily temperature at Flat Creek from summer 2025 and 2023

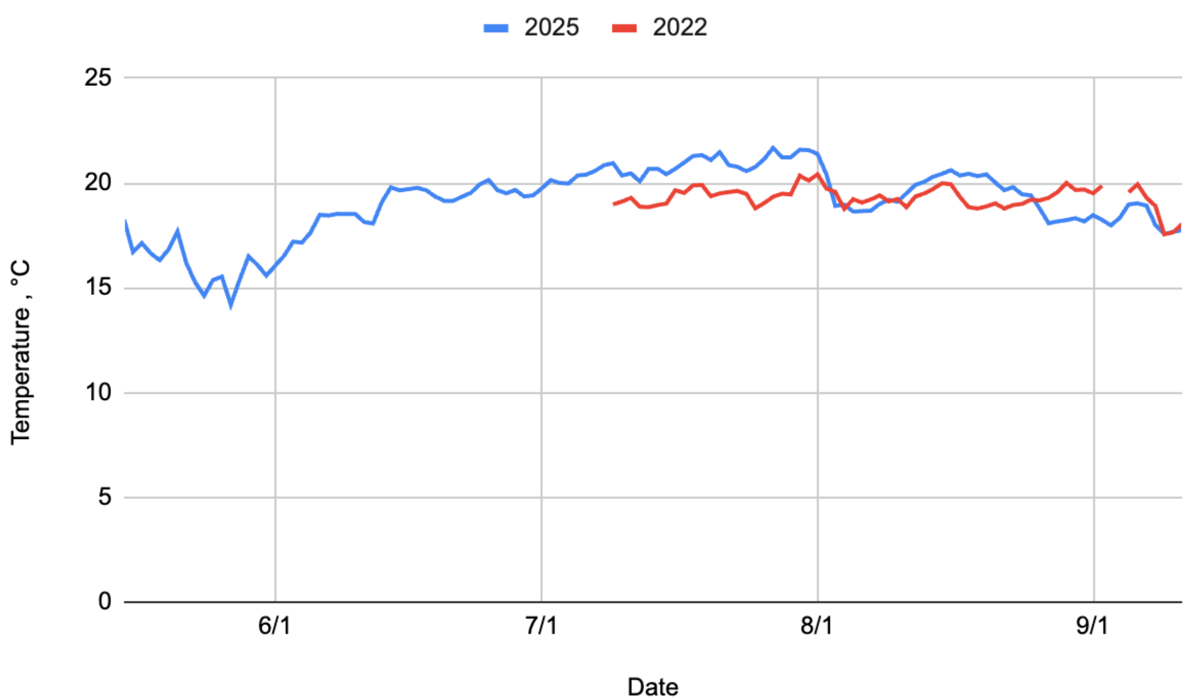

Figure 10. Mean daily temperature at Burgin Cove from summer 2025 and 2022.

Air temperature did have a significant effect on water temperature as expected *(Table 3)*. The mean of post-Helene residuals was significantly higher than mean of pre-Helene residuals at all sites except for Flat Creek, indicating that post-Helene water temperatures were warmer than would be expected based only on air temperatures. This means that at every site besides Flat Creek, the changes in water temperature can be partially explained by Tropical Storm Helene. However, the residuals tell us how far away the data points are from the expected temperature, and when looking at the post- residuals, it is seen that at all of the sites, the residuals are above the expected temperature. Air temperature accounted for over 80% of variation in water temperature at Grassy Branch, but only 43% at Beetree Creek.

Table 3. Summary of regression statistics; all regression equations were significant (p=<0.001).

Site	Equation	r^2 Values	Pre-Helene mean residuals	Post-Helene mean residuals	p-value comparing pre- and post-residuals
Beetree Creek	y=0.74x+4.93	0.43	-1.01	1.01	<0.00001
Burgin Cove	y=0.31x+12.74	0.60	-0.37	0.34	<0.00001
Flat Creek	y=0.56x+6.44	0.65	-0.03	0.03	0.67
Grassy Branch	y=0.62x+6.78	0.83	-0.15	0.15	0.0007
Haw Creek	y=0.56x+6.78	0.59	-0.55	0.55	<0.00001
Sweeten Creek	y=0.62x+7.50	0.78	-0.23	0.23	0.00001

4. Discussion

The results of this study suggests that Tropical Storm Helene did have a significant effect on streams in the Swannanoa River Watershed. Macroinvertebrate results showed that of the eight stream sites, only Flat Creek and Burgin Cove had a significant difference in mean FBIBI, and only Flat Creek had a significant difference in mean %EPT. This means that only these two sites had statistically significant negative effects after Helene. When looking at the macroinvertebrate community composition, the large decline of certain families from these two sites is interesting. There was a large decline of Plecopteran families at both sites, and this order is one of the most pollution-intolerant orders, with their tolerance values ranging from 0-2 (Hilsenhoff, 1998) indicating that there may have been an increase in pollution in those streams after Helene. There was a large increase of Baetidae at both sites, and a large increase in Chironomidae at Flat Creek. Both of these families primarily feed on organic matter in the streams (Merritt and Cummins, 1996), possibly suggesting that more organic matter was deposited into streams by Helene. Red Chironomidae is also a pollution-tolerant species with a tolerance value of 8 (Hilsenhoff, 1988).

Flat Creek seems to be the site that was most affected, since both the mean FBIBI and mean %EPT differed significantly between pre- and post- data. Flat Creek was also sampled by UNCA's Stream Ecology class two months after Helene, and it was seen that the macroinvertebrates took a large hit. The stream was sampled differently as the class did six samples total instead of eight, but from the first six samples done on September 10th 2024, 58 macroinvertebrates were collected and IDed. We returned to Flat Creek on November 4th, 2024 to do the same procedure, and only four macroinvertebrates were collected in total. Even though Flat Creek was significantly affected by Helene, the macroinvertebrates seem to have recovered their numbers, as we collected an average of 49 macroinvertebrates per sample this summer. However, it may take longer for macroinvertebrates to fully return to their original community structure. Unfortunately there is no data for the other sites from so soon after Helene, so it is hard to tell if this is true for all sites. Comparing this study to Angradi (1997), they found that there may have been small shifts, but overall community structure was little affected by floods. Snyder and Johnson (2006) found that macroinvertebrates in Appalachian streams are rather resilient to disturbance, as macroinvertebrates reached a healthy community after 3 years. They stated that the community composition differed more based on the seasons, but they did have some evidence supporting that the flood had lasting effects on trophic structure (Snyder and Johnson, 2006).

It is rather surprising that the mean FBIBI and mean %EPT of the six other stream sites were not significantly affected by Helene. This could be due to the fact that three of the sites were in more urbanized areas, so the macroinvertebrates may already be more resilient to disturbance. An implication for further study is to look at the functional feeding groups of the macroinvertebrates before and after Helene in order to provide a better understanding of how the macroinvertebrates have reacted to this disturbance.

The temperature results showed that the effects of Tropical Storm Helene did potentially have an impact on the water being warmer this summer. There was only one site that did not show a significant difference in residuals, Flat Creek. This tells us that the five other sites could have possibly had a decline in riparian zone, but further research is needed. Bowler et al. (2012) concluded that streams with less trees in the riparian zone had cooler temperatures compared to streams with more trees. It is surprising that Flat Creek did not have a significant temperature difference, because it was the only site with a significantly affected mean FBIBI and mean %EPT. This suggests that the decline of water quality at Flat Creek was not due to water temperature, but perhaps by another factor such as pollution or increased sediment. A limit of this portion of the research paper is that two of the HOBOware dataloggers were lost, so we did not get the full results from all eight sites.

An implication for further study is to look at GIS canopy cover data before and after Helene to provide more validation that Helene did have a significant effect on the riparian zone. A decrease in the riparian zone could also affect the functional feeding groups of macroinvertebrates in different ways.

V. Conclusion

It is important that studies based on stream systems after natural disasters increase as the climate continues to change. Tropical Storm Helene had a negative effect on stream health at two sites, and increased water temperatures across the Swannanoa River Watershed. Of the two affected sites, macroinvertebrate abundance was not affected, but the community structure indicated a decline in health as the mean %EPT and mean FBIBI differed significantly. Five of the six sites with data had warmer water temperatures that could partially be attributed to Helene, suggesting a possible loss of riparian zone. My research from the smaller tributaries of the Swannanoa River can help inform recovery efforts, such as those from my community partner RiverLink, to continue working on restoration while making sure that time and resources are going to the areas that need it most.

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