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Comparison of Macroinvertebrate Communities between Forested and Urban streams

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Abstract

Urbanization is known to impact watersheds negatively in a number of ways. For streams, this often includes poor water quality and increased sediment concentration. Macroinvertberates respond to these changes and will likely be found where they can tolerate certain levels of environmental stress. Streams with an abundance of pollution and oxygen sensitive taxa are representative of cleaner stream conditions. This study aimed to analyze the macroinvertebrate community for eight stream sites within the Swannanoa River basin and to compare communities between urban and forested sites. We found that urban sites had a higher Family-Based Index of Biotic Integrity (FBIBI) than forested sites, indicating less-than-ideal environmental conditions for common bio-indicators such as Ephemeroptera, Trichoptera, and Plecoptera orders. Research on urban streams suggests that this is the normal pattern, citing sediment pollution and nutrient enrichment to be the top concerns. Conductivity was highest in urban sites downstream and the inverse was true for dissolved oxygen. Scoured banks and incised channels found at urban sites with high conductivity are indicative of increased flow volume and velocity during precipitation events eroding soil. Two sediment tolerant taxa, Chironomidae and Oligochaeta composed most of the community for Grassy Branch and Sweeten Creek. Forested sites had higher diversity including abundances of EPT.

1. Introduction

Anthropogenic activity is changing and developing the Southern Appalachians leading to urbanized streams and floodplains over time. Urban streams are often in poor shape due to channel modification, increased runoff, and disturbance within the stream and floodplain. This is known as “urban stream syndrome” (Walsh et al. 2005) which includes a flashy hydrograph, increased concentration of sediment, nutrient, and contaminant pollution, altered channel morphology and flow, and a reduction in biodiversity. Loss of riparian vegetation also contributes to water temperature by reducing shade, and can increase algae growth while decreasing the diversity of aquatic organisms. As a result, urban streams are generally warmer and have less capacity to retain dissolved oxygen.

Aquatic macroinvertebrates represent a large and diverse community within Appalachian freshwater streams. They form the dominant animal communities within headwater streams and contribute to important ecological functions. Many species require specific environmental conditions to thrive, and respond quickly to changes in water quality. Notably, the insect orders Ephemeroptera, Trichoptera, and Plecoptera are intolerant to low dissolved oxygen and higher water temperatures which makes them ideal bioindicators for water quality (Herman et al. 2015). As urbanization further degrades streams, it is important to study how aquatic ecosystems react to anthropogenic development and pollution.

The Swannanoa rivershed boasts a large number of small streams across elevation and pollution gradients which feed into the larger French Broad River, of which sections have been put on the 303(d) list under the Clean Water Act for impaired water quality. While macroinvertebrates have shown to be effective indicators for water temperature, dissolved oxygen and pollution, there is still much to learn about their response to urbanization and how it impacts water quality within the Southern Appalachians. By sampling streams around the watershed we can assess the current state of stream water quality and predict how urbanization could impact community structures.

2. Methods

We sampled eight tributaries within the Swannanoa River basin, including four forested and four urban streams. The four forested sites were Burgin Cove, Flat Creek, North Fork and Camp Branch. Flat Creek is located in Montreat, NC and is covered by hardwood shade with shallow water. Burgin Cove is located towards the headwaters and lies next to rural housing with trees shading the stream. Camp Branch is a small shallow stream with little shade where we sampled. North Fork is located near a gravel quarry with shade cover. The urban streams include Sweeten Creek, Haw Creek, Grassy Branch, and Bee Tree Creek. Sweeten Creek is located within a heavily urbanized area and surrounded by asphalt. Both banks are heavily incised and the stream is somewhat shallow with gravel sediment covering the bottom.

Haw Creek is located behind a Lowe’s home improvement store and is filled with trash. The stream has shade cover and the bottom is covered in fine sediment. Grassy Branch is located close to a small urban area and next to a golfing range. The bottom was filled with soft sediment and embedded golf balls. Bee Tree Creek is located underneath a bridge and next to an open field on one side.

Dissolved oxygen and conductivity were measured using probes. We measured dissolved oxygen and conductivity once per site, taken between 6/5/2023-6/9/2023. We measured within the selected tributaries as well as the region where each tributary meets the Swannanoa River. In total we had 14 measurements for both conductivity and dissolved oxygen readings. We selected spots within each stream and within the Swannanoa that would allow the most accurate reading, so we chose areas deep enough to submerge the probe fully. The probes were submerged making sure to not touch the streambed with the probe to reduce interference. We held the probes in long enough to get a stable reading before recording the measurement. Measurement data were then used to construct a scatter plot comparing dissolved oxygen as a function of conductivity.

Two riffles and two pools were selected for each tributary site. For each riffle and each pool, we used a random number generator to determine the exact spot to sample from. We did this twice for each riffle and pool, totaling 8 samples per site. Macroinvertebrates were collected using a surber sampler, where larger stones were scraped into the net and removed from the sites briefly to expose the smaller stones. Sites were disturbed thoroughly for 2 minutes making sure to keep the net in front of the sample site. Nets were then filtered through a wire sieve and the samples were placed into jars filled with ethanol and covered. The jars were stored in a dark cool area until ready to sort through. Macroinvertberate were identified using a LICOR dissecting scope and keyed to family. Macroinvertebrate tolerance index values were used to find the FBIBI (Hillsenhoff 1988) for each site. Calculations were done using the Hilsenhoff Biotic Index method, and sample data were grouped together for each stream to find the average FBIBI per stream.

We performed an analysis of variance (ANOVA) on the 8 sites using the sample data to determine if there were significant differences in FBIBI among all sites. This was done in google sheets using the XLminer extension. If a significant difference was found, a T-test was performed to compare the means of each site.

3. Results

Chironomidae was the most commonly sampled macroinvertebrate family, although this differs between sites. Five sites were found to have Chironomidae as the most abundant macroinvertebrate with Grassy Branch(58.4%) followed by Burgin Cove (50.3%), North Fork (41.9%), Camp Branch (36.6%), and Sweeten Creek (27.9%). Hydropyschidae were more abundant at two sites including Bee Tree (48.1%) and Haw Creek (27.7%). Baetidae were most abundant at Flat Creek (26.4%). Oligochaetes were also found at every site but notably had high abundance within Grassy Branch (24.9%) and Sweeten Creek (19.4%) (Table 2).

Overall, urban sites had higher FBIBI compared to forested sites (Figure 1). Grassy Branch and Sweeten Creek had FBIBI values calculated at 7.72 and 6.63. Flat

Creek had the lowest FBIBI at 3.9. Burgin Cove, North Fork, Camp Branch, and Haw Creek were all within a small range (4.75-5.31).The ANOVA found that the means of all 8 sites were significantly different (P=0.004, df=7). Comparing sites revealed Flat Creek(p=0.006), Burgin Cove(p=0.006), North Fork(p=0.03), Camp Branch(p=0.018), Haw Creek(p=0.017), and Bee Tree(p=0.044) to have significantly different FBIBI than grassy branch. No sites were significantly different when compared to Sweeten Creek.

Flat Creek had both the lowest conductivity (17.19 ms/cm) and the highest concentration of dissolved oxygen (9.52mg/L). Camp Branch had the second lowest conductivity (32.5ms/cm) and the second highest dissolved oxygen concentration (9.38mg/L). Haw Creek had the highest conductivity (132.9) and the lowest dissolved oxygen concentration (8.29) (Figure 2, table 1)

4. Discussion

Some significant differences exist between sites, especially when comparing headwater forested streams to highly urbanized streams. Grassy Branch was the most different from all sites, being comparable only to Sweeten Creek . These two sites also had the highest FBIBI scores and abundances of tolerant macroinvertebrates. Oligochaetes and Chironomidae are both highly tolerant of pollution, which is also often a characteristic of urban streams. Bee Tree Creek and Haw Creek are urban sites with higher FBIBI than forested sites but were not significantly different when compared. The lowest FBIBI calculation came from Flat Creek at 3.9, indicating taxa with a wide range of tolerance and ecological niches representative of stream conditions. Flat Creek is one of the forested sites in the study closer to the headwaters**.** At this site, abundant large rocks cause rapid flowing riffles. Riffles are an important mechanism in adding oxygen to the water as flowing water “folds" on itself, trapping air as bubbles. In addition, plentiful rocky substrate provides habitat for dissolved oxygen sensitive macroinvertebrates**.**

The forested streams in the study were found to have a greater ratio of intolerant taxa and are able to support them due to high dissolved oxygen and low conductivity. Urban streams may be less capable due to a variety of factors impacting dissolved oxygen and conductivity. Bank development and runoff can increase erosion and pollution (Walsh et al. 2005) within the stream contributing to higher sedimentation, making environments less suitable for sensitive taxa.

Pollution and human activities contribute to homogenization of microhabitats and communities within streams by reducing habitat diversity. In “untouched” streams the river continuum (Vannote et al.1980) exhibits homogeneity at the highest and lowest order, however the stream is very diverse otherwise (Barnum et al. 2017). Within these streams native species were highly successful and population decline came from groups who already had a weak presence. For urban streams, the opposite is true. Human activity in streams damages structures such as woody debris, rock substrate, and morphology which decreases habitat quality and diversity. Increased pollution also pushes out intolerant taxa, decreasing the diversity of potential colonizers.

Urban sites likely suffer from stormwater runoff which contributes to pollution and exacerbates erosion (Chen et al. 2007 , Mallin et al. 2009). The banks feature little vegetation except within the riparian zone and the surrounding area is covered with concrete. This is most likely an issue for urban sites with high conductivity like Sweeten

Creek, Grassy Branch, and Haw Creek. Stormwater runoff into streams is intensified due to impervious surfaces and it can carry hydrocarbons and deposited sediments on the road (Chithra et al. 2015). High conductivity in these streams could be a result of the added pollutants which would impact water quality**.** Urban streams exhibit symptoms which reflect this condition, notably with the morphology of the bank and the stream. Sweeten Creek has steep deep banks which abruptly drop into the stream, which is shallow during low to normal flow. The morphology could suggest that during precipitation events high flow volume runs through the channel and likely enters as runoff.

The tributaries deliver sediment and pollution loads to the Swannanoa, the latter leading to a gradual increase in conductivity along the river downstream. At points corresponding to urban tributaries, the increase in conductivity for the Swannanoa was much higher than those from the upstream forested sites(table 1, figure 2). The difference might be impacted by the concentration of pollutants. Between the upstream tributaries and the corresponding Swannanoa sites the difference was very little, which could mean that the tributaries received less pollution from runoff. The forested sites in general had little human development within the stream and they did not run through heavily urbanized areas. The urban tributaries on the other hand suffer from bank erosion and potentially increased stormwater runoff as a result of human development around the area.

Stream chemical concentration is very dynamic and can change significantly through disturbance. dissolved oxygen and conductivity likely undergo changes in response to disturbance and may also fluctuate based on the time of the day, temperature, weather, climate, and flow volume. This study did not take periodic measurements of these variables and instead measurements were taken once before sampling. Having access to this information could reveal more about how urbanization impacts stream diversity and how streams react to disturbance. Specifically it could help determine if runoff or channel and bank erosion has more of an impact on the stream, and how the variables respond to changes in environmental factors.

L5. Conclusion

Forested and urban streams differ in many ways, and by using macroinvertebrates to test for FBIBI as well as environmental variables we have identified some key comparisons. Urban streams such as Grassy Branch and Sweeten Creek have high FBIBI calculations and high relative abundance of tolerant taxa indicating poor water quality. These sites were significantly different from both forested and other urban streams. Forested sites meanwhile had the lowest FBIBI and highest relative abundance of intolerant taxa and EPT. Conductivity and dissolved oxygen may have an inverse relationship and also influence stream communities. Urban streams had higher conductivity likely due to urban runoff picking up pollutants from impervious surfaces and depositing them into the stream. Dissolved oxygen was also lowest within urban streams when compared to forested streams. Forested streams might have more dissolved oxygen due to less urban runoff and large riffles which add greater amounts of oxygen to the water. This may help to foster a large abundance of intolerant taxa within forested streams and decrease FBIBI. Overall we conclude that urban streams have worse water quality than forested streams due to the differences in FBIBI, and that dissolved oxygen is negatively impacted by increases in conductivity stemming from runoff.

6. Figures and Tables

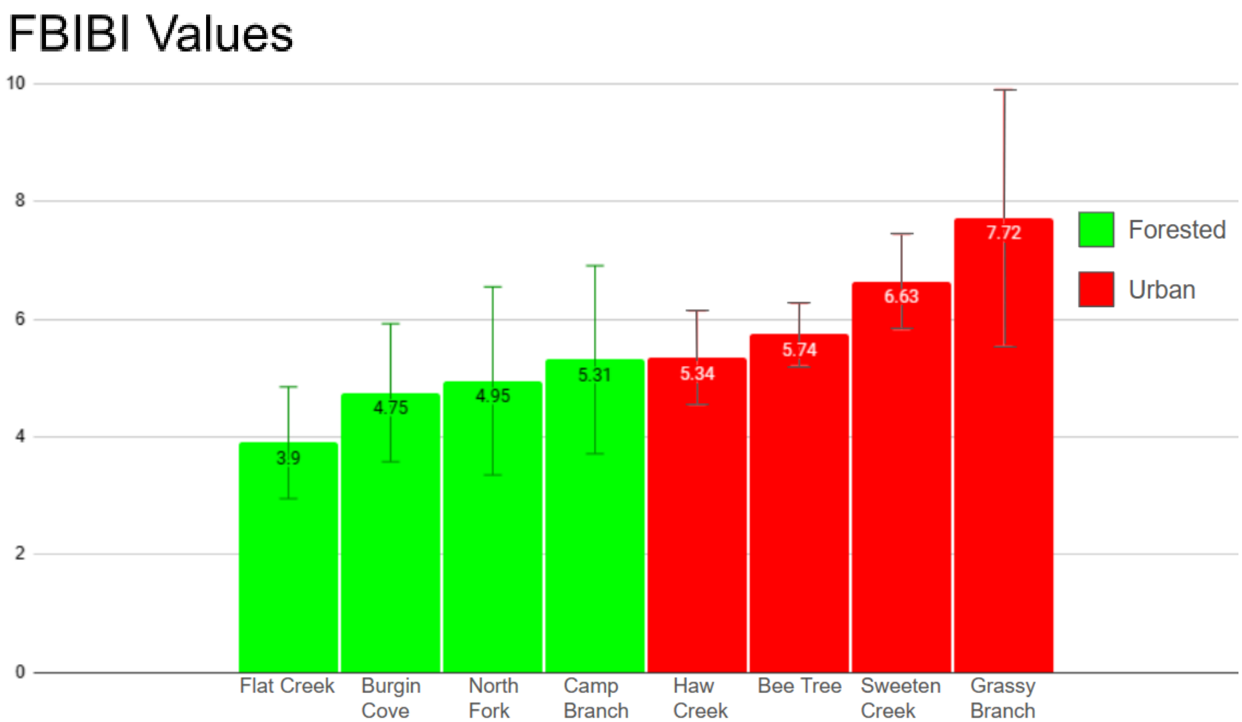

Figure 1: FBIBI sorted lowest to highest with standard error bars

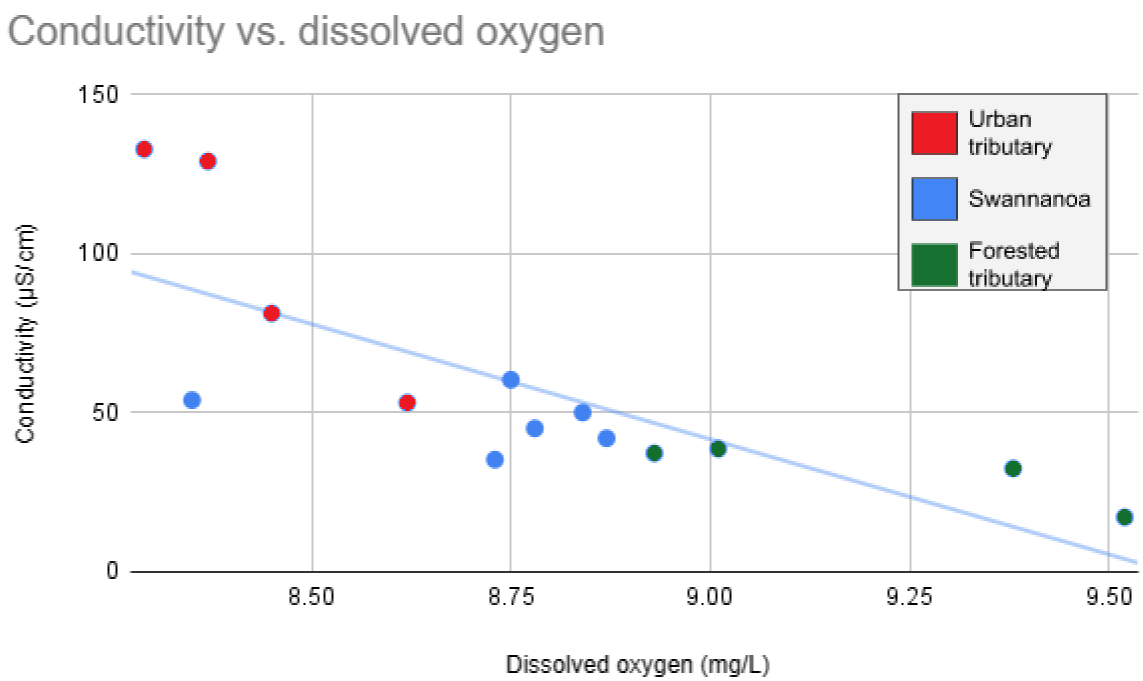

Fig 2. - Relationship between dissolved oxygen and conductivity for tributaries and Swannanoa River sites.

	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)
Sweeten Creek	8.37	129.1
Sweeten Creek Swannanoa	8.75	60.4
Haw Creek	8.29	132.9
Haw Creek Swannanoa	8.35	54.0
Grassy Branch	8.45	81.3
Grassy Branch Swannanoa	8.84	50.1
Bee Tree	8.87	42.0
Bee Tree Swannanoa	8.78	45.1
North Fork	8.93	37.3
North Fork Swannanoa	9.01	38.7
Burgin Cove	8.62	53.2
Black Mountain Swannanoa	8.73	35.3
Flat Creek	9.52	17.2
Camp Branch	9.38	32.5

Table 1. - Dissolved oxygen and Conductivity measurements for each tributary with corresponding measurements of the Swannanoa River where the tributary meets.

	Bee Tree	Camp Branch	Flat Creek	Grassy Branch	Haw Creek	North Forkl	Burgin Cove	Sweeten Creek
Tipulidae	5.13	5.40	1.52		8.21	4.30	1.59	4.79
Siphlonuridae				0.73				
Chironomidae	30.13	36.59	19.29	58.44	18.97	41.94	50.26	27.93
Leuctridae							0.53	
Leptophlebiidae		1.74	4.57			1.08		
Oligochaeta	5.13	8.36	3.55	24.94	9.74	2.69	4.76	19.41
Cyrenidae				0.24	1.03		1.06	
Pleuroceridae		0.17	1.02		0.51		1.59	
Chloroperlidae	0.32	4.88	17.77		1.54		7.41	
Elmidae		18.29	2.03		1.02		9.53	
Aeshnidae							0.53	
Baetidae	0.32	10.98	26.40	7.09	16.92	19.35	1.59	21.28
Dytiscidae							0.53	
Psephenidae	1.28	1.74	1.02		4.62			
Rhyacophilidae		1.22					1.59	
Heptageniidae	0.32	0.52			0.51	5.91		
Hydropsychidae	48.08	8.19		6.85	27.69	12.90	1.59	18.09
Perlodidae	0.32						4.23	
Haliplidae					0.51			
Nematocera			2.03	1.22			2.65	1.86
Perlodidae			15.74			0.54	3.70	
Perlidae	0.96	0.17	2.03			4.84		
Hydroptilidae	0.32					1.08		
Philopotamidae	3.21	1.74	2.03		1.03	0.54		0.53
Glossosomatidae							1.59	0.27
Simuliidae	4.17		1.02	0.49	7.69	3.76	5.29	5.85
Peltoperlidae	0.32							
Megaloptera						1.08		
Total	312	574	191	400	195	186	230	300

Table 2: Tributaries and the percent (%) composition each family contributes to the total number of individuals.

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8. References

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