Benthic macroinvertebrates used as a biomonitoring tool to assess Quittapahilla Creek water quality

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Introduction

Freshwater tributary streams are subject to anthropogenic contamination from a wide range of agricultural and urban sources. Anthropogenic factors that affect water quality cause ecosystems to degrade, with negative consequences to biodiversity. Humans use 70% of the global freshwater for agricultural purposes (Vitousek 1997). By-products from such land use include nitrogen deposits that can be up to 20 times higher in a river with human interaction than one under pristine conditions (Vitousek 1997). Increased nutrient and sediment pollution can lead to an increase in water turbidity. As surrounding areas get built-up, suspended solids and phosphates concentrations increase in nearby waterways. Heavy metal street surface contaminants are caused from urbanization of surrounding areas (Wanfelista 1977). Water quality can be affected by human pollution, non-biodegradable plastics and garbage that contaminate waterways. In urbanized parts of the world, quarry and mine runoff add hard water into freshwater ecosystems (Wang 2007).

Macroinvertebrate species can be used to indirectly measure water quality in rivers and streams (Lenat 1988). Biodiversity can be used as a sign of overall stream health. Poor water quality can be indicated by high populations of species with high tolerance levels, meaning that those species will thrive in a degraded environment (Lenat 1988). Macroinvertebrate orders Ephemeroptera, Plecoptera, and Tricohoptera are associated with good water quality (Wallace 1996). A correlation is present between indices of macroinvertebrates and overall stream health (Barbour 1996). Specific resource depletion increases with an increasing number of species in a community.

The Quittapahilla Creek (Quittie) cuts through the heart of Lebanon County, Pennsylvania. Spanning 35.4 miles from source to mouth, it deposits into the Swatara Creek, before emptying into the Susquehanna River, and eventually the Chesapeake Bay (Quittapahilla 2016). The Quittie flows throughout rural land, giving water to suburbanized land as it flows west. Storm drains flow into the body of water from the city of Lebanon, PA.

There are a number of potential pollutants in the Quittapahilla Creek. Local mining operations quarry for limestone and other natural minerals, creating wells that may contaminate water with runoff. In the more urbanized parts of Lebanon County, stormwater runoff may add contaminants such as heavy metals and oil. In the rural areas, agricultural runoff may flush nitrates from fertilizer use. Erosion of the Quittapahilla Creek banks adds sediments during heavy rainfalls due to the lack of vegetation in some of the surrounding areas (Newell 2004).

The Quittapahilla Creek received a Pennsylvania Department of Environmental Protection, Growing Greener Program Grant for a streambank restoration project to help improve water quality of creek. Restoration work was conducted at Quittie Creek Nature Park in Annville, PA from October 2014 through April 2015.

The objectives of this study are to analyze the benthic macroinvertebrate community both upstream and downstream from a Quittapahilla Creek streambank restoration site. We compared the communities before and after this project took place, to determine its impact on macroinvertebrates.

Methods

Sampling sites were chosen to match the sampling areas in the Fish and Boat Commission's in-stream physical habitat and fish cover monitoring report that was completed as an in-kind match towards the grant. The control site (40.3277 / -76.5005) was upstream of the treatment site (40.3288 / -76.5093); sampling at both sites occurred within swiftly moving riffles.

On September 7, 2015 a 500 nm surber net was used to collect macroinvertebrates from six different riffle sites. Three sites were located upstream of the Quittapahilla Creek streambank restoration project site and three sites were located downstream from the site. The collection process was repeated on September 14, 2015, yielding twelve collection sites total. The net was placed in a riffle and all material within one square meter of the front of the net was overturned and brushed with hands to collect all macroinvertebrates. The net was removed from the water, and collected organisms were placed in a jar filled with stream water. Upon returning to the lab, contents of the jars were sorted, and the macroinvertebrates were placed in vials of ethanol until identification could be conducted. Sites were also sampled twice, September 30, 2013 and October 3, 2013 before the restoration project began. Six samples were taken at each site on each day.

Using a dissecting scope and *Peckarsky's Freshwater Macroinvertebrates of Northeastern North America*, the collected macroinvertebrates were identified to the genus level where applicable. The data was organized in a spreadsheet, concurrent with data collected from the same sites in 2013. The macroinvertebrates were classified by feeding group, class, and tolerance level. Calculations for Family Biotic Index (FBI), Biotic Index (BI), Evenness, Species Abundance, Simpson's Dominance, Simpson's Density, Shannon-Weiner Index, and Coefficient of Community were performed.

The following equations were used to calculate each respective category

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

BI= $\Sigma (n_i \times a_i) / N$

Evenness= H' / H' max

Species Abundance= (# of individuals of species A) / (total # of individuals)

Simpson's Dominance= $\Sigma n_i(n_i-1) / N(N-1)$

Simpson's Density= 1- Simpson's Dominance

Shannon-Weiner Index= $- \Sigma (p_i \times \ln p_i)$

Coefficient of Community= $(2S_{ab}) / (S_a + S_b)$

Results

Table 1 shows the various taxa collected and the number of individuals for each taxa. Overall, the 2015 upstream site yielded 258 macroinvertebrate individuals while the downstream site yielded 359. In 2013, 393 and 334 macroinvertebrates were collected upstream and downstream, respectively. The total number of Hydropsychidae drastically increased over the two-year span, from 9% of the total organisms collected in 2013, to 65% of the total collected in 2015. In contrast, the Podinominae (a subfamily of the Chironomidae) population drastically decreased from 2013 to 2015, 59% to 10% respectively. There were considerably fewer

Planariidae collected in 2015 than in 2013. In 2013, 9% of organisms collected were identified as Planariidae, but that number dropped to just over 2% in 2015. Also of interest was the presence of two invasive species in the creek. The rusty crayfish, *Ocronected rusticus*, and the Asian clam, *Corbicula fluminae,* were found upstream and downstream in 2015. While the rusty crayfish was also common at both sites in 2015, the Asian clam was found only in the upstream site. Neither of these species were collected during the 2013 collections, however, Dr. Urban's Ecology class has frequently encountered the rusty crayfish and Asian clam throughout the Quittie since 2010.

In 2013, there were more taxa collected downstream as opposed to upstream (Fig 1). Although there were fewer taxa collected downstream in 2015 than in 2013, more taxa were collected in 2015 than in 2013 at the upstream site. In 2013, species evenness was higher at the downstream site than at the upstream site (Fig 2). This reversed itself in 2015, as the upstream site demonstrated a substantially higher evenness value than the downstream site.

Although the Biotic Index has increased both upstream and downstream since 2013, both numbers still equate to very good water quality, with little organic pollution (Fig 4, Table 2). The upstream site recorded a higher BI than the downstream site in 2015, opposite from what was observed in 2013. The same holds true for the Family Biotic Indices. The 2013 data show that the upstream site had a lower FBI compared to the downstream site (Fig 5). This flipped as well in 2013, with the upstream site showing a higher value than downstream. Both the 2013 and 2015 data show that the Quittie contains good water quality based on FBI recordings.

Collectors were the feeding groups that dominated the findings both upstream and downstream. The data show similar values at each site, with the exception of shredders. There was a considerably higher percentage of shredders downstream as opposed to upstream, whereas there were lower numbers of grazers and predators found downstream compared to upstream.

Discussion

Our macroinvertebrate data suggest a change in environmental conditions may have occurred from 2013 to 2015 both upstream and downstream of the streambank restoration project site. The biodiversity and evenness results showed a greater decline over the two-year period for the downstream site. While it is difficult to pinpoint a reason why these sites changed, it is possible that the act of restoring the banks may have had a short-term negative affect on the macroinvertebrate communities, due to a short-term increase in erosion caused by the construction process. We anticipate that the water quality will improve in the coming years.

Another possible explanation for the change in water quality is the difference in numbers of common invertebrates collected, specifically Hydropsychidae, Podinominae, and Planariidae. There were far fewer Hydropsychidae collected in 2013 than in 2015 and far more Podinominae. Podinominae prefer faster moving, cold water. While water temperature was not recorded in 2013 or 2015, it is possible that the creek water temperature increased, causing the number of Podinominae collected to drop significantly. The drop could also be explained by Podinominae emerging from the water at a difference times in 2013 compared to 2015 (Midges 2016).

There was a noticeable difference in the number of certain feeding groups collected between the upstream and downstream sites of 2015. Upstream of the restoration project was home to a large number of collectors with small numbers of shredders, grazers, and predators. Downstream, however, the percentage of shredders was much greater than upstream, with fewer predators and grazers collected. This could be explained by the amount of leafy coverage surrounding the creek at each site. There was much less canopy covering the stream and surrounding the banks at the upstream site compared to the downstream site, where there are many more trees shading the creek. The increased population of grazers upstream could be due to increased benthic algae, caused by more direct sunlight as a result of less canopy. The shredder population does as the name implies, and shreds leaf litter. More leaf litter would decrease the need to compete for resources, allowing for a larger percentage of the community to be made up of shredders.

Two invasive species were found in the Quittapahilla Creek, the rusty crayfish and the Asian clam. The rusty crayfish is native to the Ohio basin, but has expanded its range into 20 additional states, including Pennsylvania. It is hypothesized that such crayfish were once used in a home aquarium or for fishing purposes, and then either dumped or left within the tributary system of the Quittie. The Asian clam is native to Asia and Australia, and was first discovered in the United States in 1938. While they pose no predation threats, Asian clams have the potential to reproduce in large quantities and clog waterways due to their hermaphroditic nature (Sousa et al. 2008).

Overall the Quittapahilla Creek is in good health according to benthic macroinvertebrates. Although water quality was calculated to be slightly worse in 2015 than 2013, it is still very good with little organic pollution based on the Biotic Index (Table 2). We plan to continue to monitor the macroinvertebrate community to determine how it changes in the years following the restoration project. Future plans for research include monitoring the populations of invasive species, adding more sampling sites, and monitoring water temperatures at the time of sampling.

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Appendix

Table 1: The number of individuals for each taxa collected in 2013 and 2015 for both upstream and downstream sites.

Family	Genera	2013 Upstream	2013 Downstream	2015 Upstream	2015 Downstream
Asellidae	*Caecidotea*	21	34	33	9
Cambaridae	*Orconectes*	1	0	2	2
Chironomidae	*Parochlus*	0	0	29	36
Chironomidae	unidentified	207	152	0	0
Corbiculidae	*Corbicula*	0	1	1	0
Elmidae	*Microcylloepus*	0	1	0	0
Elmidae	*Optioservus*	0	0	12	4
Elmidae	*Stenelmis*	6	3	3	0
Ephemeroptera	*Centroptilum*	0	1	0	0
Ephemeroptera	*Siphlonurus*	0	1	0	0
Ephemeroptera	*Tricorythodes*	1	0	0	0
Ephydridae	unidentified	0	0	1	0
Gammaridae	*Gammarus*	8	37	6	47
Hydropsychidae	*Ceratopsyche*	0	6	0	0
Hydropsychidae	*Cheumatopsyche*	65	23	0	0
Hydropsychidae	*Hydropsyche*	46	27	152	248
Lumbriculidae	unidentified	0	11	7	3
Planariidae	unidentified	31	26	12	4
Simuliidae	*Simulium*	6	8	0	0
Tipulidae	*Antocha*	0	2	0	2
Tipulidae	*Prionocera*	0	0	0	3
Tipulidae	*Tipula*	1	1	0	1
Total Individuals		393	334	258	359
Species Richness		11	16	11	11

Table 2: Water Quality Based on Biotic Index (adapted from Hilsenhoff, 1977)

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.0	Very poor	Severe organic pollution

Figure 1: Species richness (# of taxa) for macroinvertebrate communities upstream and downstream of the stream bank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

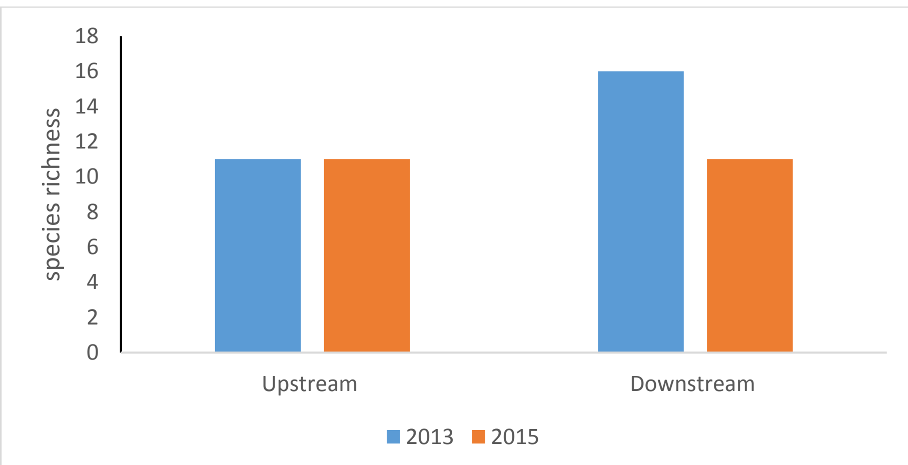

Figure 2: Species evenness for macroinvertebrate communities upstream and downstream of the stream bank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

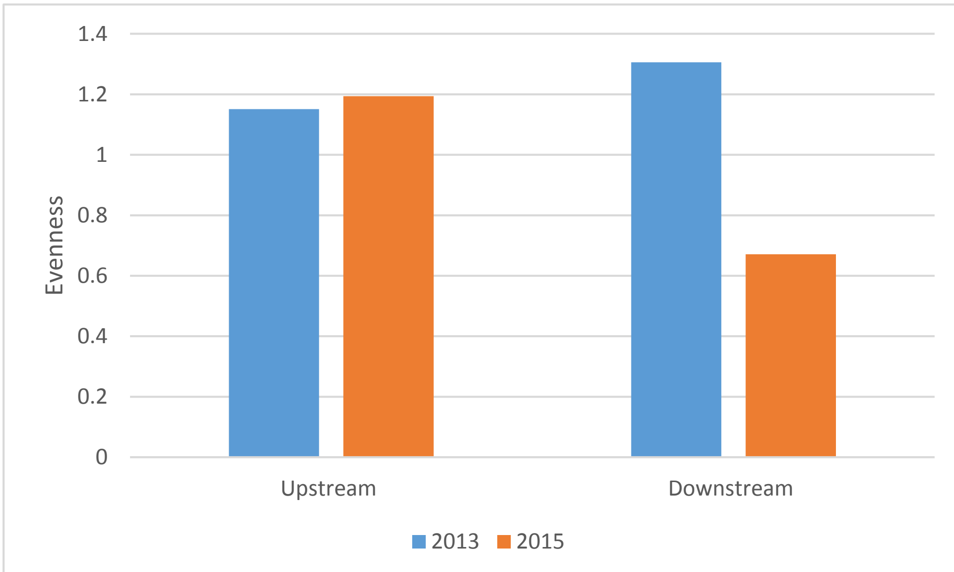

Figure 3: Shannon-Weiner Index of macroinvertebrate communities upstream and downstream of the stream bank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

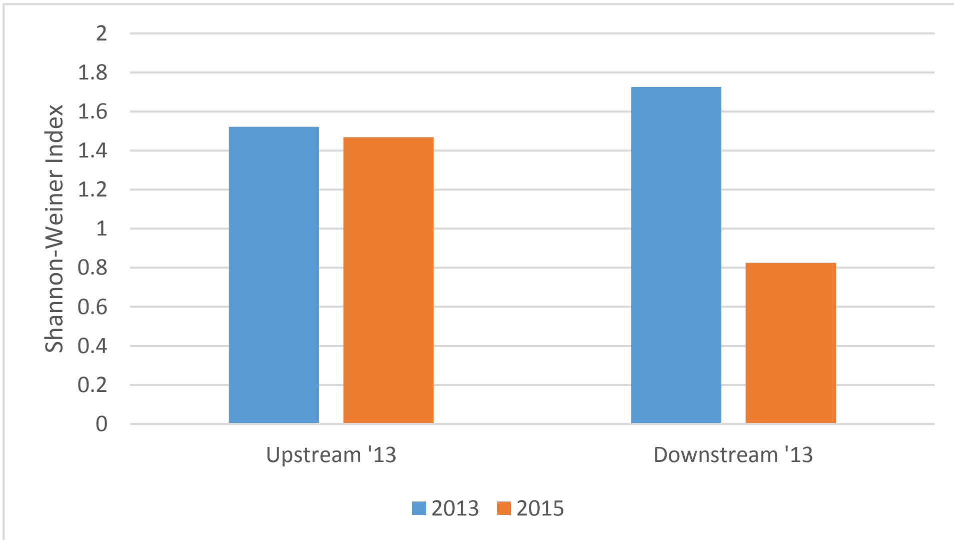

Figure 4: Biotic Index (BI) of macroinvertebrate communities upstream and downstream of the streambank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

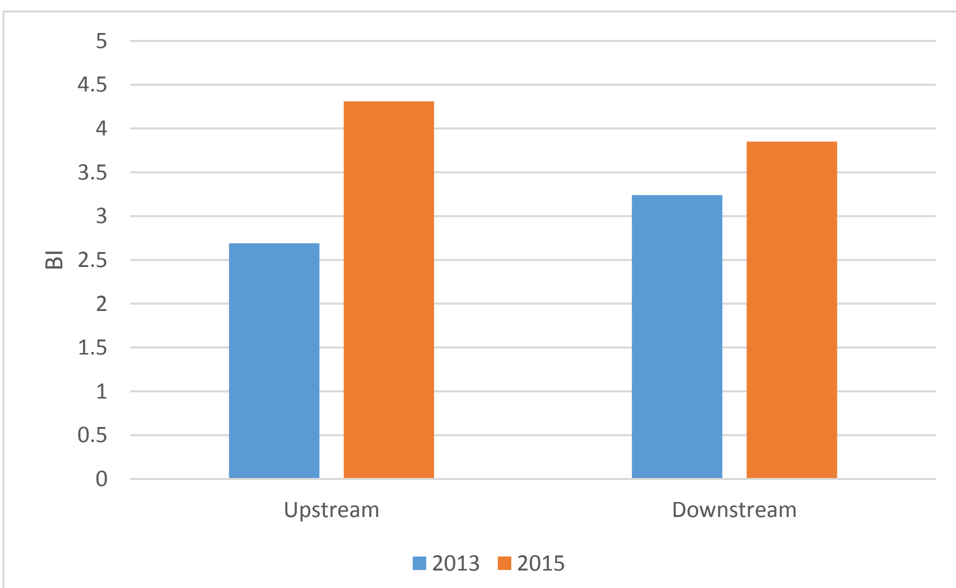

Figure 5: Family Biotic Index of macroinvertebrate communities upstream and downstream of the streambank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

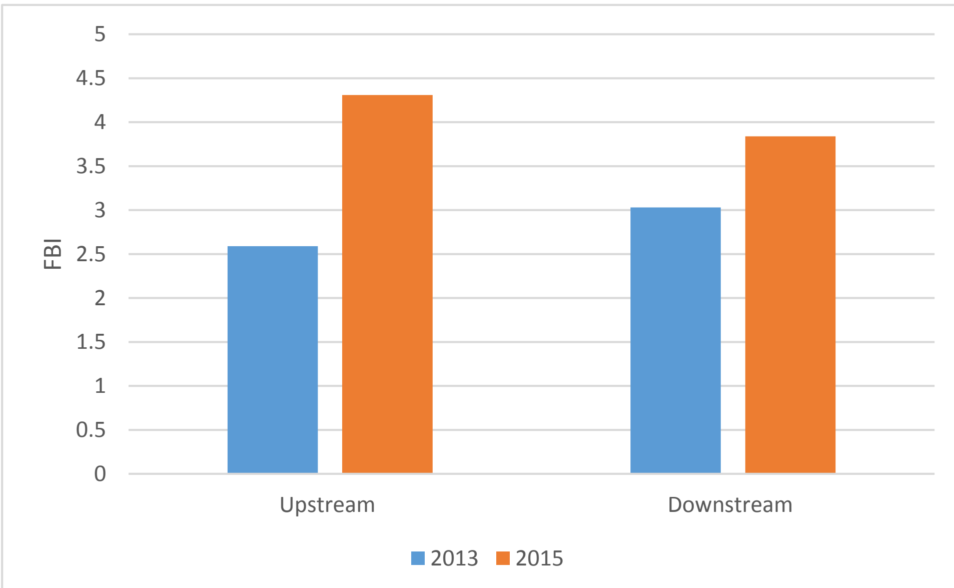

Figure 6: Simpson's Diversity of macroinvertebrate communities upstream and downstream of the streambank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

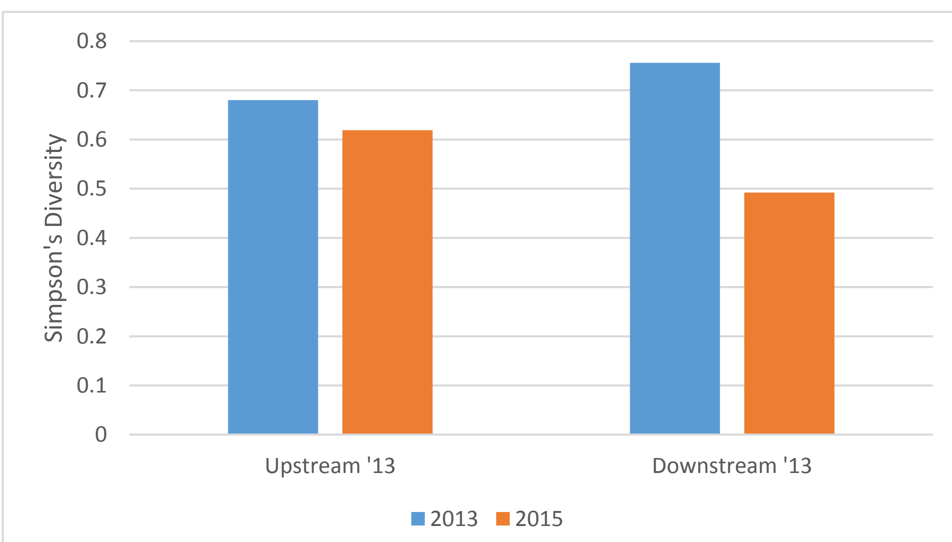

Figure 7: Simpson's D of macroinvertebrate communities upstream and downstream of the streambank restoration project. Blue bars indicate results before the project in 2013, while orange bars show results after the restoration project was completed in 2015.

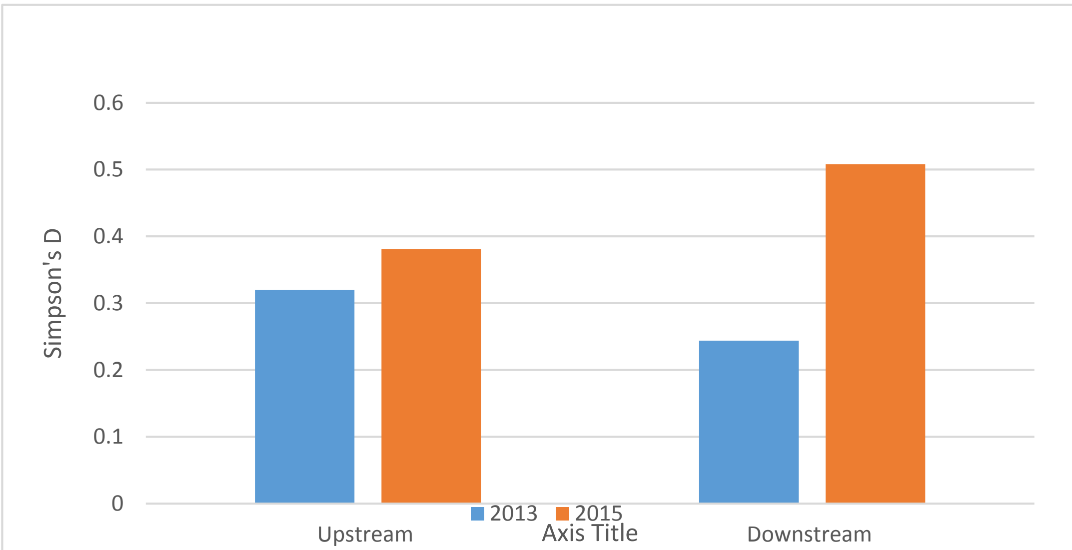

Figure 8: Percentage of macroinvertebrate feeding groups collected upstream from the stream bank restoration project in 2015.

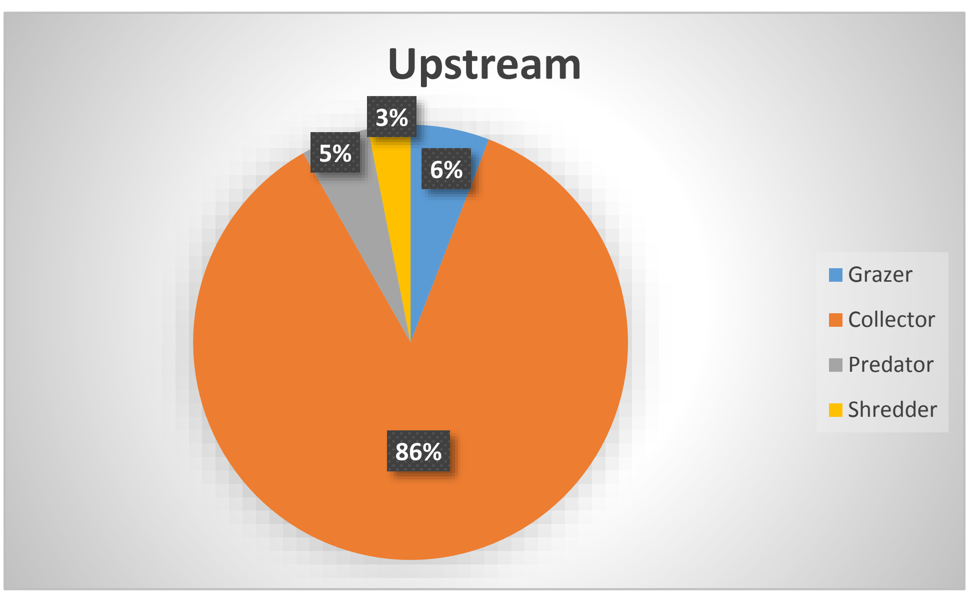

Figure 9: Percentage of macroinvertebrate feeding groups collected downstream from the stream bank restoration project in 2015.