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Understanding the Effect of Human Development on Nutrients and Biota in Carp Lake River and Little Black River

Abstract: Human development like agriculture and golf courses can have an effect on nutrients in streams, habitat structure, and macroinvertebrate diversity in rivers. We compared these variables in Carp Lake River and Little Black River, two northern Michigan rivers with different amounts of human development. We used bioassays to determine patterns of nutrient limitation in each river compared to nutrient samples at an upstream and downstream site within each river, mapped habitat, and sampled for macroinvertebrates at the mouth of each river. We found that, as we expected, limiting nutrients were more of a factor in Carp Lake River, likely because of agriculture and golf courses adding nutrients to Little Black River. Developmental impact was also indicated within Little Black River because of increased chloride levels compared to Carp Lake River. Habitat structure was influenced more by underlying geology than sedimentation due to development. Based on the EPT and Percent Diptera Indices of Carp Lake River and Little Black River, the water quality of Little Black River is lower relative to Carp Lake River. Our results suggested that proper management of agriculture and golf course land is important because both types of development can have adverse effects on water quality.

Growing human populations have had significant impacts on land use and development within watersheds. River habitats and biota diversity are strongly influenced by the amount and type of land use surrounding the river (Allen, 2004). Development can cause a change in the morphology of habitats and have a negative effect on the biodiversity (Allen, 2004). One of the biggest effects that development has on river habitats is nutrient loading, specifically nitrogen and phosphorous, which important nutrients but cause negative effects in excess (Kline and Morgan, 2011). Increased amounts of nutrients in rivers have been observed when land use intensifies within the watershed, and historically has been known to have a relation with source inputs of organic pollution, nutrient content, and river biota (Dodds et al., 1998). Biotic communities are altered when there are excessive levels of algae due to increased levels of nutrients within rivers (Dodds and Welch, 2000).

In areas with low development nutrients can be a limiting factor that influences river diversity. All organisms need nutrients, like nitrogen and phosphorous, to be able to grow and reproduce. When limiting nutrients are factors influencing a river the organisms do not acquire sufficient levels of nutrients and cannot survive (Tank et al., 2007). The traditional view of freshwater systems indicates that phosphorus limits primary productivity however current research and analysis supports the motion that both nitrogen and phosphorus limit primary productivity (Dodds and Welch, 2000). With limited nutrients and thus limited primary productivity biotic communities suffer due to primary producers being at the base of most food webs within rivers (Dodds and Whiles, 2010).

Macroinvertebrates are specifically affected by nutrient loading and limitation. More diversity and quantity of macroinvertebrates has been found in rural areas compared to urbanized watersheds (Smith and Lamp, 2008). Poor water quality along with habitat degradation contributes to the loss of the unique orders of macroinvertebrates common in undeveloped streams (Smith and Lamp, 2008). One way to determine poor water quality is by the use of an EPT (Ephemeroptera, Plecoptera, Trichoptera) index because these orders of macroinvertebrates do not thrive in polluted water (Kitchin, 2005). Another way to determine the degree of poor water quality is to use the percent Diptera index because the order Diptera are resilient and are adapted to cope with more than one extreme condition (Mathewes and Walker, 1987). Faria et al. (2006) were able to experimentally determine that Diptera were fit to thrive under poor water quality and contamination.

Agriculture is a type of development that has been found to have strong impacts on river habitats and biodiversity (Kline and Morgan, 2011). It is a necessity for society, and as a result the land around rivers has been shaped into open fields with insecticide, herbicide, and fertilizer

accumulations in the runoff (Kline and Morgan, 2011). For example, researchers in Maryland showed that agriculture occurring in the watershed increased total nitrogen and total phosphorous amounts in rivers (Kline and Morgan, 2011). Furthermore, water quality, habitat, and biological diversity of biota have been shown to decline when agricultural development increases due to insecticide and herbicide runoff containing toxic chemicals (Allen, 2004; Klein, 1990).

Golf courses are another example of development that can influence river habitats. Rivers and small streams add an aesthetic appeal to many golf courses which make them popular sites to use to shape the courses. The maintenance of fairways, greens, and tees can also contribute to the increased amount of nitrogen and phosphorous found in rivers due to runoff (Klein, 1990). Mankin (2000) found that how golf courses are maintained can have an effect on the amount of nutrients that are added to the runoff by using appropriate amounts of fertilizer and having proper, functional irrigation systems.

In learning that agriculture and golf course development had an effect on river systems we wanted to determine how much and what was most critically affected. We chose to survey two different rivers; Carp Lake River and Little Black River. Both rivers are a part of the Straits of Mackinac watershed. Carp Lake River was determined to be a second order river according to the Strahler stream order that flows into Lake Michigan. Little Black River is a third order river, determined by the same order system, flowing into Lake Michigan. Both rivers belong to the Straits of Mackinac watershed and their outlets are near the straits. Carp Lake River is generally undeveloped without any farmland, and the only type of development is a low budget golf course currently in the process of being sold. In contrast, Little Black River is highly developed flowing through multiple agricultural fields and a golf course that is currently played. The varying amounts of development should show contrasts between each river which would be important to

determine how development can affect a river. We chose to survey these two rivers because of the varying development between them and because both lead into two of the Great Lakes.

We expect to see agricultural and golf course development to have a negative effect on river nutrients, chemistry, habitat structure, and macroinvertebrate diversity. We hypothesize increased nutrient levels in Little Black River due to the amount of development along the river. The increased amounts of nutrients will indicate that Little Black River is not nutrient limited, but we predict that Carp Lake River will show signs of nutrient limitation. The higher intensity of development increasing the amount of sediment input (Sponseller et al., 2008) will have a significant influence on the habitat structure between the rivers resulting in Little Black River having finer substrates. Finally, we predict that Carp Lake River will host a more diverse and abundant macroinvertebrate community, higher EPT index, and a lower percent Diptera index in relation to Little Black River.

Methods:

Nutrient Limitation

To determine whether nutrients were limiting in either river, we constructed nutrient diffusing substrate bioassays following the methods of Tank et al. (2007). Each bioassay consisted of five replicates of four treatments, nitrogen addition (+N), phosphorus addition (+P), nitrogen and phosphorus addition (+NP), and a control with no added nutrients (C). We randomly assigned treatments to each metal bar to which they were attached. We deposited the bioassays into each river with rebar and zip ties on July 16, 2013. We then left the bioassays at each site for twenty days before collecting them on August 5, 2013. After they were collected the glass discs were taken to the University of Michigan Biological Station (UMBS) Chemistry Lab so the chlorophyll a on each disc could be analyzed.

To begin our analysis, we washed forty vials and corks with soap and water, then rinsed each with distilled water, and finally rinsed them again with acetone. We then labeled each vial with location and treatment, put in the corresponding glass disc from the bioassay, and filled them with ten milliliters of acetone using a pipette. We stored the vials overnight in the freezer to allow the acetone to extract the chlorophyll a from the glass discs. We analyzed the amount of chlorophyll a found in each vial using a spectrometer. To compare the values of the limiting nutrient data we individually ran a two-way ANOVA for each river, comparing the means of the nitrogen, phosphorus, and nitrogen and phosphorus treatments to the mean of the control. We used a one tailed two sample t-test assuming unequal variances to compare the control bioassays between both rivers to determine which river could support more periphyton growth under normal conditions.

Nutrient Sampling

To be able to compare our limiting nutrient data with the developmental effects of the rivers we also took nutrient samples. We used acid washed bottles to collect water samples from upstream and downstream of our bioassay site (Figure 1). CLR had a total distance of 9.07 miles between the upstream and downstream site. The total distance between the upstream and downstream sites of LBR was only 2.27 miles. We rinsed out each bottle three times with river water before filling them to the brim, and placing them on ice in a dark cooler. Water samples were also transported to the UMBS Chemistry Lab to be analyzed for total phosphorous (TP), soluble reactive phosphorous (SRP), ammonium nitrogen (NO4-N), nitrate/nitrite nitrogen (NO3-N), and chloride (Cl).

Chemistry, Discharge, and Light

We measured pH, conductivity, dissolved oxygen, water temperature, and air temperature. We used an Accumet AP Series Handheld pH/mV/Ion Meter to measure pH, a YSI salinity conductivity meter to measure conductivity and water temperature, and a YSI dissolved oxygen meter to collect dissolved oxygen measurements. We collected pH and dissolved oxygen measurements four times from CLR and five times from LBR. Conductivity measurements were gathered from CLR three times but collected from LBR four times. We used a two sample t-test assuming equal variances to compare conductivity, dissolved oxygen, and discharge between CLR and LBR. Additionally, we ran a two sample t-test assuming unequal variances to compare pH. We measured discharge on two separate occasions from each river using the HACH FH950.0 velocity meter. We averaged the two values for each river. On our last visit to both sites we decided take light irradiance measurements using a photometer from the surface and maximum depth of each river.

Habitat Mapping

We mapped habitat along a 100 meter transect downstream from our bioassay in each river to map the habitat without affecting our bioassay experiment. Along the transect we marked a cross section across the stream every 10 meters and recorded each wetted width at the 10 meter intervals. Along each 10 meter interval we used a 0.5 square meter quadrat in five locations across the stream. Within each quadrat we determined the depth, cover (presence/absence), periphyton index (scale 0-3; 3 being the most periphyton, Table 1), percent cover of each substrate type (clay, silt, sand, gravel, pebble, cobble, and boulder), percent cover of aquatic vegetation, percent cover of woody debris, and embeddedness (scale 0-5; 5 being least amount embedded, Table 2) With this data we were able to take an average of the percent cover for each type of substrate. To compare the depth, periphyton index, woody debris,

embeddedness, coarse substrate, and fine substrate between the two rivers we also used a two sample t-test assuming unequal variances.

Macroinvertebrates

Using the average percent cover of each type of substrate we were able to determine which substrates dominated each river and thus where to collect macroinvertebrates. We decided to collect from the three most dominant types of substrate from CLR and LBR. We collected from sand and gravel, pebble, and cobble in CLR and from clay, gravel and pebble, and cobble in LBR. We took five macroinvertebrate samples from each substrate type from both CLR and LBR searching through each sample for fifteen minutes. We sampled using shovels and sieves that had 1 millimeter mesh by shoveling equal amounts of each substrate and then filtering it through the sieve. When a macroinvertebrate was found it was placed in a whirl-pak containing 95% ethanol in order to be preserved before being identified to order and functional feeding group back in the lab. To compare the macroinvertebrate data of both rivers we used an EPT Index, Percent Diptera Index, and a Shannon Diversity Index. To determine the EPT Index we took the sum of all of the Ephemeroptera, Plecoptera, and Trichoptera and divided it by the total number of organisms collected from each river. We used similar methods to calculate the Percent Diptera Index but we only took the sum of the Diptera found in each river. To calculate the Shannon Diversity Index we took the sum of the proportion of individuals multiplied by the natural log of the proportion of individuals.

Results:

Nutrient Limitation

Our bioassay results suggest that primary producers in CLR were co-nutrient limited by both nitrogen and phosphorus while LBR was only nitrogen limited. In CLR the interaction term

(N+P) as well as the main effects of N and P were statistically significant in our two-way ANOVA (+N: F= 314.80, df= 1, p< 0.001; +P: F=56.03, df= 1, p< 0.001; +NP: F= 56.76, df= 1, p< 0.001). The most chlorophyll a on average was found on the nitrogen and phosphorus addition (10.01 mg/L) compared to the nitrogen addition (5.06 mg/L), phosphorus addition (1.69 mg/L), and control (1.70 mg/L) of the bioassays in CLR (Table 3). In contrast LBR was found to only be significantly limited in nitrogen while phosphorus and the interaction term (N+P) were not significant (+N: F= 5.36, df= 1, p= 0.034; +P: F= 2.81, df= 1, p= 0.113; +NP: F= 0.675, df= 1, p= 0.423). Within LBR there was on average more chlorophyll a found on the bioassays with nitrogen addition (1.75 mg/L) compared to the phosphorus addition (0.85 mg/L), nitrogen and phosphorus addition (1.19 mg/L), and control (1.70 mg/L) (Table 3). CLR had significantly more chlorophyll a on the control bioassays than LBR (t= 2.64, df= 8, p= 0.015).

Nutrient Sampling

The results from UMBS Chemistry Lab indicated that the CLR upstream site contained less nutrients except for chloride compared to the upstream site of LBR. Total phosphorus, soluble reactive phosphorus, ammonium, and chloride all decreased from the CLR upstream to downstream sites. Nitrate was the only nutrient that increased in abundance in CLR with distance downstream. Soluble reactive phosphorus was found in low abundance upstream and downstream of CLR with only a 0.1 difference between the sites. Total phosphorus, soluble reactive phosphorus, ammonium, and nitrate all decreased with distance downstream along LBR while chloride increased. Nitrate had the most drastic reduction in LBR with an abundance of 129.3 µg-N/L in the upstream site decreasing to 1.1 µg-N/L in the downstream site (Table 4).

Chemistry, Discharge, and Light

There was no significant difference in pH between CLR (8.69) and LBR (8.53) (t= -1.68, df= 5, p= .08, Table 5). There was a significant difference in conductivity between both CLR (415.65 µS) and LBR (303.47 µS) (t= 6.76, df= 4, p= <.001, Table 5). There was no significant difference found between the DO levels in CLR (9.94 mg/L) and LBR (9.28) (t= -0.65, df= 7, p= 0.27, Table 5). The difference in discharge between both CLR (21.68 m^3/s) and LBR (-1.03 m^3/s) was found to be significant (t= -4.30, df=2, p= 0.02, Table 5). The average water temperatures of both CLR and LBR were around 21°C and the average air temperature was 24.50°C for CLR and 22.80°C for LBR (Table 5). There was more light penetrating CLR than LBR indicated by our photometer readings. CLR had 86.31% of surface incident light reaching the maximum depth while LBR only had 18.92% of surface incident light reaching the maximum depth.

Habitat mapping

CLR varied in wetted with from 7.7 meters at the beginning of our 100 meter transect to 11.5 meters at the end which was different from LBR which had a range of 10.7 meters to 13.4 meters along the entire transect. The average depth along the entire CLR transect (0.30 meters) was significantly shallower than the average depth of LBR (0.69 meters) (t= 12.74, df= 92, p= <0.001, Figure 2). The periphyton index mean of CLR (2.7) was found to be significantly higher than the mean periphyton index of LBR (1.35) (t= -11.23, df= 91, p< 0.001, Figure 3). Both streams varied in substrate cover with CLR containing more sand, gravel, pebble, and cobble and LBR consisting of more clay substrate (Figure 4). The mean amount of coarse substrate was significantly higher in CLR (0.897) compared to LBR (0.312) (t= -12.22, df= 81, p< .001, Figure 5). There was significantly less fine sediment found in CLR (0.112) than in LBR (0.688) (t= 11.9, df= 80, p< 0.001, Figure 6). When comparing the degree of embeddedness between the

rivers we found that CLR (3.85) was significantly less embedded than LBR (1.68) ($t= -9.40$, $df= 77$, $p< 0.001$, Figure 7). CLR contained on average significantly less aquatic vegetation (0.002) than LBR (0.172) ($t= 6.71$, $df= 54$, $p< 0.001$, Figure 8). The amount of woody debris in each river was the only aspect of each habitat that was not found to be significantly different ($t= 0.86$, $df= 77$, $p= 0.20$, Figure 9).

Macroinvertebrates

We sampled a total of 303 macroinvertebrates from CLR while only 98 total macroinvertebrates were colleced from LBR. The most abundant order of macroinvertebrate found in CLR was Trichoptera (73%) while the most abundant order in LBR was Diptera (78%) (Table 6). CLR had a lower abundance of Diptera (14%) while LBR had a drastically lower abundance of Trichoptera (1%). Both CLR and LBR had their most abundant order collected from the same type of substrate, cobble (Figure 10 and Figure 12). There was a lower abundance of Ephemeroptera found in CLR (3%) relative to LBR (7%) (Table 6). A higher abundance of Plecoptera were found in CLR (2%) compared to no Plecoptera being present in LBR (Table 6).

The most prevalent functional feeding group collected from CLR were scrapers (72%) while the most abundant functional feeding group sampled from LBR were gathering collectors (86%) (Figure 11 and Figure 13). Gathering collectors were found to be the second most abundant feeding group found in CLR (20%) while scrapers were found to be the second most prevalent feeding group in LBR (9%) (Figure 11 and Figure 13). The rest of the feeding groups found between the two rivers were filtering collector, filtering feeder, shredder, and predator (Figure 11 and Figure 13).

Diptera were found to be more abundant in LBR (68%) compared to CLR (14%) it resulting in a higher Diptera Index for LBR (Table 7). The higher abundance of Ephemeroptera,

Plectoptera, and Trichoptera in CLR (78%) relative to LBR (7%) resulted in a higher EPT Index for CLR (Table 7). The Shannon Diversity Index for both rivers was found to be quite similar with a value of 1.11 for CLR and 1.10 for LBR (Table 7).

Discussion:

LBR showed indications of being impacted by development based primarily on high levels of nutrients including chloride along with high conductivity, the low nutrient limitation, according to our bioassays, and a low EPT index when compared to CLR. Chloride levels increased between the upstream (6.6 mg/L) and downstream (29.8 mg/L) sites of LBR, which happened to be the only nutrient to experience an increase within LBR. Morgan et al. (2012) found that chloride was a major contributor to conductivity in rivers in Maryland being affected by road density within the watersheds. When comparing the conductivity of CLR to LBR the results show that conductivity was lower in CLR which also contained less chloride leading us to believe that chloride was a contributing factor to the high conductivity of LBR.

We suspect that the differences in discharge between LBR and CLR affected the nutrient retention and export within each reach, with a lower discharge increasing retention in LBR compared to CLR based on the discharge data we collected. Nutrient retention and export in rivers can be described as a nutrient spiral as nutrients are cycled downstream as a result of net downstream flow (Dodds and Whiles, 2010). This spiral can be affected by the abiotic and biotic characteristics of the river. For example, the length of the nutrient spiral should be longer in rivers with greater discharge, decreased uptake rates, increased disturbance of benthic zone, and insect drift (Dodds and Whiles, 2010). Discharge was, on average, negative in LBR (-1.03 m^3/s) indicating a very low flow rate and at times stagnant water. In contrast, CLR had an average positive discharge (21.68 m^3/s) which resulted in a continual flow of steady velocity. The low

discharge in LBR indicated a short nutrient spiral, whereas CLR discharge suggested a longer nutrient spiral than LBR.

The rate at which nutrients spiral downstream is important because it allows for a comparison of how nutrients are retained among different rivers with different watershed landuse (Dodds and Whiles, 2010). The shortened nutrient spiral in LBR as a result of low discharge likely explains the sharp decline in nitrate concentrations (128.2 μg/L) from upstream to downstream reaches in contrast to CLR which increased in nitrate from upstream to downstream (32.9 μg/L). The associations between nitrogen concentrations and discharge can be strong (Marcé and Armengol, 2009), and concentrations of nitrate have been found to be significantly higher in agricultural rivers (such as LBR) compared to undeveloped rivers (such as CLR) (Mulholland et al., 2008). In association with nitrate concentrations the rate of total nitrate uptake has been shown to be greater in agricultural rivers suggesting that higher nitrate concentrations stimulates uptake in these rivers (Mulholland et al., 2008). The short nutrient spiral, high retention rate of nutrients, and agricultural development of LBR allowed for nutrients, especially nitrate, to be assimilated faster and more frequently which explains the large decrease in nitrate we found between the upstream and downstream sites, and indicates that nitrate input from agricultural development likely stimulated production in LBR.

The nitrogen limitation in LBR suggested by our bioassay results (Tank et al., 2007) also supports the idea that nitrate is being taken up at a high rate in LBR. We observed an abundance of aquatic macrophytes at our lower LBR site that were able to grow despite the high turbidity of the water that likely negatively affected the growth of periphyton on our bioassays. The limitation in LBR was not great because there was not a large difference between the amounts of chlorophyll a on the nitrogen addition (1.74 mg/L) compared to the control (1.06 mg/L) (Table

3). We found that the amount of chlorophyll a was lower on our control glass discs in LBR relative to CLR indicating that even though CLR was co-nutrient limited more periphyton was able to grow without the aid of added nutrients relative to LBR (Table 3). The fact that there was more growth on the control bioassay from CLR compared to LBR indicated that there were confounding factors, like the amount of fine sediment and availability of light, influencing the amounts of chlorophyll a on our bioassays because both nitrogen and phosphorus were limited in CLR and there were increased amounts of nutrients in LBR.

The greater proportion of fine substrate in LBR relative to CLR could be attributed to both underlying geology and developmental effects influencing the degree of embeddedness of each river. We found coarser substrate in CLR, and after surveying LBR we determined that there was a majority of fine substrate, specifically clay. A surficial geology map of Michigan from the Great Lakes Ecological Association (1982) suggested that LBR is underlain by lacustrine clay and silt. Clay is a fine particle substrate that can explain the high embeddedness we found in LBR relative to CLR. Wood and Armitage (1997) describe three phases of sedimentation resulting in embeddedness: during the first phase coarser particles close gaps and crevices, then medium sized particles fill in smaller crevices, finally the finer particles accumulate closing off surface and subsurface layers. Increased levels of development also increase sediment inputs in rivers which can alter substrate characteristics (Sponseller et al., 2008). Because LBR has both a high degree of agriculture, runs along and under many roads and through a golf course, we suspect some of the embeddedness we detected was due to development. With the underlying geology of LBR we cannot confirm that the embeddedness was due solely to the increased amounts of development.

The confounding factors of underlying geology and differences in discharge that influenced our bioassays had a similar role in affecting the periphyton index of CLR and LBR. Periphyton relies on light availability, nutrients, and substrate in order to grow and thrive (Dodds and Whiles, 2010). In contrast to our hypothesis periphyton index was higher in CLR compared to LBR. We initially assumed that increased nutrients resulting from increased development in the watershed of LBR would result in increased periphyton growth. However, we did not take into account the effect of the predominance of clay in the substrate of LBR. The clay in LBR caused constant turbidity in the river, reducing light penetration available for periphyton growth. In fact, only about 19% of incident light reached the substrate at maximum depth (~0.54 meters) in LBR compared to 86% of incident light reaching at maximum depth (~0.25) in CLR. Periphyton growth is primarily light limited; for example Cashman et al. (2013) also found that the biomass of periphyton in a river was heavily reliant on light availability. Because LBR contained more nutrients, except for nitrate at the downstream site, and was not as nutrient limited compared to CLR, we concluded that it was light rather than nutrients, limiting periphyton growth and the results from our bioassay controls. In addition to simply limiting light, fine sediment can affect periphyton, in a variety of ways including reducing the organic content of periphyton cells and preventing attachment by smothering (Wood and Armitage, 1997). Because of the underlying clay geology increasing the turbidity of the river and affecting periphyton growth and consequently our index we cannot link the periphyton index of LBR to agriculture and golf course development in the watershed.

The macroinvertebrates sampled from LBR indicate affects from development on water quality relative to CLR. It has been found that the quantity of macroinvertebrates in rivers decreases with increased land use (Sponseller, 2008). We found almost twice as many

organisms in CLR compared to LBR. As expected we found a higher percent of Diptera within LBR because Diptera, specifically the Chironomids we found, utilize fine substrate to construct cases and tubes (Wood and Armitage, 1997). More importantly our EPT index of CLR was much higher than that of LBR because it can be used to assess river water quality since the orders of species are hypersensitive to pollutants, indicating that a lower EPT index may be a result of impacts by development (Kitchin, 2005). Based on our EPT index results we can conclude that the water quality of CLR is better than that of LBR because of the higher index of CLR. We cannot conclude that the difference in water quality was due to development because of the confounding factors of the clay geology and turbidity. The most interesting aspect of our macroinvertebrate data came from our Shannon diversity index. Even though the percent Diptera and EPT index were higher for LBR and CLR respectively the diversity found within each river did not vary by much. The EPT index indicated that water quality was lower in LBR, but whether it was due to development or the confounding factors the diversity of LBR was not different from that found in CLR.

We can conclude that development has had some impact on LBR compared to CLR because of the increased chloride levels, bioassay nutrient results, and the EPT and Percent Diptera Indices. The underlying geology of LBR and light availability were confounding factors that could have had a greater effect on our bioassays, periphyton index, and macroinvertebrate data than development. We were confidently able to determine that CLR was co-nutrient limited while LBR was only nitrogen limited based on our bioassays. We were unable to conclude that the increased amount of nutrients due to agriculture and golf course runoff had a significant effect in LBR compared to CLR based on the growth found on the control bioassays. We believe the lacustrine clay and silt substrate of LBR influenced the amount of growth on the control

bioassays and also our periphyton index more than development. Using the EPT and Percent Diptera Indices we can conclude that the water quality of LBR is less than that of CLR but it is uncertain whether that is due solely to development or was also influenced by the underlying geology. More research is required to determine significant impacts due to development on LBR compared to CLR. It is known that cropland found in agricultural areas can add as much as 184 lb/acre/yr of nitrogen and 80 lb/acre/yr of phosphorous to rivers in the area. Golf courses can have a bigger impact on the watershed because the greens alone can add 213 lb/acre/yr of nitrogen while the fairways and tees can add around 150 lb/acre/yr of nitrogen. Greens were found to only add 44 lb/acre/yr of phosphorous but around 90 lb/acre/yr of phosphorous added to the watershed by the fairways and tees (Klein, 1990). Considering our results with this given data it is hard to say that LBR was not experiencing some impact from the surrounding agricultural land and golf course relative to CLR.

Figure 1: Map of our upstream and downstream sites of both Carp Lake River and Little Black River.

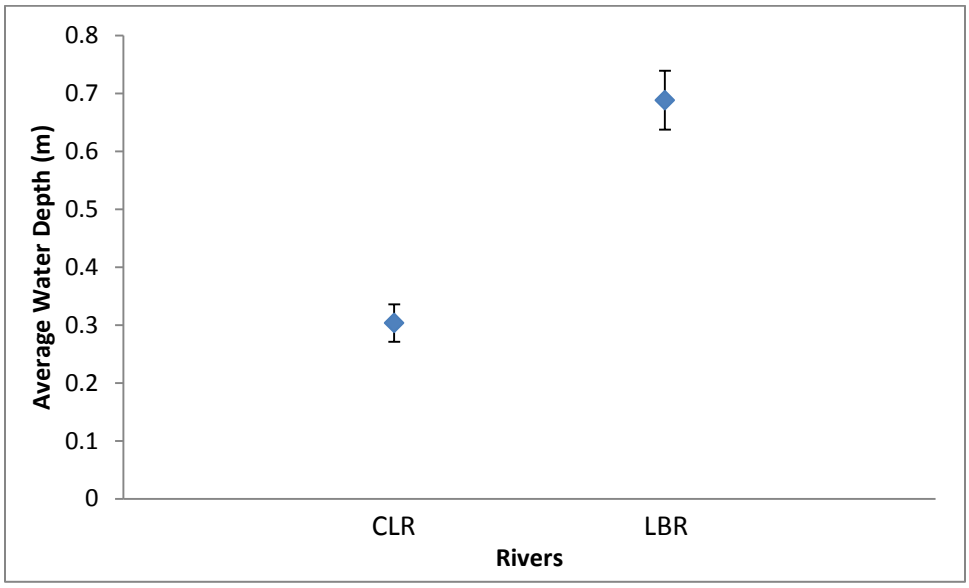

Figure 2: Average water depths of CLR and LBR. CLR is significantly shallower than LBR (t= 12.74, df= 92, p= <.001). Error bars show two standard errors from the mean.

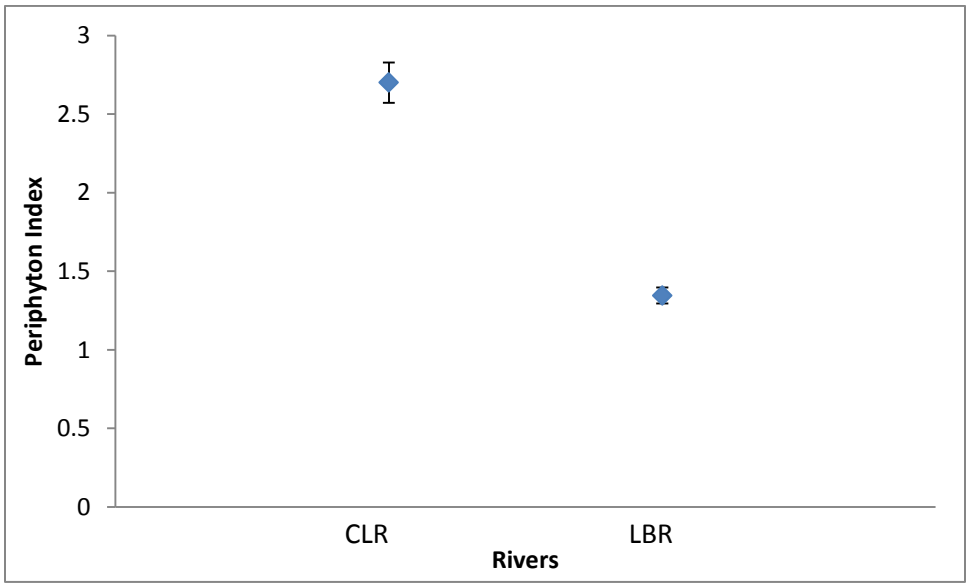

Figure 3: Periphyton Index for CLR was found to be significantly higher (Scale 0-3) relative to LBR (t= -11.23, df= 91, p< .001). Error bars show two standard errors from the mean.

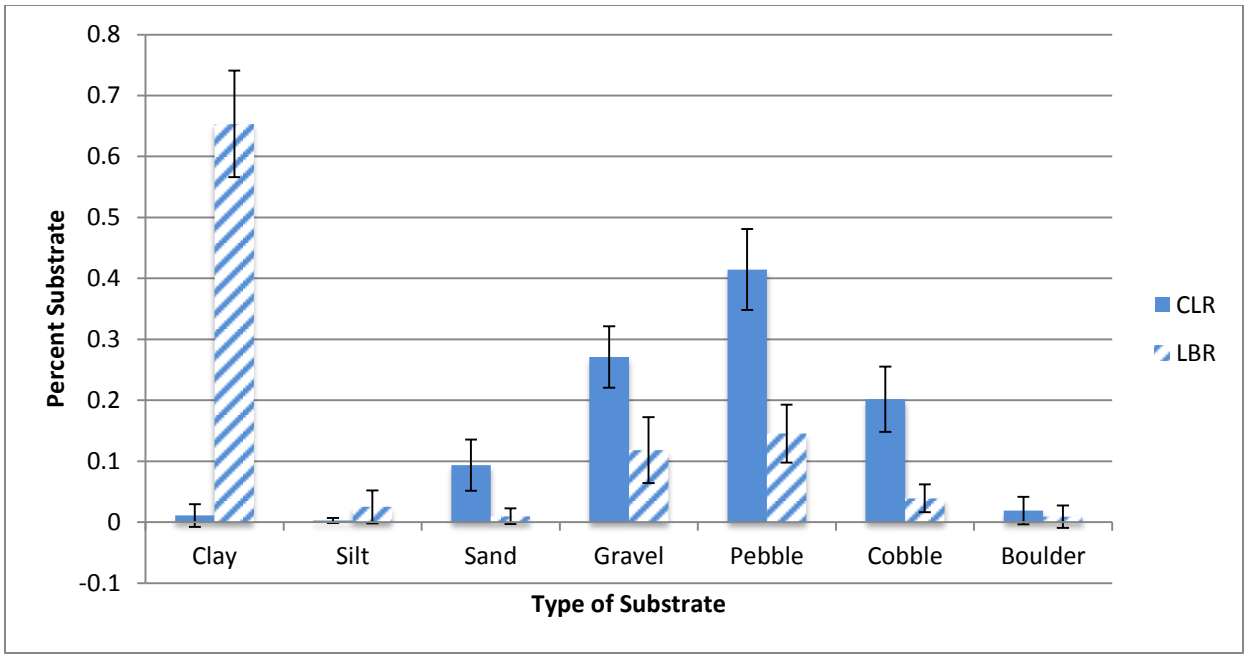

Figure 4: Percent Substrate Cover. CLR does not have nearly as much clay as LBR and contains more coarse sediment like gravel, pebble, and cobble. Both CLR and LBR have similar amounts of boulder. There appears to be significantly more sand in CLR than LBR according to the standard error bars.

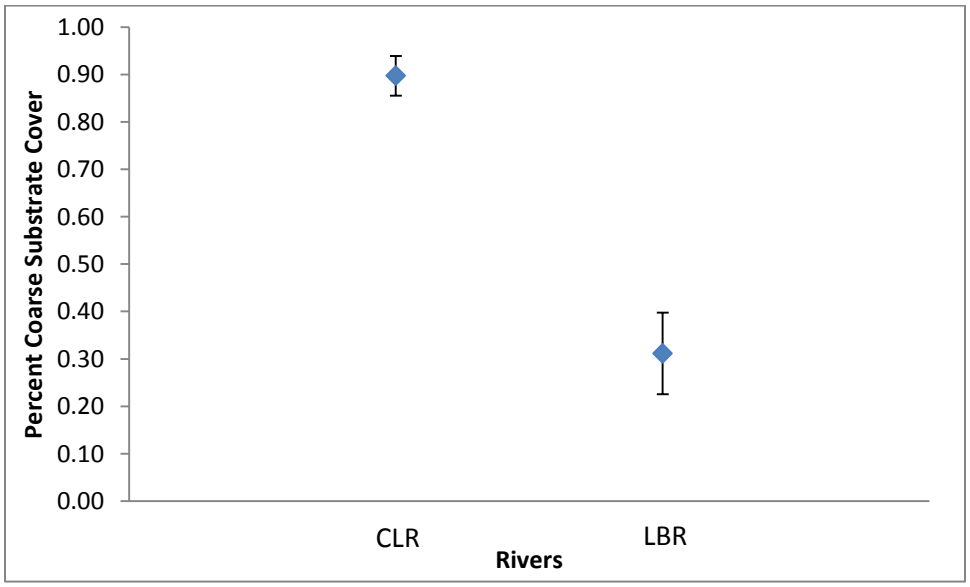

Figure 5: Percent of coarse substrate cover was significantly higher in CLR compared to LBR (t= -12.22, df= 81, p< .001). Error bars show two standard errors from the mean.

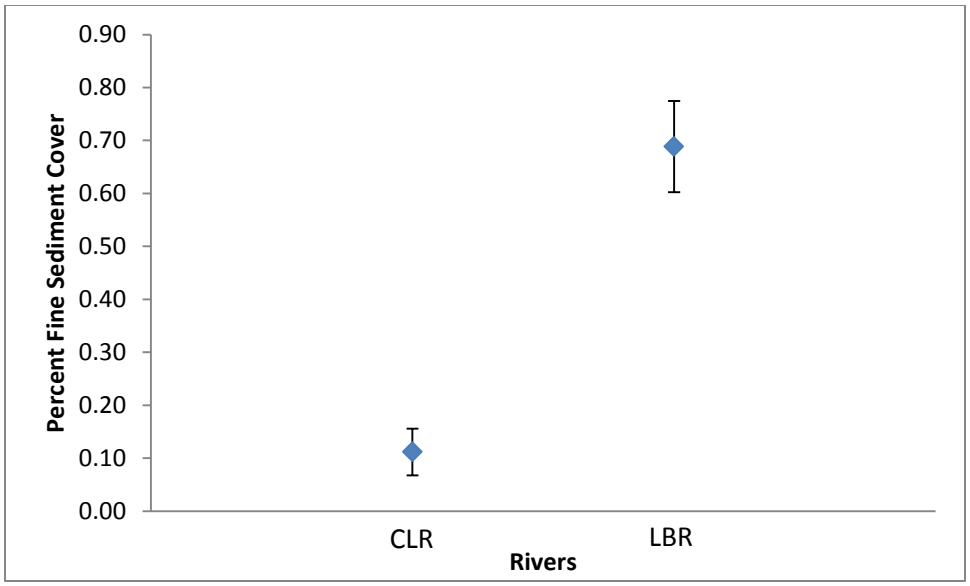

Figure 6: Percent fine substrate cover in CLR was significantly less than LBR (t= 14.40, df= 59, p< .001). Error bars show two standard errors from the mean.

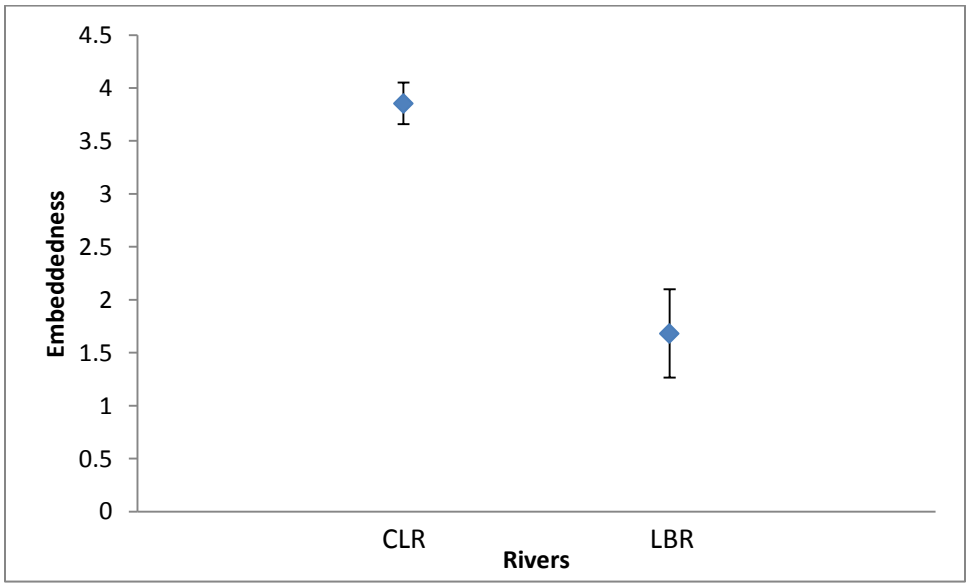

Figure 7: Embeddedness was significantly lower in CLR compared to LBR (Scale 1-5) (t= -9.40, df= 77, p< .001). Error bars show two standard errors from the mean.

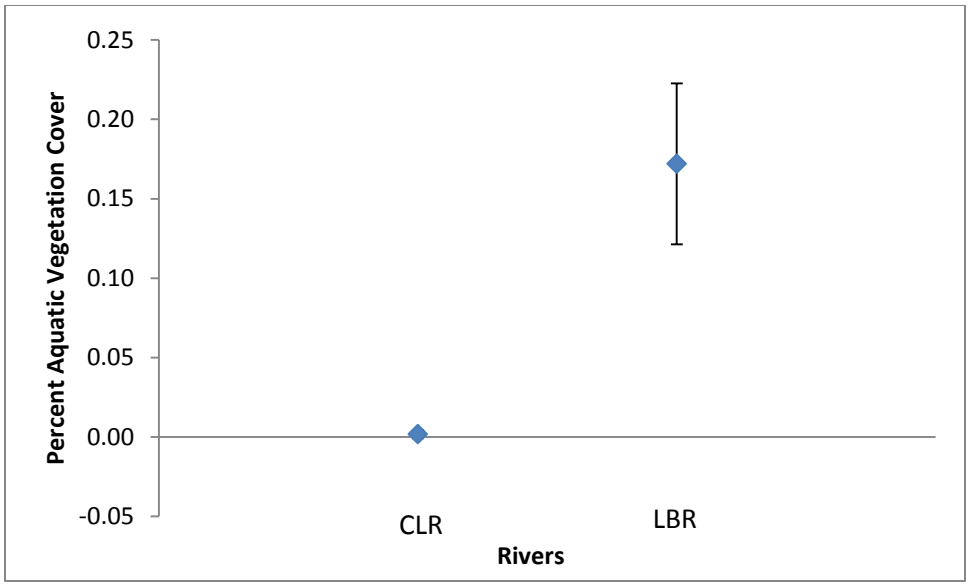

Figure 8: Aquatic vegetation cover was significantly lower in CLR relative to LBR (t= 6.71, df= 54, p< 0.001). Error bars show two standard errors from the mean.

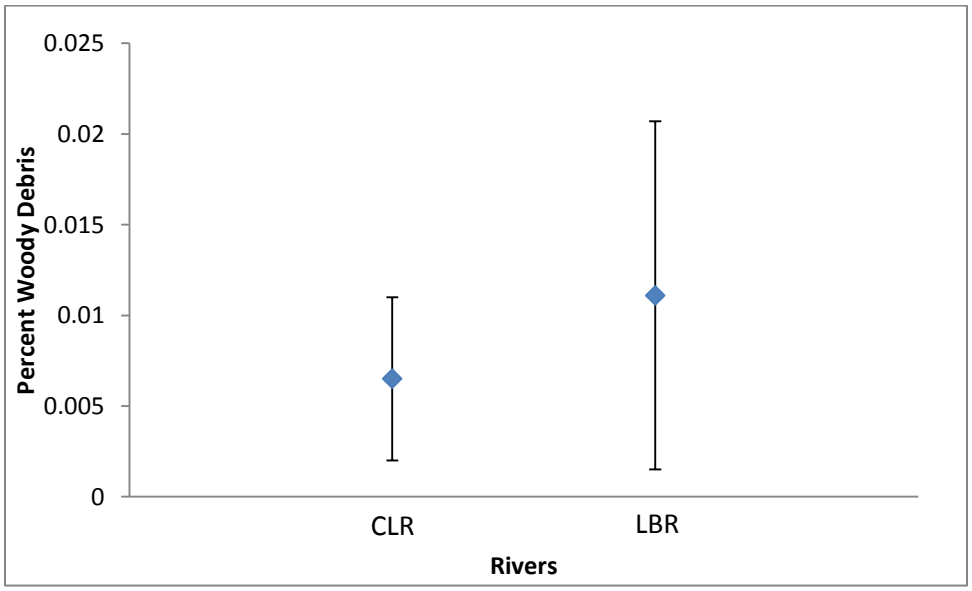

Figure 9: Percent of woody debris was not found to be significant in either CLR or LBR (t= 0.86, df= 77, p= 0.20). Error bars show two standard errors from the mean.

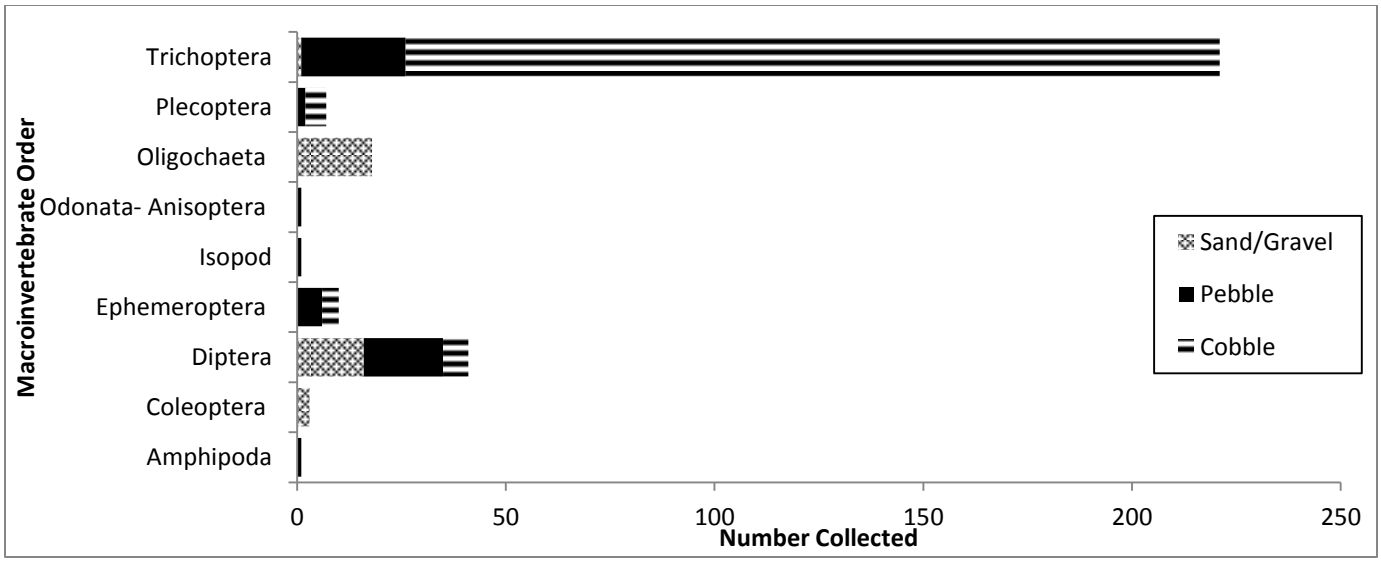

Figure 10: Amounts of macroinvertebrates found in CLR according sampled substrate types. Cobble contained the most macroinvertebrates and the majority collected was Trichoptera. The least amount of macroinvertebrates collected was from the sand/gravel substrate. Similar amounts of Diptera were found in sand/gravel and pebble. Ephemeroptera, Plecoptera, and Trichoptera were all found in CLR.

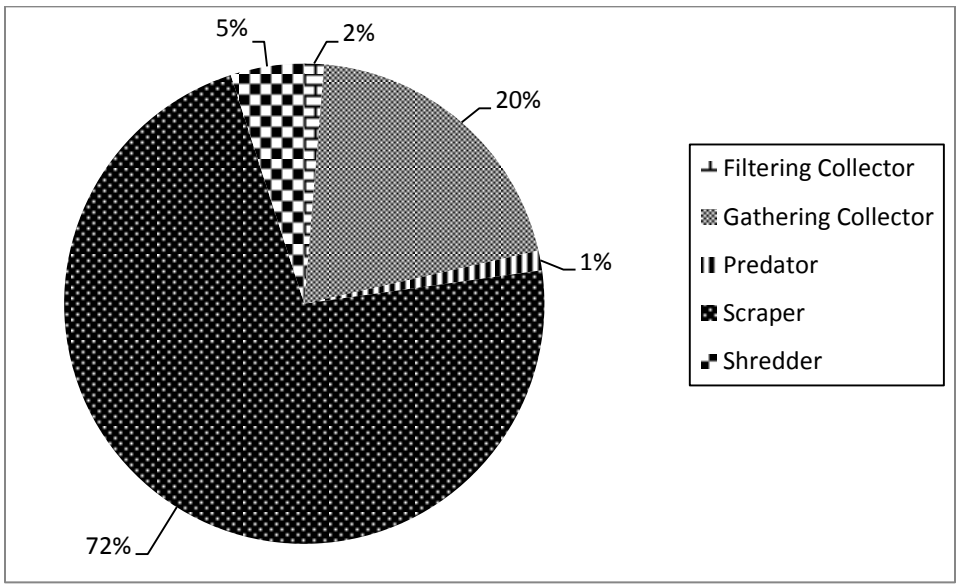

Figure 11: Proportions of functional feeding groups of CLR. Seventy two percent of the macroinvertebrates found were scrapers which were the most abundant. Gathering collectors comprised twenty percent of the macroinvertebrates. Predators, shredders, and filtering collectors were also found but consisted of less than or equal to five percent of the macroinvertebrates.

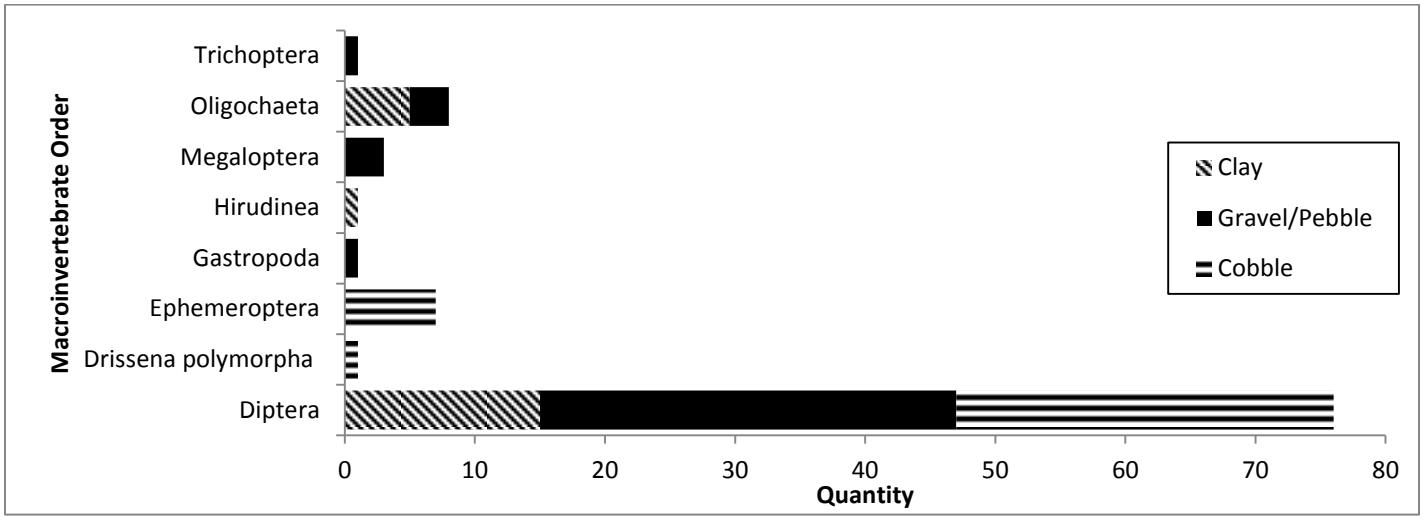

Figure 12: Amounts of macroinvertebrates found in LBR according sampled substrate types. The most macroinvertebrates were collected from gravel/pebble with a majority of them being Diptera. Similar amounts of Diptera were found in the cobble substrate as the gravel/pebble substrate. Clay contained the least amount of macroinvertebrates. Ephemeroptera and Trichoptera were found but no Plecoptera.

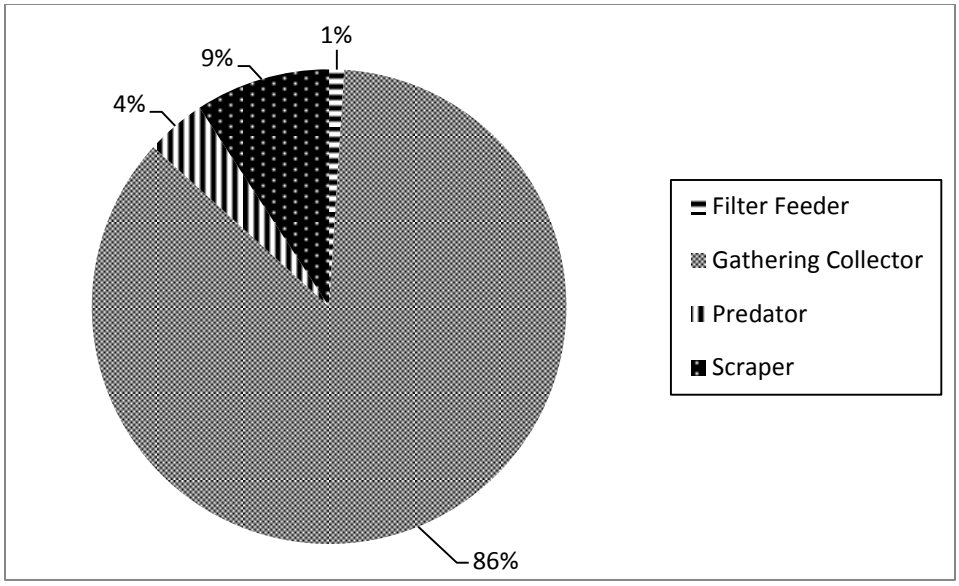

Figure 13: Proportion of functional feeding groups found LBR. Gathering Collectors were the most abundant functional feeding group found in LBR with eighty six percent of the macroinvertebrates collected belonging to this group. Scrapers only consisted of nine percent of the macroinvertebrates, and the only other two groups found were predators and filter feeders which comprised of less than five percent of the macroinvertebrates.

0	Rocks feel smooth with no "sliminess"
1	Rocks feel slimy or slightly fuzzy
2	Rocks are quite fuzzy or spongy feeling
3	Filamentous algae growing off rocks

Table 1: Periphyton Index.

1	>75% of surface covered by fine sediment
2	50-75% of surface covered by fine sediment
3	25-50% of surface covered by fine sediment
4	5-25% of surface covered by fine sediment
5	<5% of surface covered by fine sediment

Table 2: Embeddedness Index.

	Control	+Nitrogen	+Phosphorus	+Nitrogen/Phosphorus
CLR	1.7013	5.0593	1.6880	10.0096
LBR	1.0455	1.7472	0.8547	1.1888

Table 3: Average chlorophyll a values of CLR and LBR. There was the most growth on the nitrogen/phosphorus bioassays within CLR. The most growth was found on the nitrogen bioassays in LBR.

	Total Phosphorus (µg-P/L)	Soluble Reactive Phosphorus (µg-P/L)	Ammonium (µg-N/L)	Nitrate(µg-N/L)	Chloride (mg-Cl/L)
CLR- Upstream	9.7	2.3	28.7	12.7	14.1
CLR- Downstream	5.2	2.2	12.2	45.6	9.9
LBR- Upstream	32.3	21.9	29.4	129.3	6.6
LBR- Downstream	22.5	8.3	17.1	1.1	29.8

Table 4: CLR contained more chloride in the upstream site compared to the LBR upstream site. Only nitrate increased in CLR with distance downstream. Only chloride increased within LBR from the upstream site to the downstream site. Both nitrate and ammonium in LBR declined with distance downstream.

	pH	Conductivity (µS)	DO (mg/L)	Discharge (m^3/s)	Water Temperature (°C)	Air Temperature (°C)
CLR	8.69	303.47	9.94	21.68	21.23	24.50
LBR	8.53	415.65	9.28	-1.03	21.82	22.80

Table 5: Chemistry and Discharge data. CLR and LBR differed in conductivity and discharge with CLR having a lower conductivity and higher discharge than that of LBR. pH, DO, water temperature, and air temperature were relatively the same between both CLR and LBR.

	CLR	LBR
Amphipoda	0.33%	0.00%
Coleoptera	0.99%	0.00%
Diptera	13.53%	77.55%
Drissena polymorpha	0.00%	1.02%
Ephemeroptera	3.30%	7.14%
Gastropoda	0.00%	1.02%
Hirudinea	0.00%	1.02%
Isopod	0.33%	0.00%
Megaloptera	0.00%	3.06%
Odonata- Anisoptera	0.33%	0.00%
Oligochaeta	5.94%	8.16%
Plecoptera	2.31%	0.00%
Trichoptera	72.94%	1.02%

Table 6: Abundance of macroinvertebrates in CLR and LBR. Trichoptera was the most abundant order found in CLR while Diptera was the most abundant order found in LBR.

	Percent Diptera	EPT Index	Shannon Diversity Index
CLR	0.14	0.79	1.1083
LBR	0.68	0.07	1.1002

Table 7: The percent Diptera was found to be higher in LBR compared to CLR. In contrast the EPT index showed opposite results indicating a reduction of water quality between CLR and LBR. The Shannon diversity index was generally the same for both rivers.

Bibliography

Allan, JD. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual Review of Ecology, Evolution, and Systematics. 35: 257-284.

Cashman, MJ; Truhn, K; and Wehr, JD. 2013. Elevated light and nutrients alter the nutritional quality of stream periphyton. Freshwater Biology. 58: 1447-1457.

Dodds, WK and Welch, EB. 2000. Establishing nutrient criteria in streams. Journal of North American Benthological Society 19(1): 186-196.

Dodds, WK; Jones, JR; and Welch, EB. 1998. Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. Water Research. 32(5): 1455-1462.

Dodds, WK; and Whiles, M. 2010. Freshwater Ecology: Concepts and Envrionmental Applications of Limnology.2nd ed. Academic Press, Burlington, MA, 811p.

Faria, MS; Re, A: Malcato, J: Silva, P; Pestana, J; Agra, AR; Nogueira, A; Soares, A. 2006. Biological and functional responses of in situ bioassays with Chironomus riparius larvae to assess river water quality and contamination. Science of the Total Environment 371: 125-137.

Kitchin, PL. 2005. Measuring the amount of statistical information in the EPT index. Environmetrics. 16:51-59.

Klein, RD. 1990. Protecting the aquatic environment from the effects of golf courses. Community & Environmental Defense Association. Maryland Line, MD.

Kline, KM and Morgan, RP. 2011. Nutrient concentration in Maryland non-tidal streams. Environmental Monitoring and Assessment. 178: 221-235.

Great Lakes Ecological Association. 1982. Michigan Surficial Geology Map. http://www.ncrs.fs.fed.us/gla/geology/images/mi-surfgeo.gif

Mankin, KR. 2000. An integrated approach for modeling and managing golf course water quality and ecosystem diversity. Ecological Modelling. 133: 259-267

Marcé, R and Armengol, J. 2009. Modeling nutrient in-stream processes at the watershed scale using nutrient spiralling metrics. Hydrology and Earth System Sciences. 13: 953-967.

Mathewes, RW and Walker, IR. 1987. Chironomids, lake trophic status, and climate. Quaternary Research 28(3): 431-437.

Morgan II, RP; Kathleen M. Kline; Matthew J. Kline; Susan F. Cushman; Matthew T. Sell; Roy E. Weitzell Jr.; and John B. Churchill. 2012. Stream conductivity: relationships to land use, chloride, and fishes in Maryland streams. North American Journal of Fisheries Management, 32(5): 941-952. DOI: 10.1080/02755947.2012.703159

Mulholland, P. J., Helton, A. M., Poole, G. C., et al. 2008. Stream denitrification across biomes and its response to anthropogenic nitrate loading. Science,.452: 202–206.

Smith, RF and Lamp, WO. 2008. Comparison of insect communities between adjacent headwater and main-stem streams in urban rural watersheds. The North American Benthological Society. 27(1): 161-175.

Sponseller, R.A., E.F. Benfield, H.M. Valett. 2008. Relationships between land use, spatial scale and stream macroinvertebrate communities. Freshwater Biology. 46(10):1409-1424.

Tank, Jennifer L., Melody J. Bernot, and Emma J. Rosi-Marshall. "Nitrogen Limitation and Uptake." *Methods in Stream Ecology*. Ed. Richard F. Hauer and Gary A. Lamberti. Burlington: Academic Press, 2007. 213-38. Print

Wood, P.J. And P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. Environmental Management. 21(2):203-217.