A Pre-Dam Removal Survey of Maple River Habitat Downstream from Lake Kathleen

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Abstract

We collected pre-dam removal data of the habitat and species composition downstream from a human-made dam at Lake Kathleen. We chose two 100 meter transects downstream from the dam and made habitat assessments (including EPT and Shannon-Weaver index) at both. We electrofished and performed snorkel surveys of both transects. We took a macroinvertebrate survey at one transect. We present this data with the hopes that another group in the future may perform a post-dam removal survey in a similar method. We recommend performing t-tests to compare species composition of macroinvertebrate indices and linear regression to test the percent cobble. We hope that the data may be compared in order to make meaningful conclusions regarding the effect of dam removal on downstream habitat.

Introduction

The damming of rivers and streams has become a major human impact on the geomorphology of aquatic ecosystems. By damming a stream or river habitat, the flow of water, nutrients, sedimentation, and energy are all changed dramatically, drastically altering ecological processes (Ligon *et al.* 1995). In addition, major damming can block migration or spawning sites for fishes, leading to dramatic reductions in fish population (Bednarek 2001). Although streams can also be dammed in natural ways, such as by beavers and hippopotamuses, the effect of these natural dams is not nearly as dramatic as the effect of human dams (Dodds and Whiles 2010).

Dam removal has become more popular in recent years as dams age and become economically unviable. The removal of a dam has also become a method of attempting to restore and recreate original pre-dam river habitat (Bednarek 2001). Dam removal quickly converts a reservoir into a riverine system, with mortality rate of all macroinvertebrate and macrophyte populations approaching 100% (Stanley and Doyle 2003). Additionally, vast quantities of sediment move downstream following dam removal (Bednarek 2001). Buildups in sedimentation can cause a decrease in streambed particle size downstream of the dam as large cobble gets buried, with potential to impact the fish and macroinvertebrate communities (Stanley and Doyle 2003).

Dam removal can have additional impacts on the downstream habitat of an ecosystem, such as the possibility of major erosion of riverbanks (Bednarek 2001). Removal of dams could also potentially have effects on water temperature downstream, ultimately influencing fish survival (Bartholow *et al*. 2005). Dam removal will also remove the physical barrier between the upstream and downstream areas, allowing downstream fishes to move upstream into new habitat.

The reservoir that forms Lake Kathleen covers 48 acres of area blocked from flow by the man-made Maple River dam. A request for proposals has recently been submitted to remove the dam, allowing Lake Kathleen to drain out into the Maple River. As the dam currently maintains status as a first barrier to sea lamprey invasion, and the upstream area provides habitat for the endangered Hungerford's Crawling Water Beetle (*Brychius hungerfordii*) and Michigan Monkey-Flower (*Mimulus michiganias*), it is important to understand the impacts of dam removal on the area before it is done (Conservation Resource Analysis 2012). The area consists of a cold-water trout stream habitat.

We propose to perform an assessment of the habitat and biological community downstream of the dam. We will perform surveys of the aquatic macroinvertebrates and fish populations, as well as the substrate covering the river bottom and general assessments of surrounding riparian habitat. We will present these data in such a way that they may be easily replicated and compared to post-dam removal surveys.

Materials and Methods

Physical data was obtained from Lake Kathleen using a HydroLAB. We took levels of light, dissolved oxygen, temperature, and pH to give a physical layout of the lake. We also took samples of water from both Lake Kathleen and the downstream Maple River, submitting them to the University of Michigan Biological Station laboratory for analysis.

We chose two 100 meter transects downstream from the dam to gather the majority of our data, each composed of one hundred meters when measured along the river bank. Transect 1 consists of habitat relatively close to the dam, at 100 meters from the dam, whereas transect 2 lies 600 meters downstream from the dam. We used the section of the stream from N45°31.708'W84°46.495' to N45°31.879' W84°46.442' as Transect 1 and the section of the stream from N45°31.521' W84°46.490' to N45°31.556' W84°46.518' as Transect 2.

We surveyed streambed composition using a 0.5 m^2 quadrat. We measured stream width every ten meters along the stream bank, then used the quadrat to measure habitat at five equidistant points along each measurement site, resulting in a total of 55 quadrat measurements taken per transect. Measurements were taken by estimating the percent coverage of the stream bottom by different substrates. The Wentworth scale was used to define the size of rocky substrate. We also averaged percent coverage by each substrate across the entire transects and found the average percent coverage by each substrate type in the transect as a whole. Averages of cobble coverage were done at each ten-meter site, and we performed a linear regression to determine if coverage by cobble changed with distance from the dam. We also took one discharge measurement at the beginning of each transect by using a flow meter to record the velocity of water at ten equidistant points along the stream. Habitat assessments surveys were performed according to guidelines provided in Procedure #51 in the Qualitative Biological and

Habitat Survey Protocols (DEQ 2008). This index provides a quantitative score on habitat quality using factors such as gravel embeddedness, current velocity, available cover, bank stability, and proximity to human development. A high score indicates a high quality habitat.

We collected data on fishes first by electrofishing each 100m transect in its entirety. We electrofished transect 1 for thirty-five minutes and transect two for thirty minutes to cover the entirety of likely fish habitat. This electrofishing was done primarily to determine which fish could be found in the stream, and the ideal fish habitats in our transects to prepare for our snorkel survey. We observed fish in their natural habitat in the stream by conducting snorkel surveys of each transect in a procedure similar to that described by O'Neal (2007). Snorkel surveys were conducted by having a team of two snorkel downstream, each observing one side of the stream. A third team member stood on the bank and recorded fish seen by the snorkeling pair. We conducted two snorkel surveys of transect 2 and a single snorkel survey of transect 1.

We conducted a survey of macroinvertebrates in transect 2. We used the habitat data to determine the number of samples taken in each type of habitat, taking more samples in the dominant habitats. Overall three samples were taken in woody debris habitat, two in macrophyte habitat, three in sandy habitat, and eight in cobble. We took samples in macrophyte, sandy habitat, and cobble using a Serber sampler with an area of 0.916 cm^2. We took samples of woody debris by finding pieces of wood within our transects and picking macroinvertebrates off of them by hand. Samples were taken for two minutes with the Serber sampler and for five minutes for the woody debris sampling. Invertebrates were transferred to whirlpacks, placed in 70% ethanol, returned to the lab at the U of M Biological Station and sorted to family and functional feeding group. Macroinvertebrate assessments were performed using the Shannon-Weaver index of biological diversity, identifying macroinvertebrates down to family, and an EPT ratio of organisms. Abundance of macroinvertebrates was also calculated as organisms/m^2 in sand, cobble, and macrophyte habitats, and as organisms/minute in woody debris habitats.

Results

We found that at Transect 1 cobble was by far the dominant substrate type, with macrophyte and sand having a slightly higher representation than woody debris (Figure 1). Transect 2 showed similar composition, except that woody debris composition was slightly higher and macrophyte composition was slightly higher, whereas sand and cobble had nearly identical representation as Transect 1 (Figure 2). Both transects fell within the “excellent” range of habitat quality as defined by the habitat assessment field guides provided by Procedure #51 in the Qualitative Biological and Habitat Survey Protocols (DEQ 2008), receiving scores of 156 for transect 1 and 163 for transect 2. The “excellent” rating is the highest qualtitative rating provided by Procedure #51.

Our electrofishing runs in Transect 1 indicated the presence of slimy sculpin (*Cottus cognatus*) and brown trout (*Salmo trutta*) (Table1). Transect 2 showed a more diverse array of species when electrofishing, with a single small white sucker and rock bass (*Amploplites rupestris*) being collected along with the sculpin and trout (Table 1). Our snorkeling survey of transect 1 found 13 brown trout, along with 3 brook trout (*Salvelinus fontanalis*) and three rainbow trout (*Onchorhyncus mykiss*) (Table 2). A small colony of white suckers (*Catostomus commersonii*) were also located in an area of woody debris by snorkeling. However, only sculpin, brown trout, and brook trout were found while snorkeling transect 2 (Figure 4).

Lake Kathleen is a shallow lake, with a maximum depth of approximately 2.5 meters. The pH and DO levels are relatively constant throughout the whole lake, with temperature reaching a minimum of 16 ^{0}C (Table 3).

Macroinvertebrate sampling resulted in the collection of 28 families of macroinvertebrates in 11 orders (Table 4). Our average EPT value between all sites sampled in Transect 2 was found to equal 0.28 (Figure4), and our average Shannon-Weaver index was found to equal 1.62 across all sampled habitats (Figure 5). Approximately 29 organisms/m^2 were collected in the sand, cobble, and macrophyte habitats, and approximately 6.5 organisms were gathered per minute in the woody debris habitat.

We also performed a linear regression of cobble with distance to determine whether there was a significant change in cobble as distance from the dam increased. Neither Transect 1 (R^2=0.022, p-value=0.663) nor Transect 2 (R^2=0.089, p-value=0.373) showed a significant change in cobble with distance from the dam (Figures 6 and 7).

Nutrient data was also taken for Lake Kathleen and our downstream Maple River area. Nitrate levels were higher in the Maple River (206 micrograms), with ammonium levels being approximately equal between the two sites. However, total phosphorous was significantly higher in the Lake Kathleen area (Table 5). The conductivity of the Maple River was slightly higher, but this can likely be explained by the movement of particles by the flow of the river. Finally, pH levels were similar, between 8 and 9 (Table 5).

Discussion

When we rated both transects using the field guidelines provided in the Qualitative Biological and Habitat Survey Protocols, both transects were found to have habitats falling well within the excellent range, the highest range given by the survey. We recommend that another rating be done after removal of the dam to see the possible effects removal may have had on the habitat quality. We predict that several sections in the rating procedure may change, such as the percent of exposed cobble, which may change due to sedimentation input from the dam (Stanley

2003). Additionally, the release of high amounts of water from the dam has the potential to erode the river bank (Pizzuto 2002), which would further decrease the score given by the assessment survey.

Dam removal has a major impact on the sedimentation of the surrounding environment. Old dams, even smaller ones, build up vast amounts of sediment in their reservoirs, much of which gets washed downstream upon removal of the dam (Doyle *et al.* 2005). We predict that this outwash of sediment could cause much of the cobble substrate that currently dominates on the streambed to be covered by finer sedimentation, resulting in a lower percent of streambed made up of cobble. In order to test this, we recommend that future studies find percent coverage of the streambed by cobble in a similar method to the one described above (see “Materials and Methods), and perform a t-test to compare the mean percent coverage by cobble before and after dam removal. Furthermore, if major sedimentation does occur, we expect the percent cobble to increase as distance from the dam increases, as more sedimentation will be dumped on the downstream areas (see Figures 10 and 11 for examples). We recommend a linear regression is done as percent cobble to distance from the dam after dam removal.

The outwash of sediment could have an additional effect for the Maple River because of the difference in total phosphorous levels between the lake and the river (Table 5). As phosphorous is stored mostly in sediment (Dodds and Whiles 2010), it is possible that this outwash of sediment could drag large amounts of phosphorous with it, leading to an increase in total phosphorous in the River. This could lead to an increase in aquatic macrophytes or algae that are currently phosphorous limited.

The removal of the dam may provide a pathway for the movement of fish between downstream and upstream habitats. These effects can be dramatic at times, such as the upstream movement of American Eel (*Anguillia rostrata*), alewife (*Alosa pseudoherengus*) and other fish to habitat formerly devoid of these species after the removal of the Edwards Dam on the Kenebec River (Hart *et al.* 2002). While our particular dam removal is unlikely to result in such a dramatic introduction of species, the species composition could very well change due to migration of downstream populations upstream where they could not initially be found. This could be beneficial for our salmonid populations (brook and brown trout), as salmonids migrate upstream to spawn. The removal of this dam could allow trout populations to travel to previously unreachable areas upstream to spawn. Removal of small dams in Denmark was found to give salmonid populations access to optimal spawning habitats, increasing their chances of survival (Bednarek 2001). In addition, possibilities exist for the removal of the dam to change the temperatures of the downstream sites, which could harm salmonid populations and make the sites temporarily less suitable for trout (Bartholow 2005). We recommend that future studies conduct a post-dam removal analysis of the fish species richness and compare with our list to determine if major changes in species composition have occurred. We recommend that 100 meter transects are snorkeled with two passes, preferably the same areas that where we collected our fishes (see "Methods and Materials, above). By comparing data collected in these passes with our data, it would be possible to determine whether the Maple River has improved in its quality as a trout stream due to increased habitat for migration, or declined due to changes in temperature and increased sedimentation.

Dam removal can also lead to a decrease in macroinvertebrate density (Thomson 2005). A study done by Thomson *et al.* (2005) found that the abundance and diversity of macroinvertebrates decreased after dam removal, likely due to sedimentation from the dam. The same study found a decrease in EPT values downstream from the removed dam. We recommend that the EPT and Shannon-Wiener indexes are compared after dam removal to our data using t-tests. We predict lower values for both indices, as shown in Figures 8 and 9. Decreased macroinvertebrate abundance could lead to a significantly worse habitat for trout, as trout feed on aquatic macroinvertebrates. However, the Thomson study did find that most of the effects are likely temporary, and will decrease as time goes on.

Among macroinvertebrates, we found the least represented functional feeding group in the downstream habitat from the dam to be shredders (Figure 5). A study performed by Cortes *et al.*(2002) suggesting that shredders were under-represented in sections of river regulated by dams, likely due to the low litter input from areas above the dam. However, after dam removal, the sediment once covered by the reservoir becomes new riparian habitat available for recolonization by vegetation. A study by Orr and Stanley (2006) found that after dam removal available sediment was colonized quickly, even within the first growing season after removal, and that species diversity was positively correlated with the number of years since removal. This increase in riparian vegetation will provide more litter fall and hence more particulate organic matter in the river. We predict that this increase in litter fall will change the macroinvertebrate composition of the downstream habitat in that in future, with an increase in percent of macroinvertebrates that fall in the shredder functional feeding group, as compared with the 6% that we see now (Figure 3). We recommend that this be tested in the future by researchers sampling macroinvertebrates in a similar method as the one described above, then comparing the average percent composition of the community identified as shredders using a t-test. We also recommend that the total % composition of functional feeding groups in the habitat be tested using a chi-square analysis to show any differences in composition, using the values we found as the expected values in the test. (Table 6).

There are many strategies to lessen the effects of dam removal. For example, while expensive, removing sediment fill behind the dam prior to removal will ensure a much lesser impact on the ecosystem from sedimentation (Pizzuto 2002). Lowering of the dam can be done in stages to achieve a similar effect (Pizzuto 2002).

Dam removal will likely change the downstream habitat of the river, and it will likely affect species composition as well. Depending on how dam removal is done and the effects on the current environment, there is potential for dam removal to be beneficial to trout due to more area for migration or for a decrease in habitat quality due to sedimentation or temperature. A post-dam analysis, when the data are compared to the data shown here, will provide an important example of the changes experienced in downstream habitat by the removal of a dam. These changes should be taken into account when dam removal is considered in the future. Dam repair can be considered as opposed to dam removal if it is predicted that the removal of the dam will cause detrimental changes to the downstream habitat.

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Table 1- This table presents an outline of the fish found by electrofishing. We electrofished transect 1 for 35 minutes and transect 2 for 30 minutes.

	Transect 1	Transect 2
Slimy Sculpin	34	27
Brown Trout	3	5
Brook Trout	0	1
White Sucker	0	1
Rock Bass	0	1

Table 2- This table presents an outline of the fish found by our snorkel survey at Transect 2.

	Transect 1	Transect 2 Trial 1	Transect 2 Trial 2
Slimy Sculpin	1	0	2
Brown Trout	13	40	45
Brook Trout	4	7	6
Rainbow Trout	3	0	0
White Sucker	10	0	0

Table 3- This table shows the physical layout of Lake Kathleen. Temperature given in Celsius, DO= dissolved oxygen.

Depth(m)	Photometer	Temperature	DO	pH
0	1260	20.7	10.79	8.24
0.5	575.3	19.8	10.21	8.22
1	480	18.5	9.37	8.09
1.5	210	17.46	10.32	8.1
2	130.5	17	10.19	8.07
2.5	91	16.9	9.68	8.03

Table 4- With this table, we can see the total richness of macroinvertebrate families found by taking invertebrate samples in Transect 2.

Order	Family
Odonata	Aeshnidae
Odonata	Calopterygidae
Odonata	Gomphidae
Amphipoda	Scuds
Bivalvia	Spheriidae
Gastropoda	Planorbidae
Gastropoda	Limnoeidae
Gastropoda	Physidae
Ephemeroptera	Ephemeridae
Ephemeroptera	Chloroperlidae
Ephemeroptera	Baetidae
Ephemeroptera	Heptageniidae
Ephemeroptera	Leptohyphidae
Tricoptera	Limmephilidae
Tricoptera	Glossosomatidae
Tricoptera	Brachycentridae
Tricoptera	Leptoceridae
Tricoptera	Hydropsychidae
Tricoptera	Lepistomadidae
Diptera	Athericidae
Diptera	Chironomidae
Diptera	Simuliidae
Diptera	Tibanidae
Oligochaeta	Segmented Worms
Plecoptera	Perlotidae
Platyhelminthes	Planeria
Coleoptera	Elmidae
Coleoptera	Gyrinidae
Coleoptera	Hydrophilidae

Table 5- This table presents nutrient data for Lake Kathleen and the Maple River. N03=Nitrate levels, NH4= Ammonium levels, TP= Total phosphorous, Cond=conductivity.
No chlorophyll a data were taken for the Maple River.

Location	NO3-N	NH4-N	TP	pH	Cond
	ug N/L	ug N/L	ug P/L		uS
Maple River	206.2	21.9	3.6	8.07	330.7
Lake Kath	158.2	22.3	8.8	8.23	291.7

Table 6- This table presents a proposed Chi-squared analysis using our functional feeding group data.

FFG	Total found	Ratio	Total found	Ratio
	pre-removal	pre-removal	post-removal	post-removal
C/G Total:	189	0.42		
FC Total:	164	0.36444		
Pred Total:	43	0.09555		
Scrap Total:	33	0.07333		
Shred Total:	21	0.04666		
Total:	450			

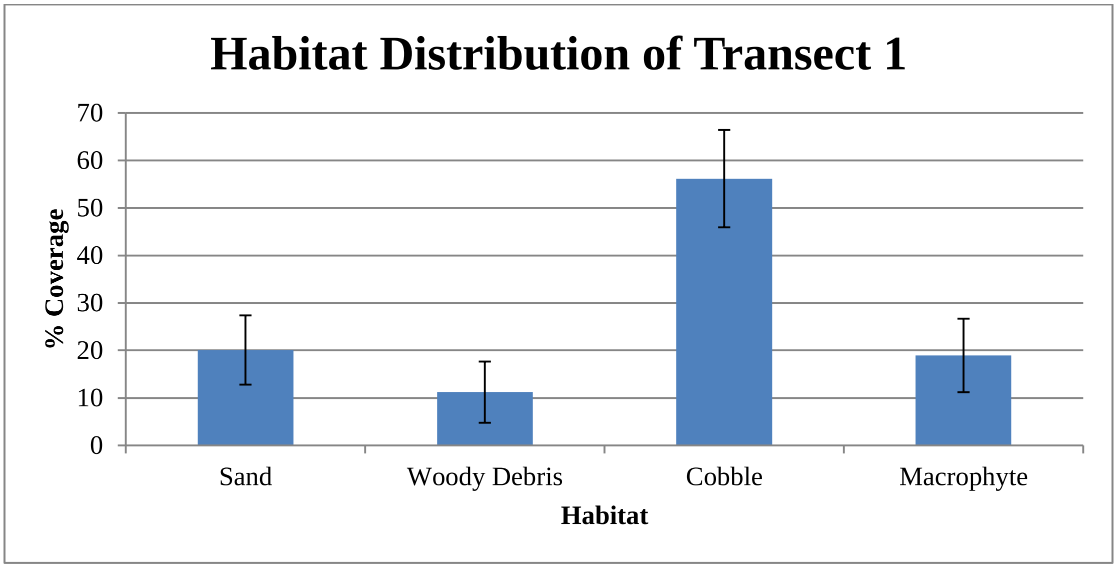

Fig. 1- This graph shows percent coverage of stream bottom by habitat type of Transect 1. Total discharge in Transect 1 was found to equal 1.61 meters cubed per second. We found the average depth of Transect 2 to equal approximately 39 centimeters.

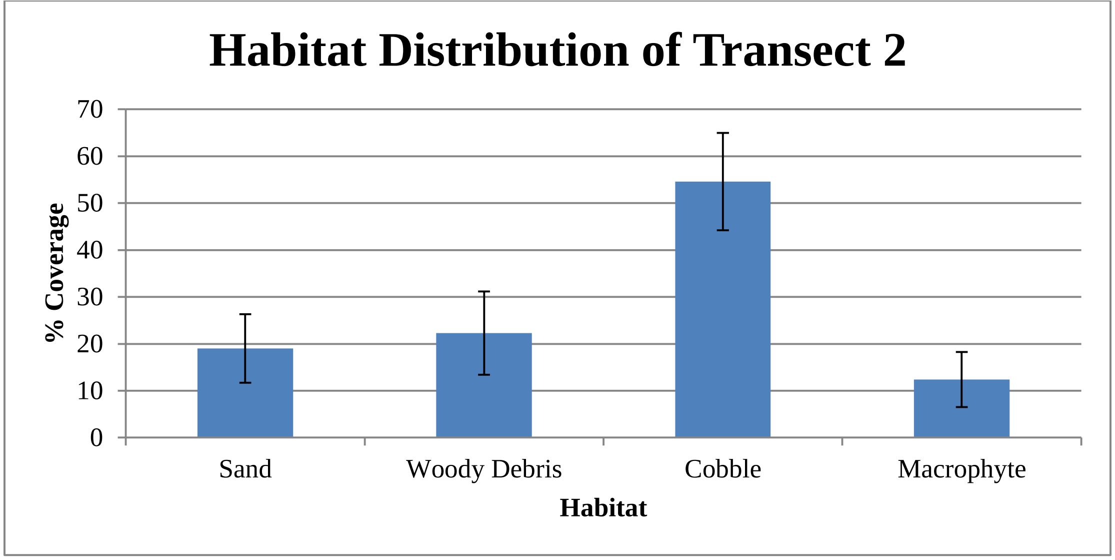

Fig. 2- This graph shows percent coverage of stream bottom by habitat type of Transect 2. Total discharge in transect one was found to equal 1.59 meters cubed per second. We found the average depth of Transect 2 to equal approximately 41 centimeters.

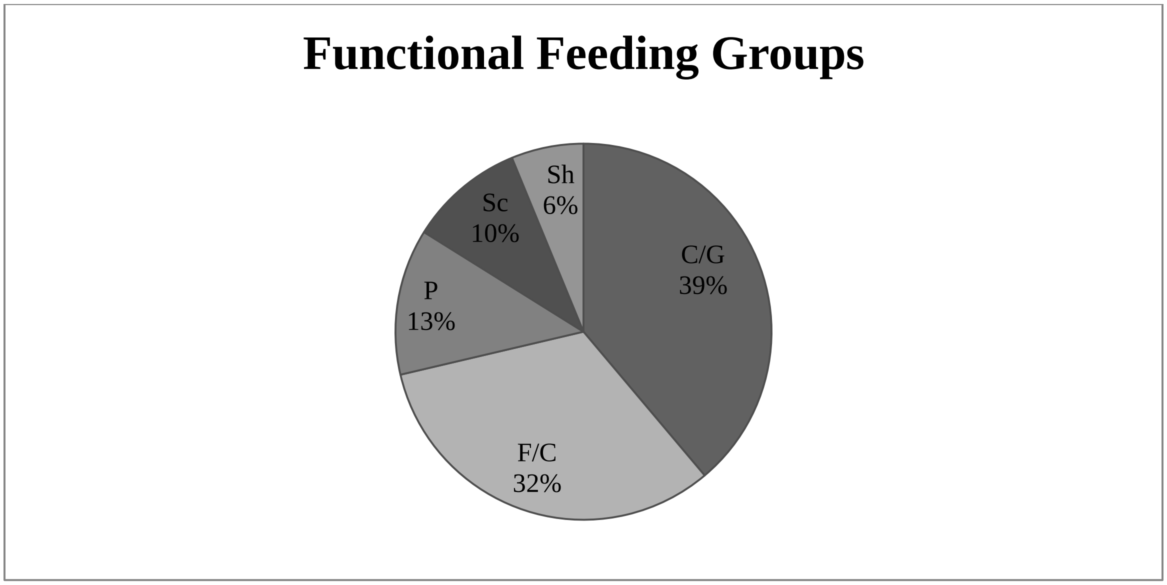

Figure 3- Percent of each functional feeding group of macroinvertebrates found at Transect 2. C/G=Collector/Gatherer, F/C=Filtering Collector, P=Predator, Sc= Scraper, Sh= Shredder.

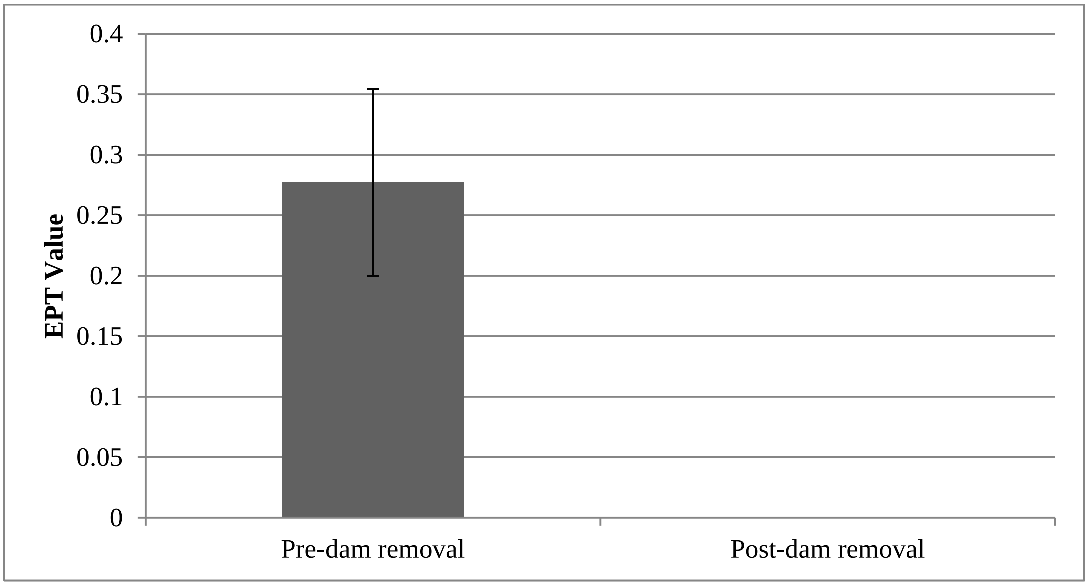

Figure 4- This figure shows the found EPT value of the Maple River area at transect 2 (600-700 meters from the dam). A space is provided to allow input of post-dam removal EPT values.

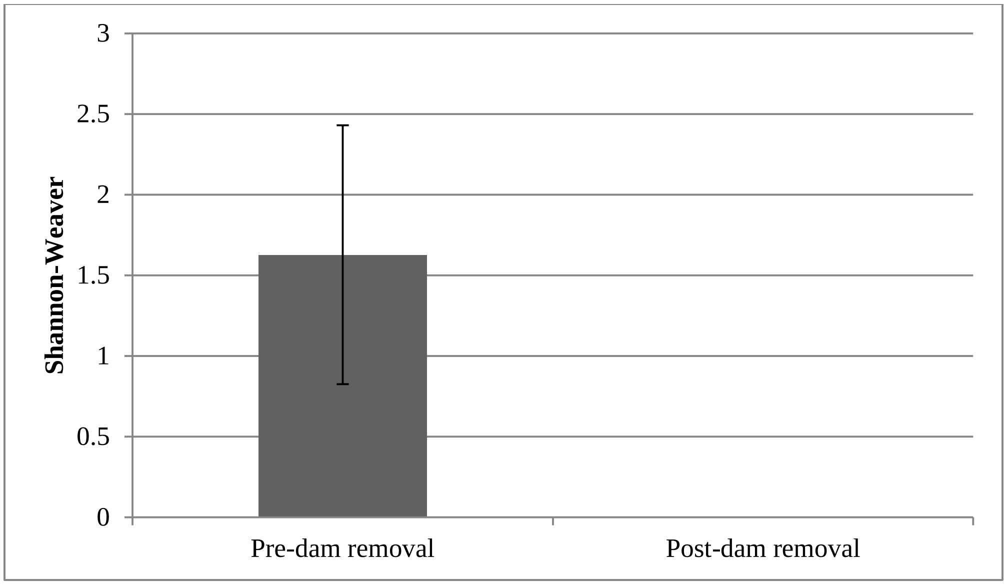

Figure 5- This graph shows the Shannon-Weaver value of the Maple River area at transect 2 (600-700 meters from the dam). A space is provided to allow input of post-dam removal Shannon-Weaver values.

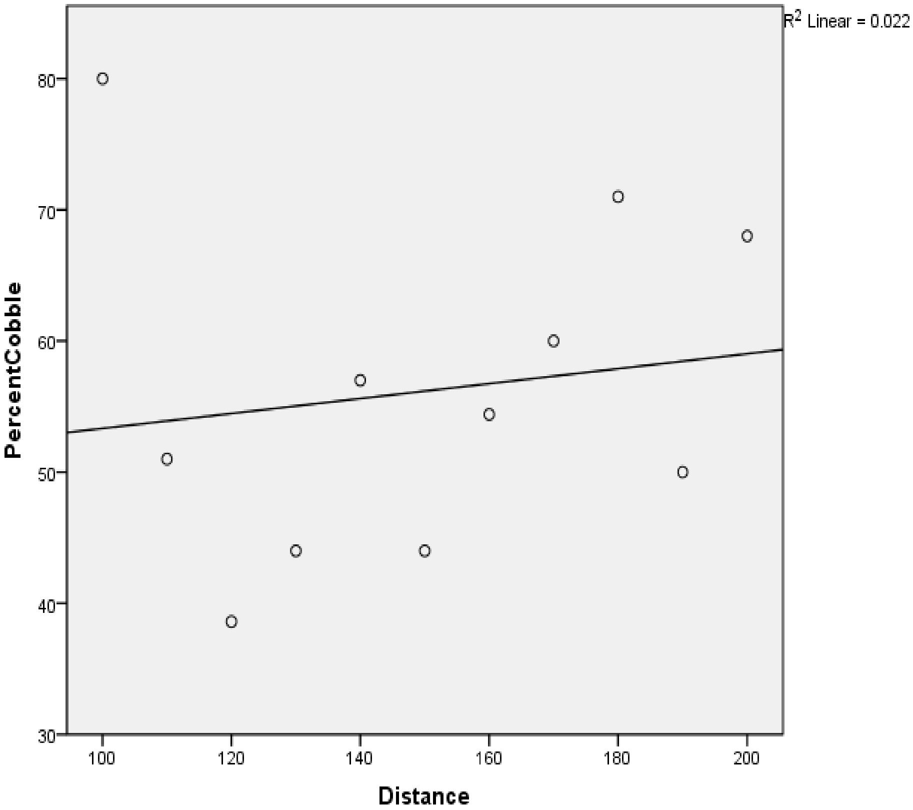

Fig. 6- This figure shows the percent composition of cobble substrate on the river bottom with distance at Transect 1. R(square)=0.022, p-value=0.663

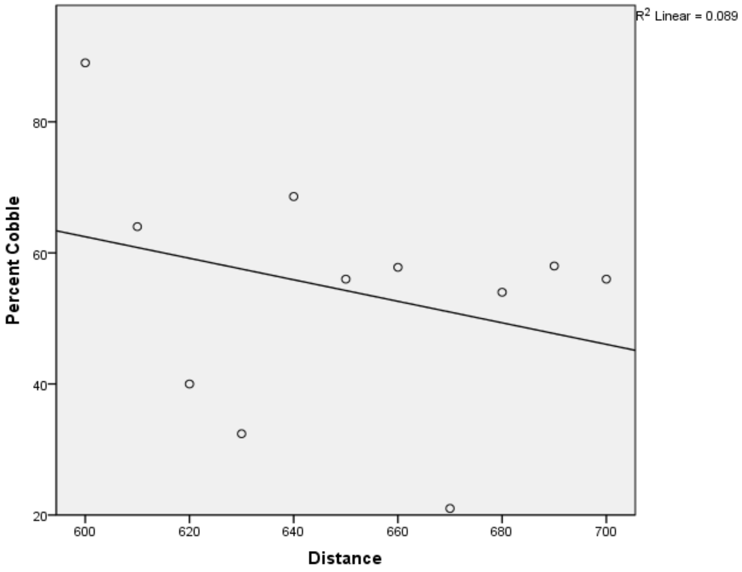

Fig. 7- This figure shows the percent composition of cobble substrate on the river bottom with distance at Transect 2. R(square)=0.089, p-value=0.373

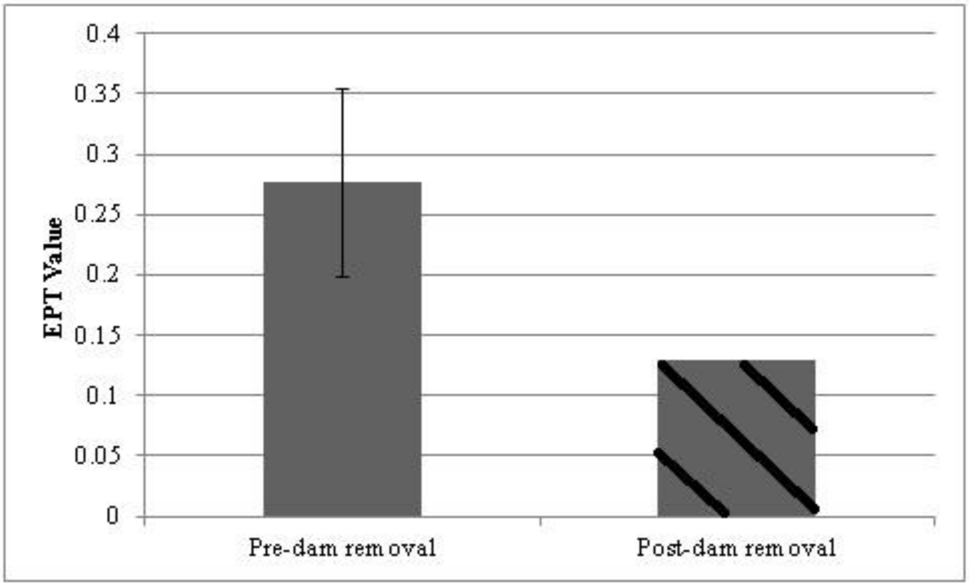

Fig. 8- A possible post-dam removal EPT value compated with the pre-dam removal value.

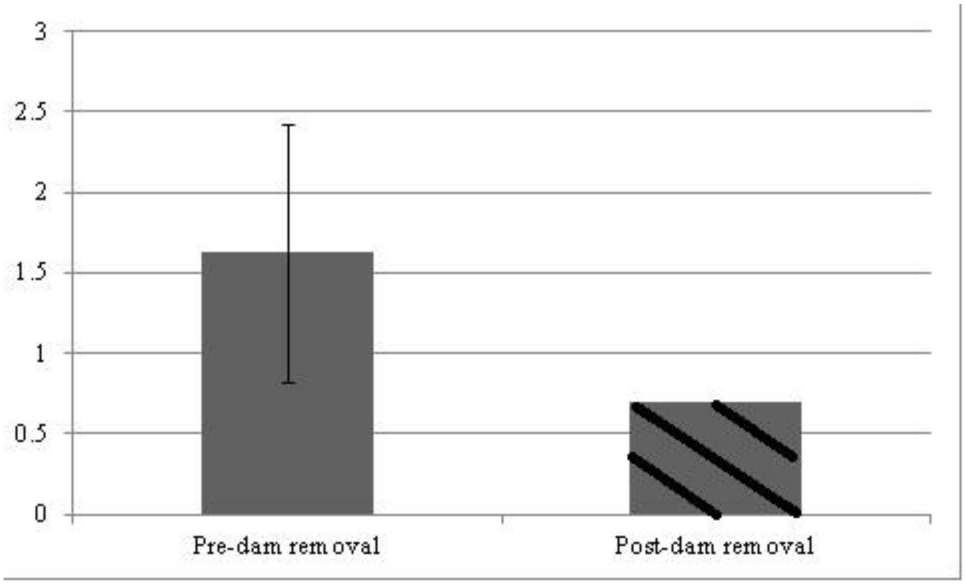

Fig. 9- A possible post-dam removal Shannon-Wiener index when compared to the pre-dam removal value.

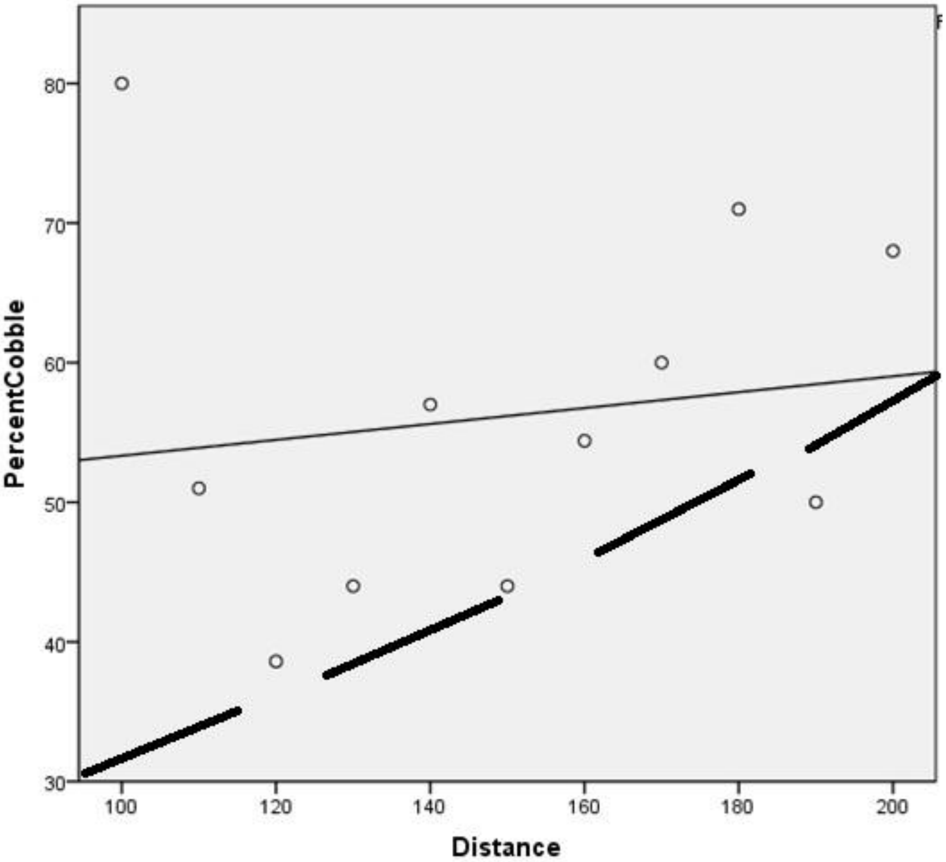

Fig. 10- The dotted line shows a possible correlation of percent cobble with distance from the dam for Transect 1.

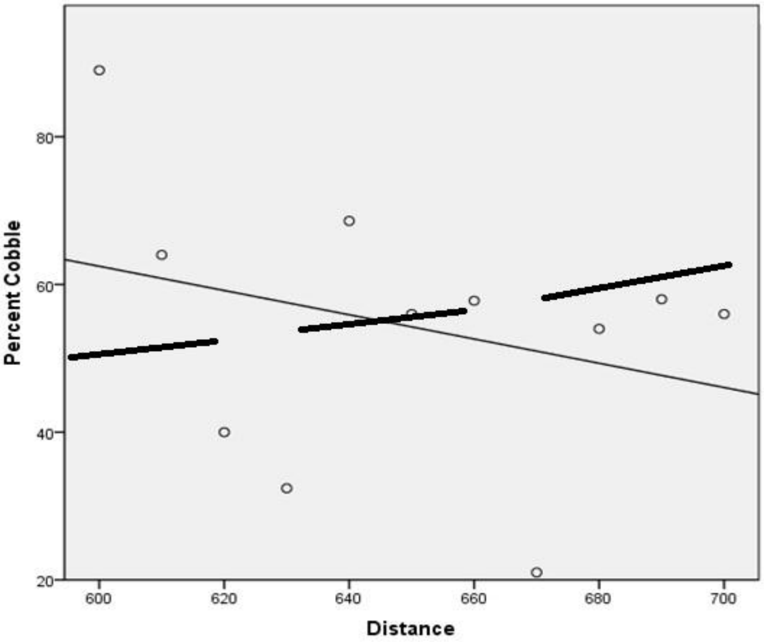

Fig. 11- The dotted line shows a possible correlation of percent cobble with distance from the dam for Transect 1.