Effects of dams on stream habitat and communities: A precursor for dam-removal study

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Introduction

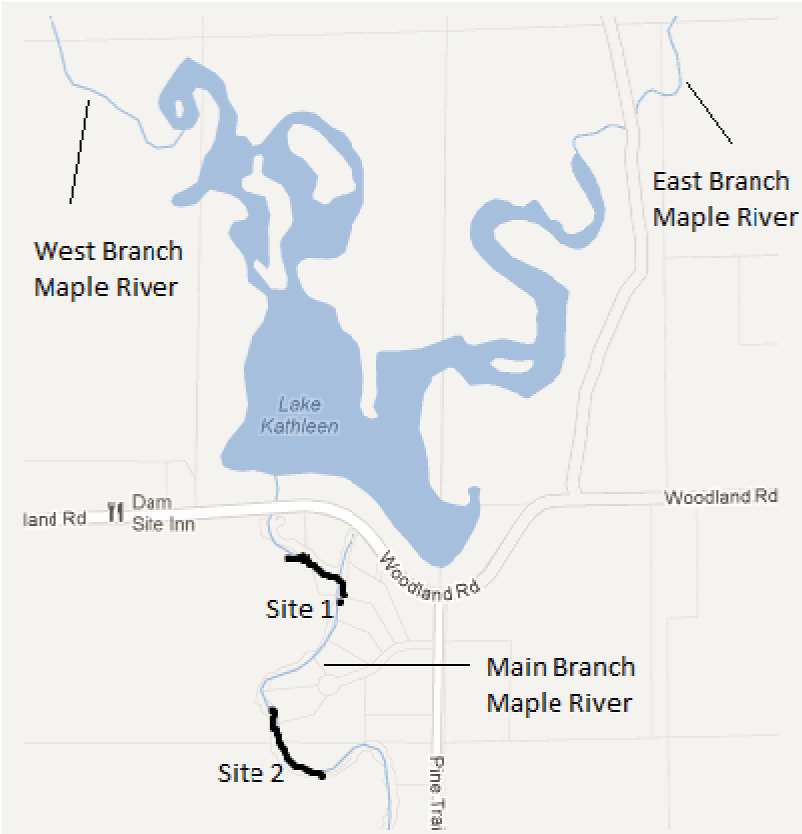
Changes to the ecosystems above and below the dam can be attributed to many factors. Sediment transfer, temperature variability, species richness, and overall habitat functionality are some of the effects dams have on river systems (Petts, 1984). Increased deposition of sediments near the dam allows for more to be deposited in the gaps between the cobbles altering habitat for macroinvertebrate and fish species (Rabeni and Jacobson, 1993). Temperature variations from the warmed water of the reservoir can create thermal barriers (Gillilan and Brown, 1997). Due to this, reservoirs created above dams can create changes in species type by physically altering habitat. (Yeager, 1994).

Dam removal is becoming more widespread as older dams are becoming increasingly eroded. Restored streams have been known to recover to pre-dam conditions if given enough time. Once a dam is removed, the recovery process is difficult because it factors in the status of the reservoir and the effects of releasing it on sediment disposition and temperature on downstream habitats (Bednareck, 2001). The changes following dam removal have negative effects on macroinvertebrate and fish species because they reduce or alter the habitat types found in rivers. Temperature variations have a smaller effect than sediment displacement after dam removal because they are buffered out rather quick in lotic systems from air diffusion and ground water recharge. More importantly, habitats are subject to deformation and displacement downstream from the increased CPOM levels following the dam removal (Bednareck, 2001).

A proposed dam removal project is the Lake Kathleen/Maple River project. The lake is a shallow warm water reservoir lake with about 48 acres of surface area created by the Maple River dam. The dam is 15 feet high and approximately 1200 feet long. The Maple River is a high quality cold water trout stream used for recreational fishing. The habitat of the river holds two endangered species; the Hungerford's crawling water beetle (*Brychius hungerfordi)* and the Michigan monkey-flower (*Mimulus michiganensis)* (Conservation Resource Alliance). Dam removal could have detrimental effects on these two species because of the habitat altercations widening stream width (Doyle et al. 2005). Our study aims to provide a thorough analysis on the habitat structure and status and species diversity downstream from the dam for comparison of these factors after the dam has been removed in the future.

Methods

We choose two 100 meter sampling sites on the main branch of the Maple River below the dam. Site 1 starting location was N45^{o}31.708' W84^{o}46.495' with an ending location of N45^{o}31.679' W84^{o}46.442' and was located 100 meters from the dam. Site 2 staring location was N45^{o}31.556' W84^{o}46.490 with an ending location of N45^{o}31.521' W84^{o}46.518' and was located 600 meters from the dam. Next we divided our two sites into 11 transects 10 meters apart.



We then observed and recorded percent cover by sand, woody debris, macrophyte, and cobble of 5 points located on each transect. We used a meter square quadrat at each point to better assess percent cover. We scored overall habitat of each site by using the Great Lakes and Environmental Assessment Section (GLEAS) procedure 51. This is used to assess the quality of cold water streams through individual metrics based on habitat. Metrics such as gravel and cobble embeddedness, substrate composition, riparian cover, current velocity and depth of channel, and bank stability (Flashpolar et al. 2002). From this we can give an overall habitat score which can be compared to post dam removal scores.

To sample macroinvertebrate we decide that greater than 150 individuals at each site would be an adequate sampling size. We used Surber samplers with an area of .916 m^2 for sand, macrophyte, and cobble samples. Woody debris was sampled using forceps to pick organisms of submerged logs for 5 minutes. Surber samplers were used for 2 minute durations. We took 8 cobble substrate samples, 3 samples sand substrate and 2 samples of macrophyte substrate. 3 woody debris samples were collected. Organisms were transferred to whirl-paks with ethanol and water to be identified to family at a later time. *Ephemeroptera*, *Plecoptera*, and *Trichoptera (*EPT*)* proportions were noted to further assess river condition and to be compared later to post dam removal EPT scores. The Shannon-Weaver index of diversities was used to explain differences in macroinvertebrate diversity which can also be compared to post dam removal scores. We identified macroinvertebrates to family and functional feeding group for comparisons and community assessment.

To observe species present we used an AC electrofisher and D shaped dip nets to catch the subdued fish. We sampled each site once and record each fish species caught. Kill racks containing 10% formalin and anesthetic were used to store fish for identification at a later time. Snorkeling surveys were performed to find relative abundances of fish communities. Snorkelers surveyed traveling upstream Site 2 was snorkeled survey twice where an average was taken and site 1 was survey only once due to time constraints. Two people snorkeled and observe fish species and abundance and the third person recorded on the stream bank. Snorkeling surveys were based on O'Neal (2007) procedures. From the snorkeling surveys we recorded abundances of fish observed at each site for later comparisons following dam removal.

To observe the physical and chemical properties of Lake Kathleen a HydroLAB was used which recorded depth, pH, dissolved oxygen, a nutrient sample was also taken and analyzed from both the Maple River and Lake Kathleen.

Results

We found that Lake Kathleen was approximately 3 meters deep. Lake Kathleen had more double the amount of total phosphorus than the Maple River. Whereas, the nitrate levels were higher for the Maple River than in Lake Kathleen (Table 1)

Site 1 scored a 156 on the GLEAS procedure 51 and site 2 scored 163. Site 1 had roughly 6 percent more macrophyte cover than site 2 whereas; site 2 had roughly 11 percent more woody debris than site 1 (Figs 1 and 2). Both sites shared approximately 20 percent cover by sand. Linear regression analysis for percent cobble with distance from the dam was used to find correlations. We found out that both of our sites on average had greater than 50 percent cobble cover making it the predominant cover substrate. Dash lines indicated predicted correlations following post dam removal (Figs 3 and 4).

Gatherers and collectors represented the highest proportion of macroinvertebrate functional feeding groups observed (Fig. 5). Filtering collectors represented the next highest proportion. Predators, scrapers, and shredders together represented a third of the function feeding groups observed. The Shannon weaver index was used to assess biodiversity among stream macroinvertebrates. Average EPT was also found for each site. Observations of post dam removal effects on these scores should be produced to provide comparisons

We found approximately equal species richness in both sites. Rainbow trout (*Oncorhynchus mykiss)* and rock bass (*Ambloplites rupestris)* were the being the only different species between the two sites. A greater number of slimy sculpin (*Cottus cognatus*) was observed in site 1 than site 2. Substantially more slimy sculpin were observed when electrofishing method was used. Site 1 had 34 slimy sculpin where site 2 had 27. When snorkeling surveys were performed we observed more brown trout then when we electrofished. Site 1 had 13 brown trout where site 2 had 40 brown trout. However, site 1 had one more Salmonid species than in site 2 since 3 rainbow trout where observe in site 1 and none in site 2. Snorkeling surveys produced greater observations of fish abundances. However, electrofishing produce greater amounts of slimy sculpin. White sucker (*Catostomus commersonii)* was also observed more in site 1 with 10 when snorkeled but site 2 only had 1 observed by electrofishing. Approximately the same amounts of brook trout were observed in both sites with 4 brook trout in site 1 and 7 brook trout in site 2 (Fig. 8,9).

Table 1 A table showing the nutrient data for Lake Kathleen and the Maple River.

	Nitrate NO3-N (µg N/L)	Ammonium NH4-N (µg N/L)	Total phosphorus (µg P/L)	pH	Conductivity (µS)	Chlorophyll-a (µg/L)
Maple River	206.2	21.9	3.6	8.1	330.7	NA
Lake Kathleen	158.2	22.3	8.8	8.2	291.7	1.5

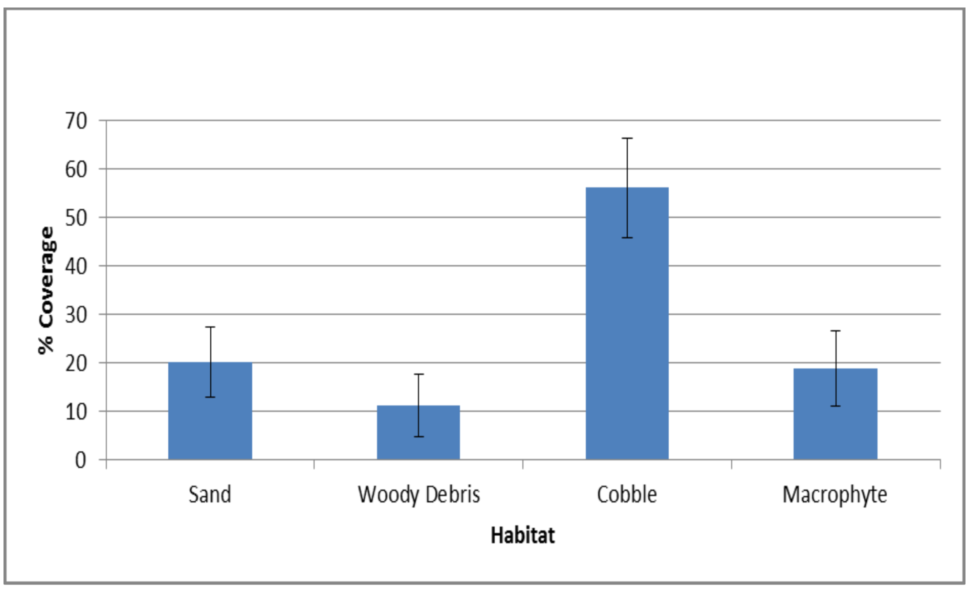


Fig. 1 A figure showing the types of habitat by percent cover in sampling site 1

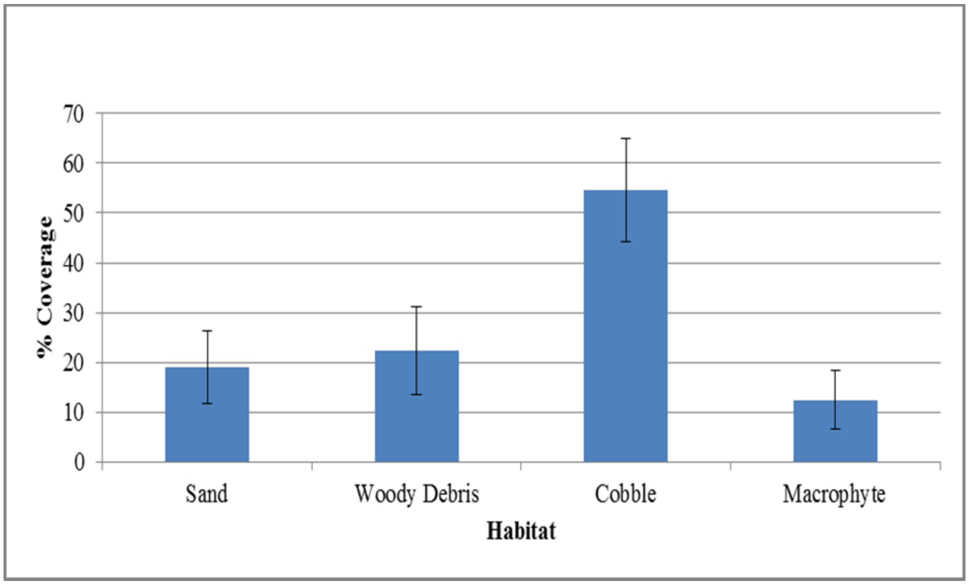


Fig. 2 A figure showing the types of habitat by percent cover in sampling site 2

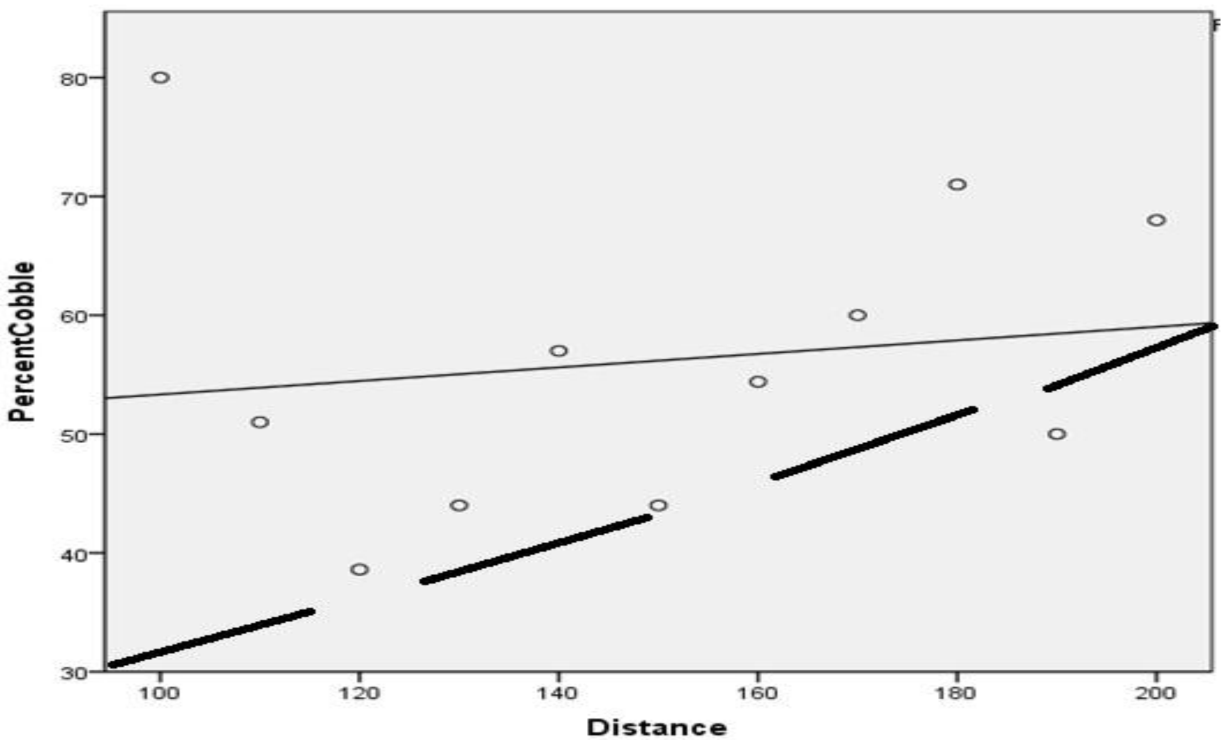


Fig. 3 A scatter chart showing no correlation between percent cobble cover and distance from dam for site 1(r^2=0.022, p=0.663). Dash line indicates predicted correlation following dam removal.

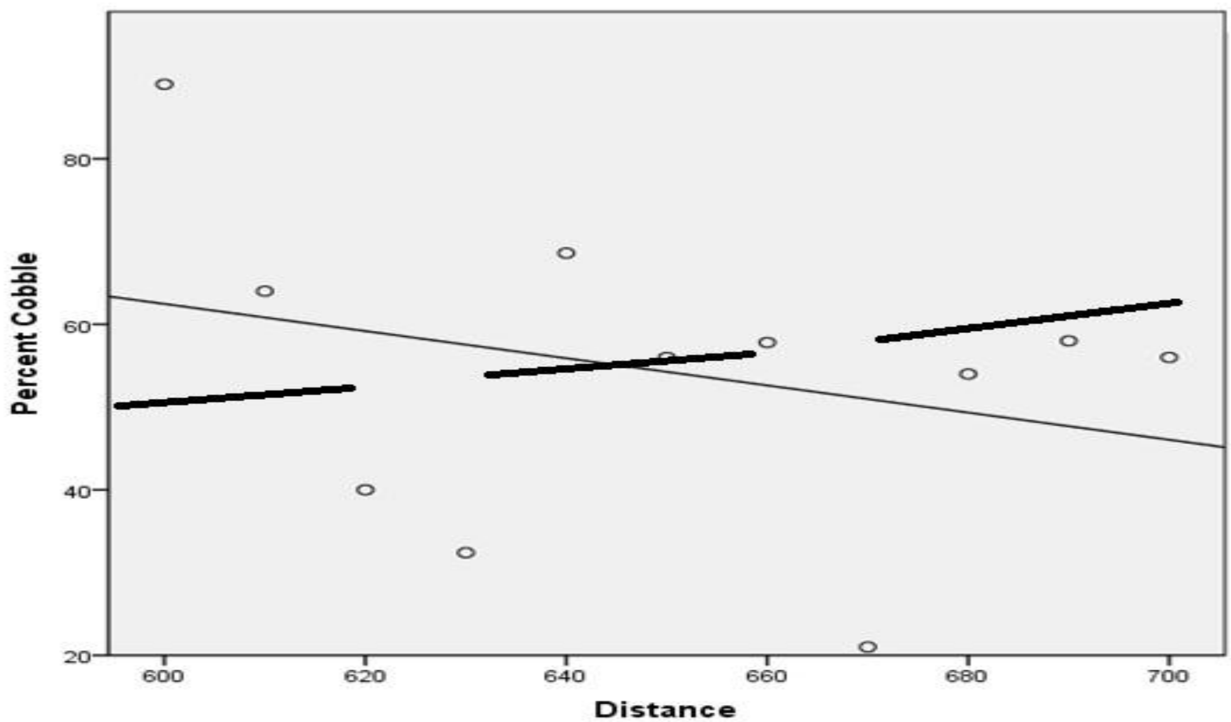


Fig. 4 A scatter chart showing no correlation between percent cobble cover and distance from dam for site 2 (r^2=0.089, p=0.373). Dash line indicates predicted correlation following dam removal.

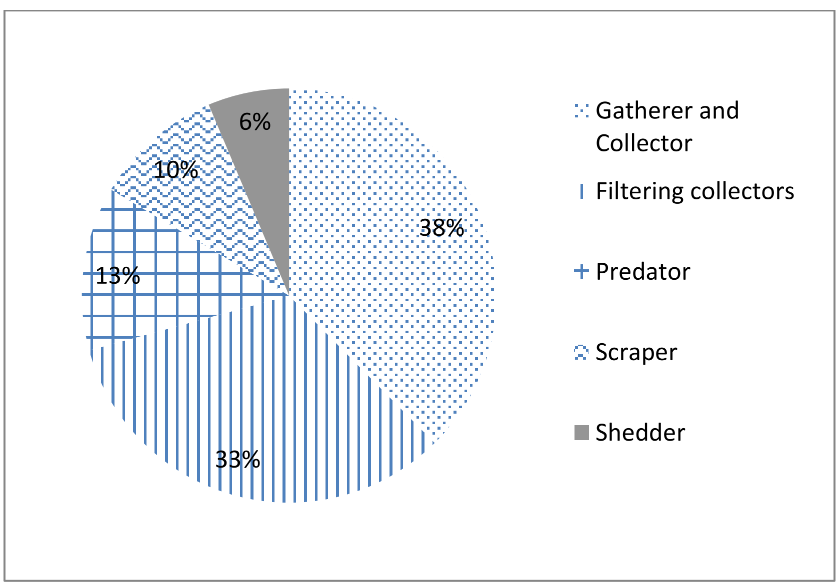


Fig. 5 A chart showing proportions of macroinvertebrate functional feeding group observed.

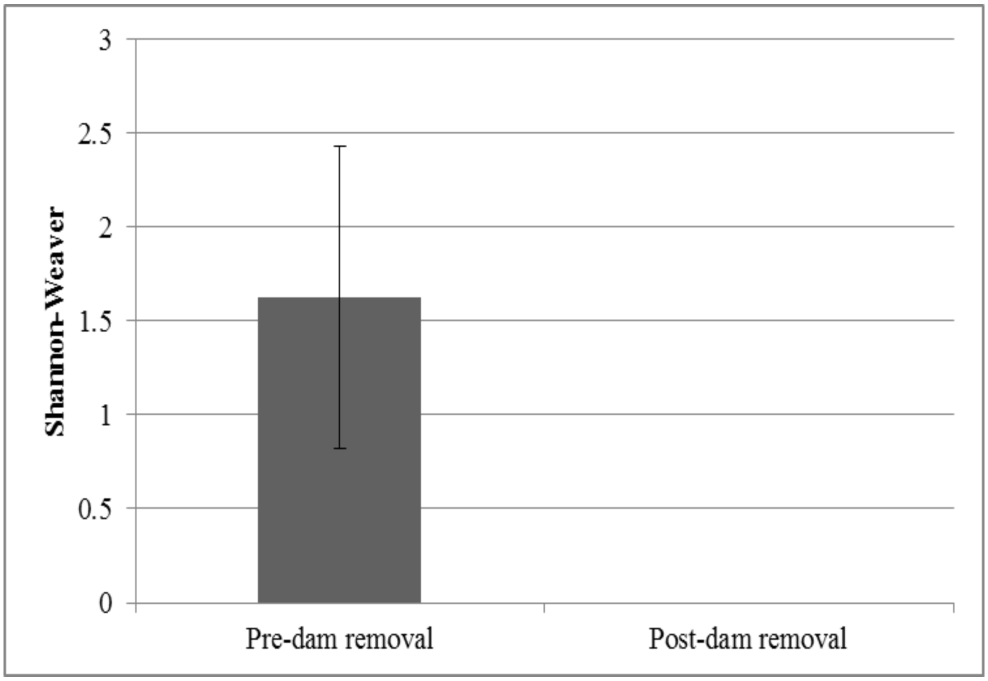


Fig. 6 A chart indicating post dam removal assessment using Shannon-Weaver biodiversity index. Post-dam removal studies should be used as comparisons.

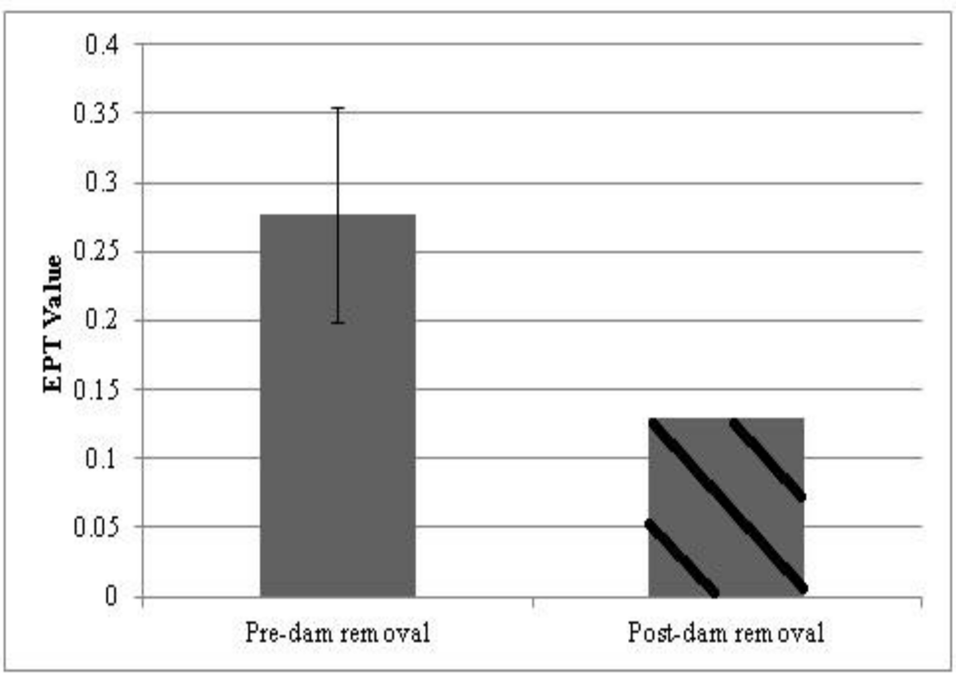


Fig. 7 A chart indicating post dam removal assessment using EPT scores. Diagonal bars on post-dam removal indicate predicted values.

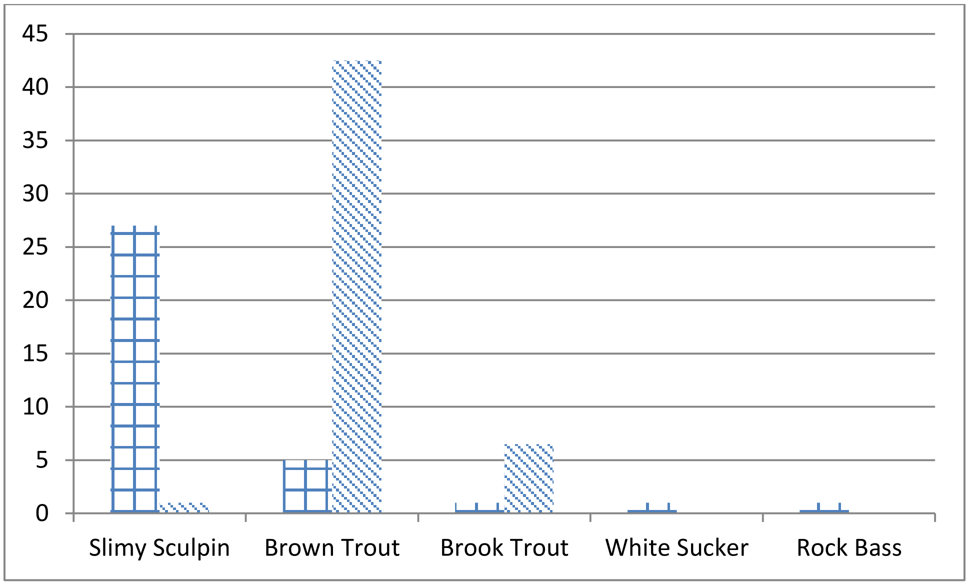


Fig. 8 A figure showing average number of fishes observed in snorkeling (diagonal lines) and electrofishing (grid) sampling methods for site 1.

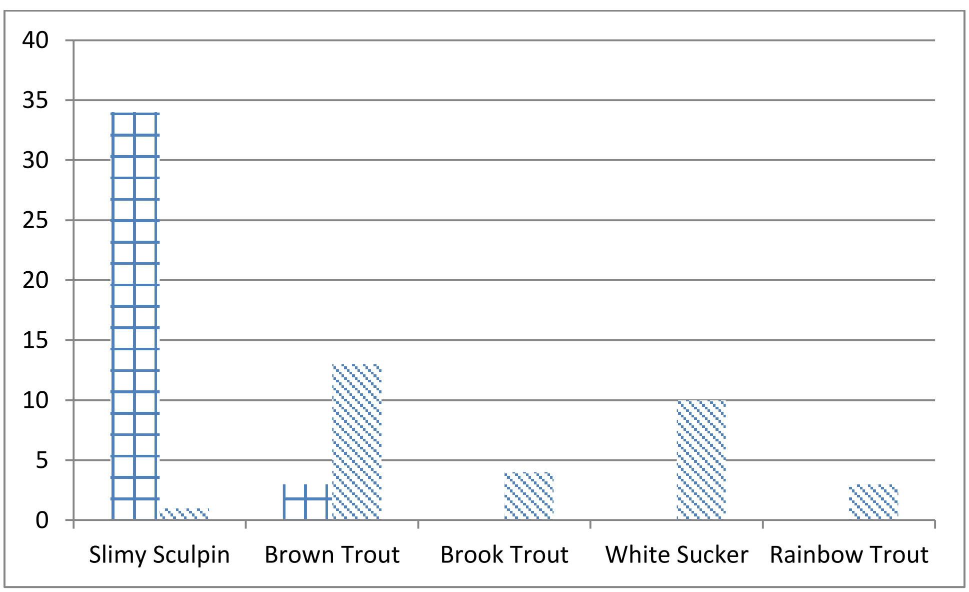


Fig. 9 A figure showing average number of fishes observed in snorkeling (diagonal lines) and electrofishing (grid) sampling methods for site 2.

The main branch of the Maple River was found to be in excellent condition. When assessed using the GLEAS 51 procedure, both sampling sites scored excellent. Greater than 50 percent of substrate was cobble in both sampling sites followed by sand then woody debris then macrophtye. The variety of substrate provides many different types of habitats for stream communities. The diversity of macroinvertebrates species that we observed also shows that river is in healthy condition. Trout was the dominate fish species found in the river showing that it has cold oxygenated water.

We found that gatherers and collectors was the highest proportion of function feeding macroinvertebrate group observed. This attributed from the affects dams have on downstream habitats. Course particulate organic matter settles above the dam within the flow along with fine sediment (Kondolf 1997). The accumulated fine matter spills over the dam and travels downstream. This is a perfect habitat for gatherers and collectors. This can also explain the similar proportion of filtering collector macroinvertebrates that we observed. Doyle et al. (2005) found that macroinvertebrate communities were indistinguishable at upstream and downstream sites following dam removal in only a year. Lessard and Hayes (2003) found that EPT scores related mostly to stream size instead of level of sedimentation. This shows that macroinvertebrate species are resilient to disturbances for dam removal. Post dam studies should be done within a year of removal because of these recovery speeds. The amount of sediment deposition downstream depends on the amount accumulated above the dam, time of release, style of release, and stream width (Bednack, 2001).Depending on the controllable factors (time and style of release); macroinvertebrate communities could serve as measure of river status and recovery speed. As Fraley (1979) observed macroinvertebrate communities decreased in diversity directly below the dam but were higher farther downstream. From this we can predict that there will be a decrease in diversity at our first dam site and possibly higher diversity at our second site following dam removal. The severity of macroinvertebrate community displacement depends on dam removal techniques.

The displacement of macroinvertebrate communities can have negative effects on fish species because they are an important food source. One species common to cold water streams are the *Salmonids,* which include trout and salmon .These fish need a certain type of habitat in order to gather food and spawn. This depends on the substrate available and the amount of substrate a fish can move with its tail. Dams have a large impact on these species because the increased fine sediment fills in loose cobble making it more difficult for these *Salmonids* species to gather food and spawn (Kondolf and Wolman 1993). This could be a reason for the higher fish abundances found at our downstream site. The Maple River is valued for its trout populations because of high quality recreational fishing and stocking of trout species (Creaser and Brown, 1927). This is reflected in our data as the dominant species in our snorkel surveys were *Salmonids* (Fig. 4 and5).

Of the Salmonid species, brown trout (*Salmo trutta*) was found to be the most abundant species on average. We observed approximately 30 brown trout in our downstream site. The upper braches of the Maple River are known to be more populated by brook trout but there are less competitive in warmer waters (Lessard and Hayes 2003). Temperature variations from the Lake Kathleen waters could have attributed to the higher abundances of brown trout. Also, brook trout are less aggressive then brown trout in foraging for food, competing for spawning areas have slower growth rates, and wider range of prey. The observed fish community distributions could have been sampling technique. Snorkeling surveys could have been biased towards brown trout because of their greater range of habitat type. We also observed many slimy sculpin at the two sites. This species of fish is adapted to riverine habitats because it feeds on benthos and lives in woody debris and cobble substrates (Rosenfeld, 2000). Sculpins are also preyed on by brown trout which could hint as to why we saw greater brown trout abundance in site 1. However, this could have been from methodology bias in snorkel surveys.

Sediment deposition does not only affect habitats physically but chemically as well. Our nutrient data shows that Lake Kathleen has more than double the amount of total phosphorus. A release of this sediment could affect downstream habitat chemical composition by supplying a limiting nutrient. This can cause eutrophication and increased phosphorus precipitate because of the oxygenated waters (Dodds and Whiles, 2010). Chemical data should be taken following dam removal to give insight on changes to nutrient input and cycling from the dam.

In addition to increased sediment deposition, temperature fluctuations downstream of dams also occur. Lake Kathleen is a shallow reservoir lake that has a surface area of 43 acres. The warm shallow water pours over the dam affecting downstream communities. Potential thermal barriers created by the varying water temperatures could force the cold water *Salmonid* species farther downstream (Gillilan and Brown 1997). However, these temperature fluxes in water are equaled out with the air downstream (Brooker, 1981).This along with groundwater inputs allow the river to return to its original temperature but still forces cold water fish species downstream (Lessard and Hayes 2003).

This allows fish species that are more adapted to warmer waters to exist there. This can be seen in our observations. The white sucker we observed in site 1 and 2 are a species that is known to travel in streams during spawning but are found primarily in lakes and are adapted to warmer waters similar to the rock bass we observed in site 2. These species are likely to have come from Lake Kathleen by traveling over the dam. Post dam removal studies should look at the spatial distribution and abundance of these species along with other fish species found in Lake Kathleen.

This study show some effects of a dam on downstream communities. The main factor is sediment deposition since it affects many other factors important to species functionality. Temperature fluxes in from the dam can cause thermal barriers. However, these changes are equaled out with the air downstream and ground water inputs. Post dam removal studies should focus on two main things: change in habitat type and substrate with distance from the dam, and the types of fish species present and their spatial distributions in relation to the dam. Macroinvertebrate communities in relation to the dam can provide information on fish communities and distributions. These factors can determine the status of the stream after and during dam removal giving insight on removal techniques and their effects on stream communities

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