Sediment Physical and Chemical Analysis on Lake Kathleen and the Maple River

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Run-of-the-river dam removal can often be a very destructive practice, even though the end goal intentions of restoration are good. Very little research currently exists on how rivers respond to dam removal, and how long certain factors such as fish life and geomorphology take to recover completely. The Lake Kathleen Dam in Pellston, MI will be removed sometime in the following two years, so it provides us with the opportunity for baseline research to compare to once the dam is finally removed. We collected benthic sediment samples from ten sites on Lake Kathleen using an Eckmann Grab, and from five sites on the Maple River Combined Branch using a transect across the riverbed at each site. We analyzed these samples for nutrient and carbon levels, as well as ran them through a sieve series in order to quantify the distribution of benthic sediment size for each site. We used these data to make predictions on how the sediment erosion following dam removal will effect ecosystem factors. Once more data is collected after the dam is removed, and compared to what we have collected here; we hope that this project can help inform the potential ecosystem outcomes for future dam removal projects.

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Benthic Sediment Analysis on Lake Kathleen and the Maple River Combined Branch

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Abstract

Run-of-the-river dam removal can often be a very destructive practice, even though the end goal intentions of restoration are good. Very little research currently exists on how rivers respond to dam removal, and how long certain factors such as fish life and geomorphology take to recover completely. The Lake Kathleen Dam in Pellston, MI will be removed sometime in the following two years, so it provides us with the opportunity for baseline research to compare to once the dam is finally removed. We collected benthic sediment samples from ten sites on Lake Kathleen using an Eckmann Grab, and from five sites on the Maple River Combined Branch using a transect across the riverbed at each site. We analyzed these samples for nutrient and carbon levels, as well as ran them through a sieve series in order to quantify the distribution of benthic sediment size for each site. We used these data to make predictions on how the sediment erosion following dam removal will effect ecosystem factors. Once more data is collected after the dam is removed, and compared to what we have collected here; we hope that this project can help inform the potential ecosystem outcomes for future dam removal projects.

Introduction

Run of the river dams provide immense services in our urbanized world including but not limited to generating electricity and flood control. Dams store water to be used for human-purposes or account for river flow fluctuations. However, in this process the level of water upstream from the dam is dramatically raised sometimes to the extent where it leads to a man-made lake system (McCully).

The changes in river channel form caused by removing these dams can affect ecosystem parameters such as riparian function, macroinvertebrate and fish life, and nutrient dynamics (Doyle et al., 2005). These parameters are greatly altered by the construction of a dam, and each one takes varying rates of time–ranging from months to decades– to recover completely (Doyle et al., 2005).

However, full recovery of a river to its pre-dam conditions following removal is not guaranteed. Following dam removal, a river may follow two trajectories: it can fully recover to pre-dam conditions or the ecosystem may only partially recover due to the long-term damage caused to the system by the presence of a dam. What determines which trajectory a river will follow is likely determined by how sensitive each ecosystem parameter is at an individual river (Doyle et al., 2005).

Dam removal is a relatively recent procedure that has gained attention and popularity. Many dams are out-of-date or ecologically damaging to a river system and therefore should be removed. Because of how new this practice is, there is a lot of potential for research that helps to illustrate how different river systems could respond to dam removal (Hart et al., 2015).

The Maple River in Pellston, MI consists of two branches–East and West– that combine to form a combined branch through a run of the river dam. The construction of this dam has created an artificial lake where the East and West Branches meet called Lake Kathleen. The Conservation Resource Alliance of Traverse City, MI is commencing the Lake Kathleen Dam Removal Project that will eventually remove this dam, draining the lake, and restoring the Maple River's riverine system.

Benthic sediment plays a very important role in aquatic ecosystems like the Maple River. The sediment that has built up at the bottom of Lake Kathleen is much different than the benthic sediment seen on the Maple River Combined Branch. Once the dam is removed, this sediment will be transported downstream and impact plant life, macroinvertebrate habitats and riverbed geomorphology.

No ecological research has ever been conducted on Lake Kathleen. Our project seeks to test sediment samples collected from Lake Kathleen and the Maple River Combined Branch for chemical composition (nitrogen, phosphates, carbon, and mercury) as well as classify the benthic sediment make-up using the Wentworth Scale. By collecting this data, the potential effects of removing the Lake Kathleen

Dam will be illuminated. These measurements will also allow the Lake Kathleen Dam Removal Project to compare the river and lake to others that had dams removed with similar chemical and physical properties. This data will be used in conjunction with other interdisciplinary research being conducted on the Maple River.

Methods

Lake Kathleen

We collected ten sediment samples from ten different sites on Lake Kathleen on July 31st, 2015. Two sites were sampled near where the mouths of the East and West Branches empty into the lake. The remaining six sites sampled were scattered across Lake Kathleen. We collected the sediment samples at each site using an ekman grab and emptied into large plastic containers and placed in a cooler with ice to be processed later in the lab. At each site, we recorded the coordinates using a GPS. We also measured dissolved oxygen (mg/L) and temperature (ºC) using a dissolved oxygen meter, however this data was not incorporated into our dam removal predictions.

Maple River Combined Branch

We have chosen ten marked sites along the Maple River Combined Branch to collect sediment samples. Two separate methods of sediment collection will be utilized at each site. Firstly, we will create a transect across the riverbed at each site using a one-meter-squared PVC quadrat. We used a stainless steel gardening spade to collect the top layer of sediment in an X-formation, in order to collect a representative sample within each quadrat. This is done so that we could collect a profile of how the benthic layer varies moving across the riverbed.

Secondly, using a quarter meter-squared PVC quadrant, we collected the top 2cm of sediment for each present type of sediment at each site. For example, if a site had cobble and sandy sediment present across the riverbed, we collected two quadrats from both of these areas to be analyzed for chemical composition and mercury levels. We stored all samples in plastic containers and Nalgene bottles to be processed in the lab.

Sample Processing

After collecting the samples, we prepare and process them in a variety of ways. For the chemistry tests we conducted on the samples, three separate Falcon centrifuge tubes and a 500mL Nalgene bottle were filled with sediment samples from each site and frozen. Three separate chemistry tests were conducted on these subsamples to determine phosphate, nitrate/ammonia, and carbon/nitrogen levels respectively at each site. Another wet sediment subsample weighing ten grams was dried at 60ºC for 48 hours to determine the dry weight of the benthos. For the river sites, these subsamples were taken from the quarter meter-squared quadrants.

In order to classify the physical size classes of the sediment makeup a sediment collector tube was used to collect an equal wet sample from the five lake sites we chose to measure and all five of the lake sites sampled. We placed the subsamples in pie tins and allowed them to dry for approximately 48 hours in an oven at 100 degrees Celsius. Once the samples were dry, we sifted each one through a >3mm sieve to remove all pebbles and cobbles and then through a subsequent sieve series composed of many different sizes. The sieve sizes openings we used were 2mm, 1/2mm, 1/8mm, 1/16mm and a collector that caught any sediment less than 1/16mm. Each subsample was poured into the sieve series and then placed on a sieve shaker for one minute. We then weighed the amount of sediment in each sieve to obtain the size distribution for the substrate at each site.

For the pebbles and cobbles greater than 3mm, we used digital calipers to measure and classify at least 100 rocks from each sample using the Wentworth Scale.

Statistical Analyses

Once we collected the particle sizes for the sediments at each site along with the results of the various chemistry tests conducted, some statistical analyses were conducted using the computer program SPSS. The first is a T-test between the carbon and nutrient levels for Lake Kathleen and the Maple River Combined Branch. The second test involved a chi-squared test on the sediment size distribution between lake and river sites. We did this by totaling the masses of sediment for each size class across the five lake and river sites, respectively.

Results

Sampling Maps

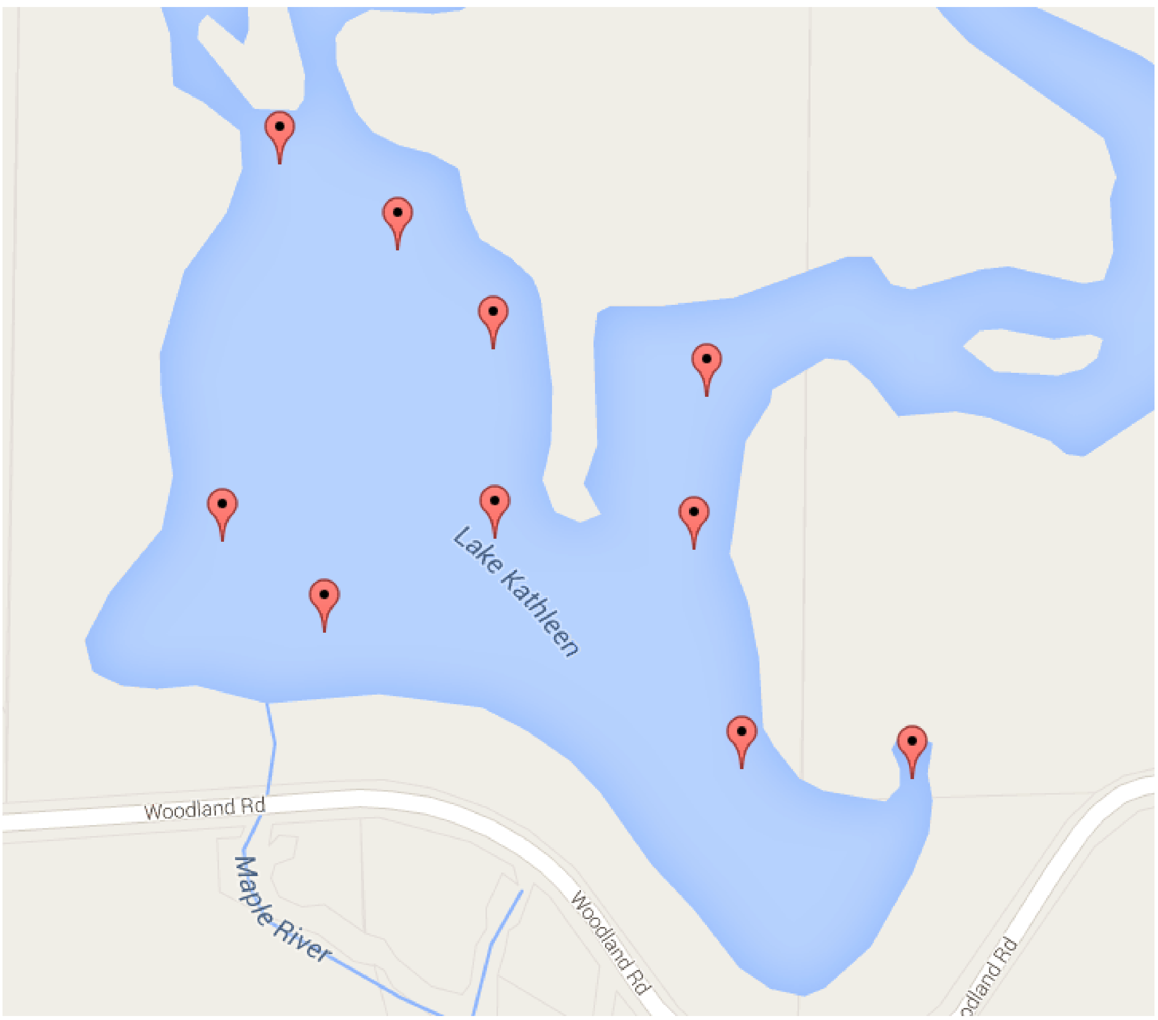

Figure 1: Sites A-J on Lake Kathleen

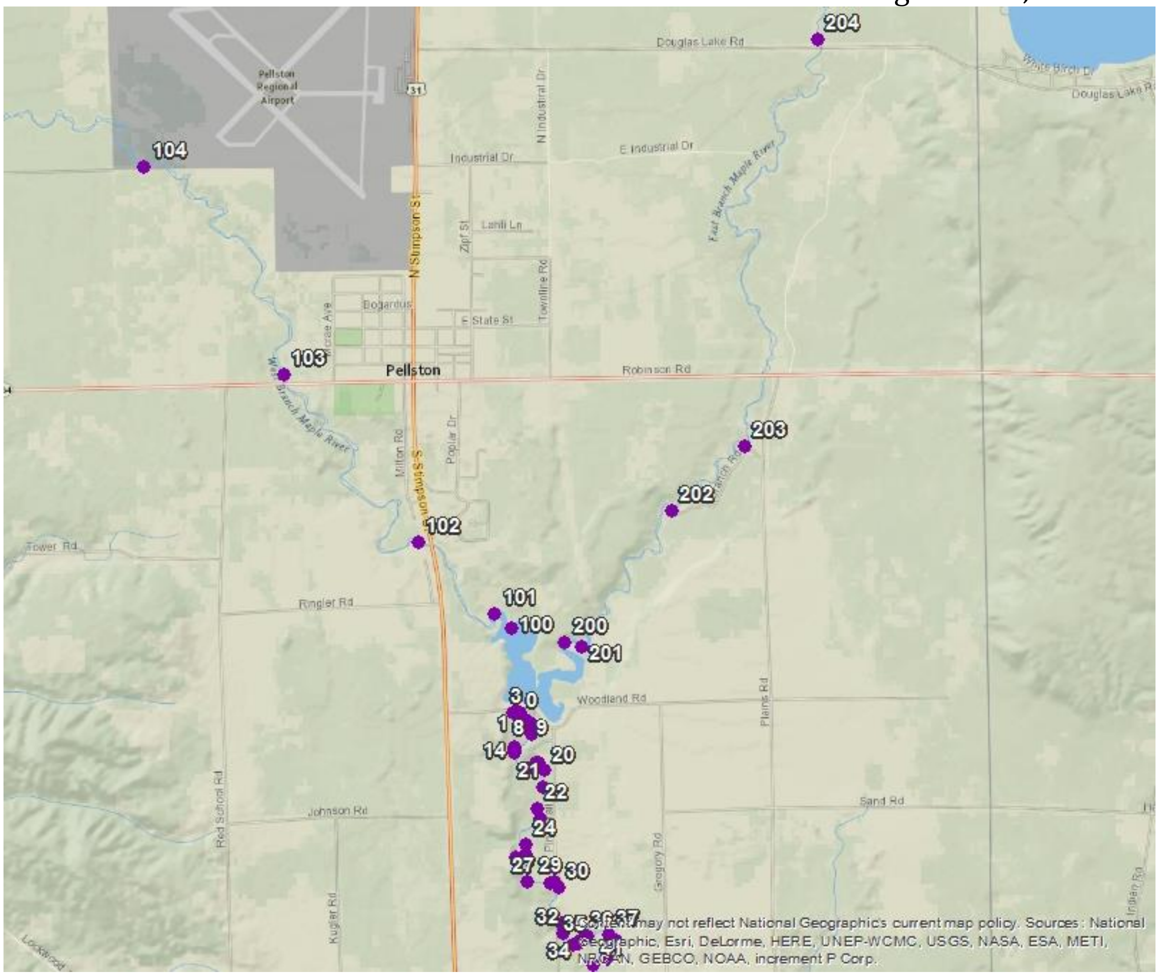

Figure 2: List of Total Sites on Maple River, with our sites located near bottom of Map

Chemistry Tests

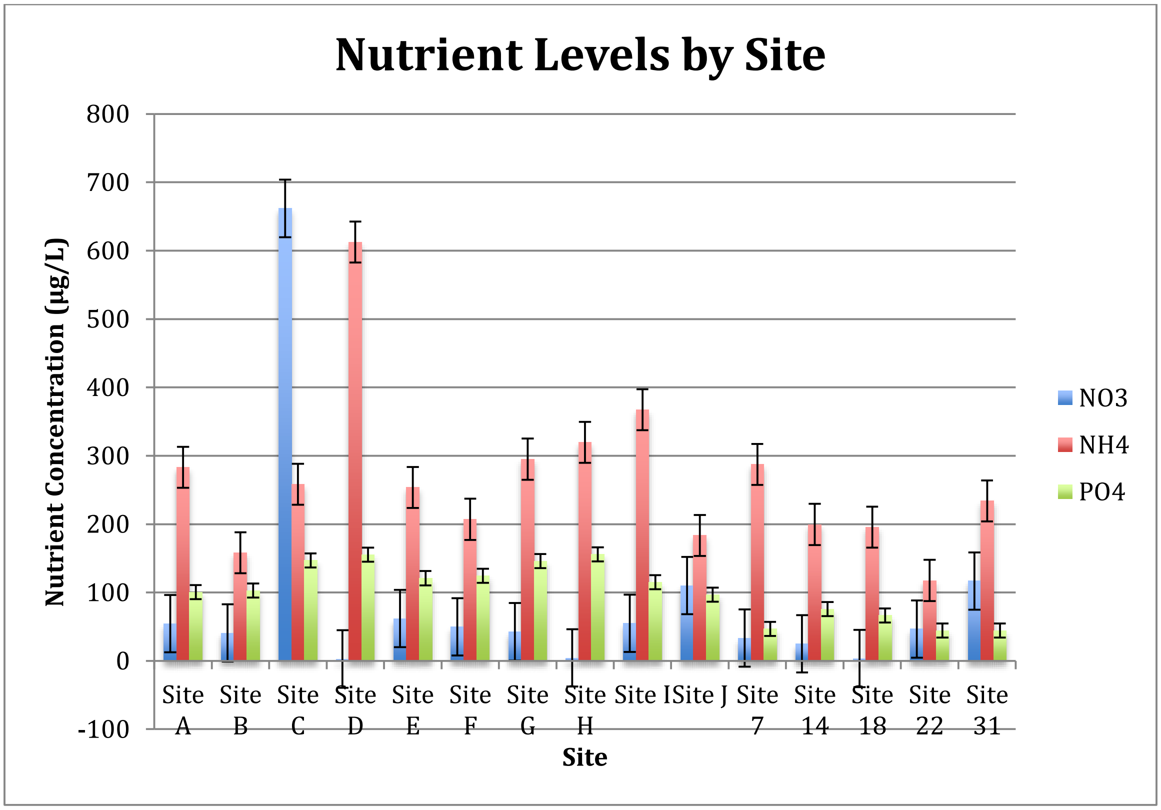

Figure 3: NO3, NH4, and PO4 levels by site

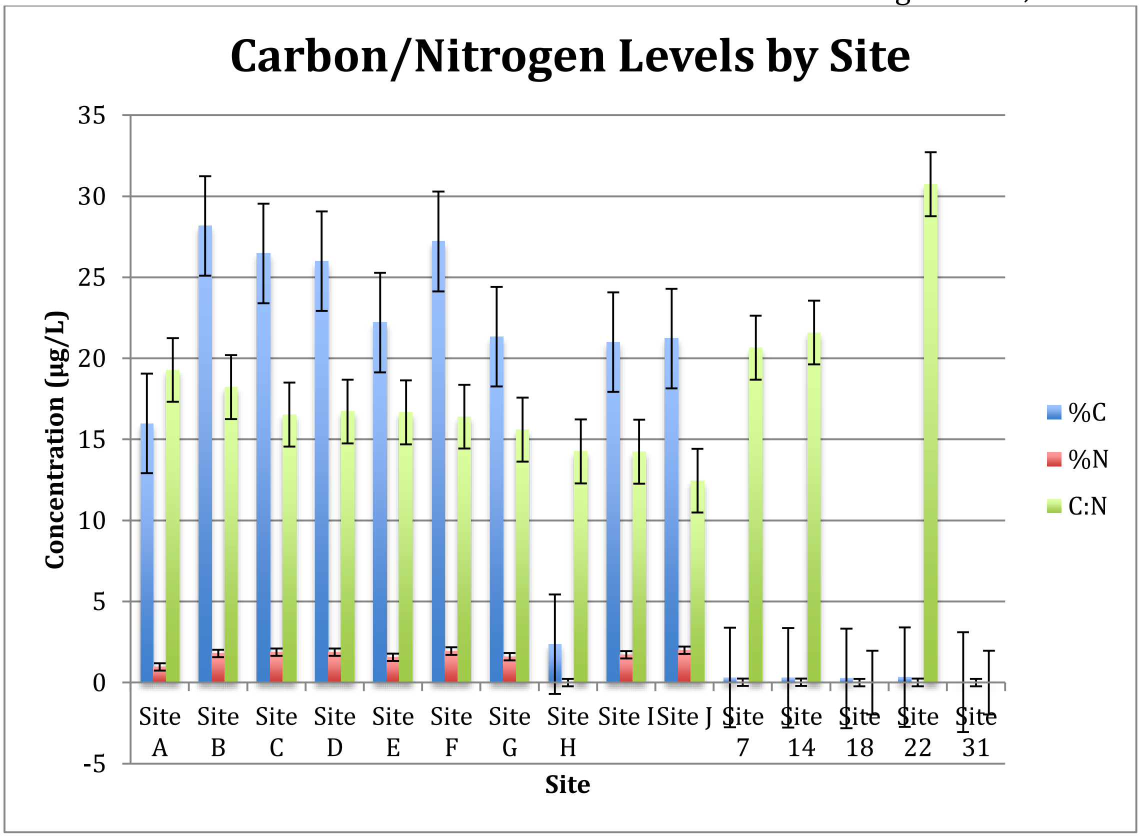

Figure 4: Percent Carbon, Nitrogen and Carbon to Nitrogen Ratios by Site.

Sediment Size Classification

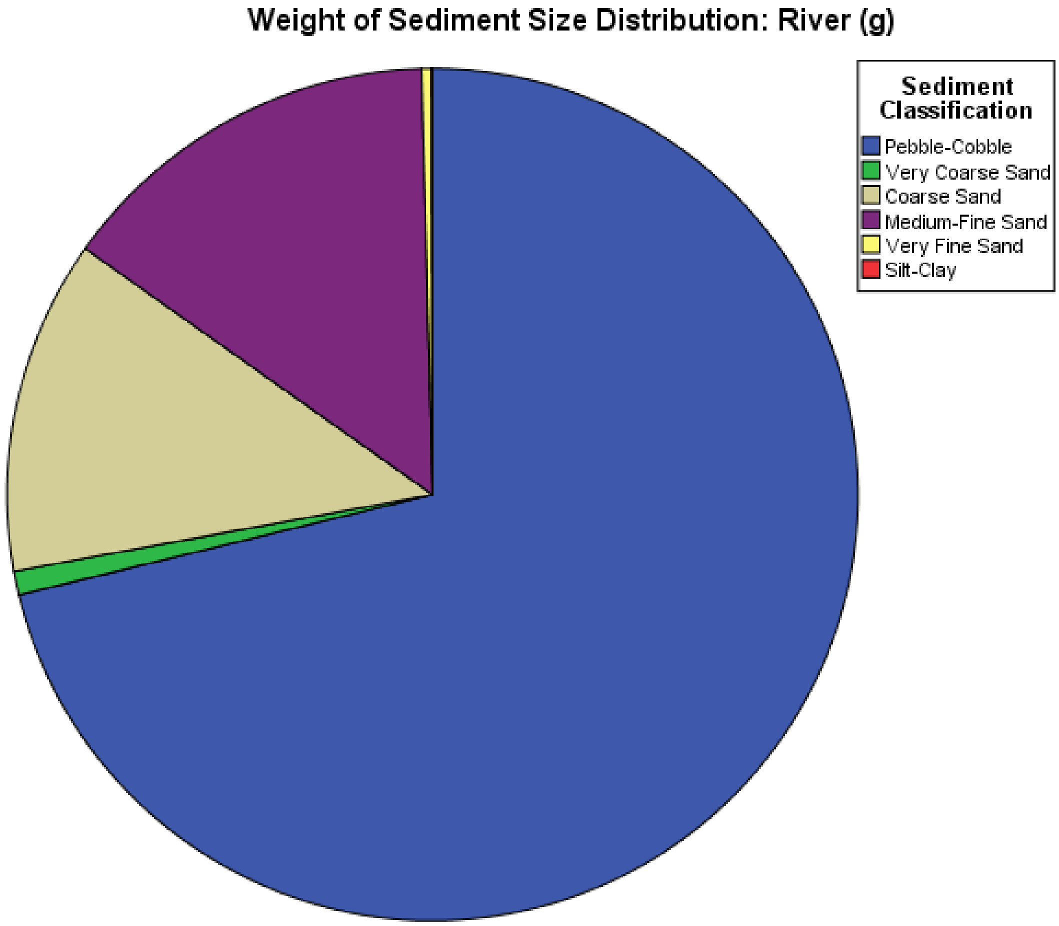

Figure 5: Sediment Size Distribution by Weight for Maple River Combined Branch Sites

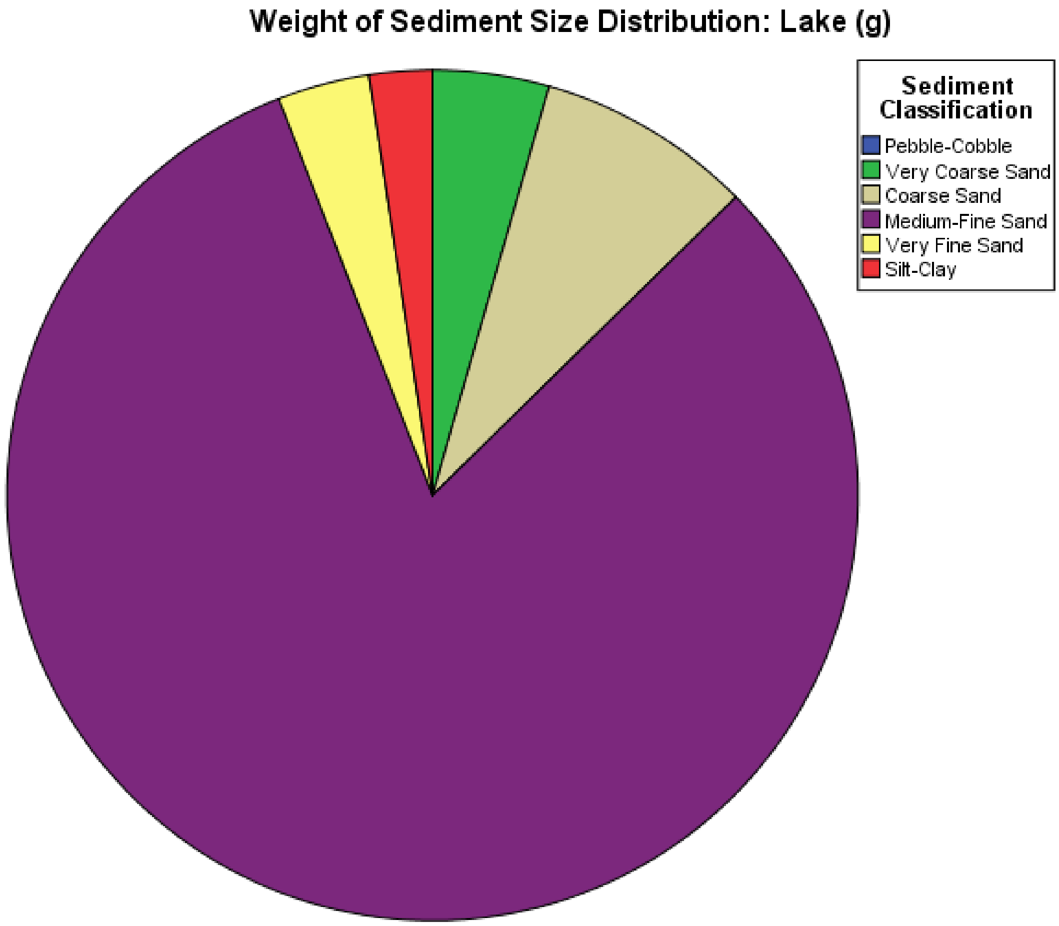

Figure 6: Sediment Size Distribution by Weight for Lake Kathleen Sites

Statistical Analyses

For the various t-tests we conducted on the nutrient, carbon and nitrogen levels between lake and river sites we observed some significant differences. For NO3 ($t=0.689$, $df=13$, $p=0.497$) there was no statistically significant difference between Lake Kathleen and the Maple River Combined Branch. For NH4 ($t=1.413$, $p=0.181$, $df=13$) there was also no statistically significant difference. For the carbon to nitrogen ratio ($t=0.231$, $df=4.083$, $p=0.829$) there was also no statistically significant difference. On the other hand, for PO4 concentrations ($t=6.243$, $df=13$, $p<0.001$), carbon levels ($t=6.054$, $df=13$, $p<0.001$) and nitrogen levels ($t=5.452$, df=13, $p<0.001$) we observed a statistically significant difference between Lake Kathleen and the Maple River Combined Branch.

For the chi-squared test we conducted on the sediment size distributions between each site, we observed statistically significant differences for both Lake Kathleen (X^2= 1589.896, df=4, $p<0.001$) and the Combined Branch (X^2=15123.597, df=5, $p<0.001$).

Discussion

Our results paint a picture of the state of Lake Kathleen and the Maple River Combined Branch prior to the removal of the Lake Kathleen Dam. There are many ecosystem parameters that will change once the dam is removed such as macroinvertebrate communities, riverbed form, fish communities, algal growth and primary production. Some of these parameters take longer to recover than others following the removal of a dam (Doyle et al., 2005).

Our results show a significant difference of nitrogen, carbon and phosphorous levels between the lake and river sites sampled. All three of these aspects are relatively higher in Lake Kathleen than in the Maple River. This means that when the dam is removed these elements and nutrients will be transported and deposited downstream. According to Doyle et al., 2005, nutrient retention was not affected much by the initial removal of the dam. On the other hand, nutrient retention appears to be affected more by the riverbed form, which is a parameter that can take years to recover from such a disturbance event (Doyle et al., 2005). Because of this, the difference in phosphate between Lake Kathleen and the Maple will likely lead to an initial increase in phosphate levels, but as time goes on the nutrient retention of the river system will even out as the riverbed form nears recovery.

However, the high levels of carbon and nitrogen trapped in the lake's sediment will have a greater effect on the river ecosystem. Although the sediment in Lake Kathleen is technically part of the same ecosystem as the West and East

Branches of the Maple River, it is considered allochthonous carbon to the Combined Branch since the dam currently prevents it from being transported downstream. Once the dam is removed, this allochthonous carbon and nitrogen will lead to the potential for an increase in primary productivity and algal bloom growth. Because there is such a significant difference in nitrogen and carbon levels between the lake and river ecosystems, this potential increase in algal blooms and primary productivity could have negative effects.

Especially since the riverbed form, and sediment size distribution will change greatly following the dam removal, this will change the river ecosystem completely. Our data shows a significant difference in sediment size distribution across all sites on the river and lake. Because of this erosion and increased sediment deposition will be present following dam removal. Higher inputs of fine sands, silts and pebbles in addition to nutrient inputs will affect macroinvertebrate populations as well as where certain aquatic plants can grow. If aquatic plants are decimated, algae can take over and flourish. The potential for flourishing algal bloom populations could lead to anoxic aquatic environments unsuitable for fish life. Especially since fish populations take up to decades to recover after dam removal (Doyle et al., 2005) the potential for an anoxic environment could be extremely dangerous to the river ecosystem.

<u>References</u>

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