Potential consequences from Maple River dam removal based on sediment properties

Jacqueline Smith

University of Michigan Biological Station
EEB 381 – General Ecology
8/17/2015
Dr. Shannon Pelini

Abstract

The oxymoron of dam removal brings to question its practicality. The process of removing it is an ecological disturbance, yet it repairs river ecosystems by reversing harmful effects from the dam's existence. Lake Kathleen is the impoundment-formed-lake of the Maple River Dam, and with the dam's impending removal, knowledge about what lies within the lake and river is important. We sampled in Lake Kathleen and along the Maple River to discover chemical and physical properties of the sediment, to understand possible ecological effects of the dam's removal. Carbon (C), nitrogen (N) and phosphate (PH_4) levels differed in Lake Kathleen, as did sediment size. However, no difference was found for nitrate (NO_3) levels, ammonium (NH_4) levels or ratio of C to N (C:N). These findings provide valuable information in regards to possible consequences of the dam's removal on the Maple River. This project is the first of its kind, by studying ecological components before and after dam removal.

Jacquie Smith
General Ecology – Pelini
Group Manuscript

Potential consequences from Maple River dam removal based on sediment properties

Abstract

The oxymoron of dam removal brings to question its practicality. The process of removing it is an ecological disturbance, yet it repairs river ecosystems by reversing harmful effects from the dam's existence. Lake Kathleen is the impoundment-formed-lake of the Maple River Dam, and with the dam's impending removal, knowledge about what lies within the lake and river is important. We sampled in Lake Kathleen and along the Maple River to discover chemical and physical properties of the sediment, to understand possible ecological effects of the dam's removal. Carbon (C), nitrogen (N) and phosphate (PH_4) levels differed in Lake Kathleen, as did sediment size. However, no difference was found for nitrate (NO_3) levels, ammonium (NH_4) levels or ratio of C to N (C:N). These findings provide valuable information in regards to possible consequences of the dam's removal on the Maple River. This project is the first of its kind, by studying ecological components before and after dam removal

Introduction

Dams and their removal have negative, ecological effects on their surrounding ecosystem. Dam effects on riparian ecosystems are one example, as they prevent continual flow of water, nutrients and sediment downstream (Oey, 2015). This disruption of flow can have just as serious consequences on the ecosystem once the disruption is removed, including on riparian vegetation, nutrient dynamics and fish, macroinvertebrate and mussel communities (Doyle *et al*, 2005). Despite potential effects on these ecological components, dam removal is becoming more common for river restoration purposes (Stanley and Doyle, 2003).

Downstream deposition creates a substantial ecological disturbance, as dams collect decades of sediment and its removal releases this collection downstream (Tullos *et al*., 2014). Erosion from this large release of sediment decreases oxygen availability and increases turbidity downstream, which can impact re-vegetation and organism return. Knowledge of what is located in the impoundment area is therefore important to understand what will be released downstream.

Removal for the Maple River Dam near Pellston, Michigan will occur summer 2016. Lake Kathleen, the impoundment-formed-lake, is located at the confluence of the East and West Branches of the Maple River. Prolonged inactivity has led to the decision of its removal. The consequence of its removal is unknown, as virtually nothing is known about Lake Kathleen. This will affect river flow, and everything at the bottom of the lake will be swept downstream. Research is being done currently to discover more about what lies in Lake Kathleen and in the Maple River to see how it will be affected by the dam's removal.

Our aim is to add sediment information to the Maple River Project to understand how the dam removal will affect erosion and chemical composition along the combined branch of the Maple River. We predicted that both chemical and sediment composition would differ between Lake Kathleen and the Maple River. For example, sediment proportions would favor finer particles and C levels would be higher in the lake compared to the river. We looked at the physical and chemical composition of sediment in the Maple River and Lake Kathleen, and interpreted our data to see if any relationship existed between the sites and physical and chemical composition. This will provide some knowledge on what is located in the lake and riverbed, and how this could affect the Maple River once the dam is removed.

Methods

Sediment Collection

We collected from fifteen sites overall, ten in Lake Kathleen and five along the Maple River. At Lake Kathleen, the sites were randomly chosen and marked using a GPS unite (Figure 1). At each location we used an Eckman dredge to collect a sediment sample that was placed in a plastic container and put in a cooler full of ice for better preservation. We then drained as much water possible from our sample and sub-sampled it into three 50mL centrifuge tubes and a Nalgene bottle. We then froze the samples, so we could run physical and chemical tests on them at the same time as our river samples.

On the Maple River we collected samples from five designated locations by the Maple River Project. At each site we picked the two most dominant microhabitats and set down a $1m^2$ PVC square and used a steel gardening spade to collect the top 2cm of soil. We placed our samples into plastic containers and held them in a cooler to later sub-sample them like we did the lake samples.

Sediment Analysis

To compare the sediment from the lake to the river, we weighed each sample and tested its physical properties. We used ten sites total, five from Lake Kathleen and five from the Maple River. To obtain its dry weight, we weighed 10g of wet sediment, dried it at 60°C for 48 hours, and reweighed it. We sieved the sediment to determine its physical properties and proportions of sediment type. Different sieve sizes determined size of the finer sediment, and digital calipers were used to measure larger cobble. We used the Wentworth scale to further classify cobble size.

We chemically analyzed sediment from all fifteen sites in the centrifuge tubes for NO_3, NH_4, PO_4, C and N measurements. To determine NO_3 and NH_4 amounts, we placed 2g of each sediment sample into 40mL of 2M solution of KCL. We shook this solution for sixty minutes and filtered it. To measure PO_4, we placed 0.2g of the sediment into Troug's solution and shook it for sixty minutes. We balanced sediment, dried it at 60°C for 48 hours and milled it to test its C and N components.

Statistical Analysis

We ran an independent T-test to see if a relationship existed between each nutrient and site (lake or river). We used a Chi-square test to determine if there was a significant difference between sediment proportions within Lake Kathleen or the Maple River.

Results

We found no significant difference between NO_3 and NH_4 levels in Lake Kathleen and in the Maple River. This is based on our independent t-test results for NO_3 (t-value = 0.698; degrees of freedom=13; p-value=0.497) and for NH_4 (t-value=1.413; degrees of freedom=13; p-value=0.181). This supports the null hypothesis that NO_3 and NH_4 levels do not differ in the lake and in the river. We also found no significant difference between C:N within Lake Kathleen and the Maple River (t-value=0.231; degrees of freedom=4.083; p-value=0.829).

We did find significant differences in PO_4, C and N levels between Lake Kathleen and the Maple River. This is supported by our independent t-test results for PO_4 (t-value=6.243; degrees of freedom=13; p-value=<0.001), for C (t-value=6.054; degrees of freedom=13; p-value=<0.001) and for N (t-value=5.452; degrees of freedom=13; p-value=<0.001).

The Chi-square test proved that there was a significant difference in sediment proportions in the lake (x^2=1589.896[a]; p-value=<0.001) and the river (x^2=15123.597[a]; p-value=<0.001), respectively. Therefore, we can reject our null hypothesis that sediment proportions in the lake and in the river are equal.

Discussion

We predicted that both physical and chemical properties would differ in Lake Kathleen compared to the Maple River. Our results supported this hypothesis for all chemical properties except NO_3, NH_4 and C:N. This implies that upon dam removal sediment and nutrient composition of the river will be altered, as everything held in Lake Kathleen will be released downstream. Higher concentrations of PO_4, C and N were found in the lake compared to the river (Figures 2, 3, 4). This influx of allochthonous nutrients after dam removal could potentially alter nutrient concentrations in the Maple River, affecting potential vegetation growth and organism return. Due to no significant differences in NO_3 and NH_4 levels, it can be predicted that their levels following dam removal will not change (Figures 5, 6).

We found that the lake sediment consisted mainly of medium-fine sand (as classified by the Wentworth scale) and contained no pebble or cobble (Figure 7). The river sediment consisted primarily of pebble and cobble (Figure 8). This indicates that there will be a large release of finer particles that could suffocate cobble and pebble ecosystems in the river.

This knowledge is vital to predict future effects on ecological components in the Maple River, such as on macroinvertebrate communities. While dam removal will negatively affect macroinvertebrate communities, they possess the quickest recovery time, with species richness recovering normally 3-7 years after removal (Hansen and Hayes, 2012). According to Hansen and Hayes (2012), however, macroinvertebrate densities could take a substantially longer time period to recover.

Macroinvertebrate populations rely heavily on habitat availability, and the high amount of cobble and pebble in the Maple River provides plenty of suitable habitats for macroinvertebrates (Doyle *et al*, 2005). The influx of finer sediment could engulf these areas, smothering the macroinvertebrates and decreasing the amount of suitable habitat for recolonization. Furthermore, the higher amounts of C, N and PO_4 in Lake Kathleen could help lead to higher concentrations in the Maple River following dam removal. These nutrients are beneficial to vegetation growth, which is necessary for the return of macroinvertebrates (Doyle *et al*, 2005). The large amounts of allochthonous C deposits are good for certain functional feeding groups of macroinvertebrates, such as shredders and gathering collectors, allowing for quicker recovery.

Dam removal is an ecological disturbance that has more effects than just on macroinvertebrate communities. There are biotic risks, such as to fish communities, mussel communities, vegetation and movement of invasive species upstream (Hart *et al*, 2002). Abiotic factors could be altered as well, such as water temperature, flow and moving of sediment (Hart *et al*, 2002). Although it is an ecological disturbance, dam removal is one of the most effective ways of eliminating harmful effects of dams on river ecosystems (Hart *et al*, 2002). It is therefore important to be aware of what is located in the impoundment area right before the dam and what lies beyond it, to fully understand possible ecological consequences of its removal.

Appendix

Figure 1

Map of Sampled Sites in Lake Kathleen

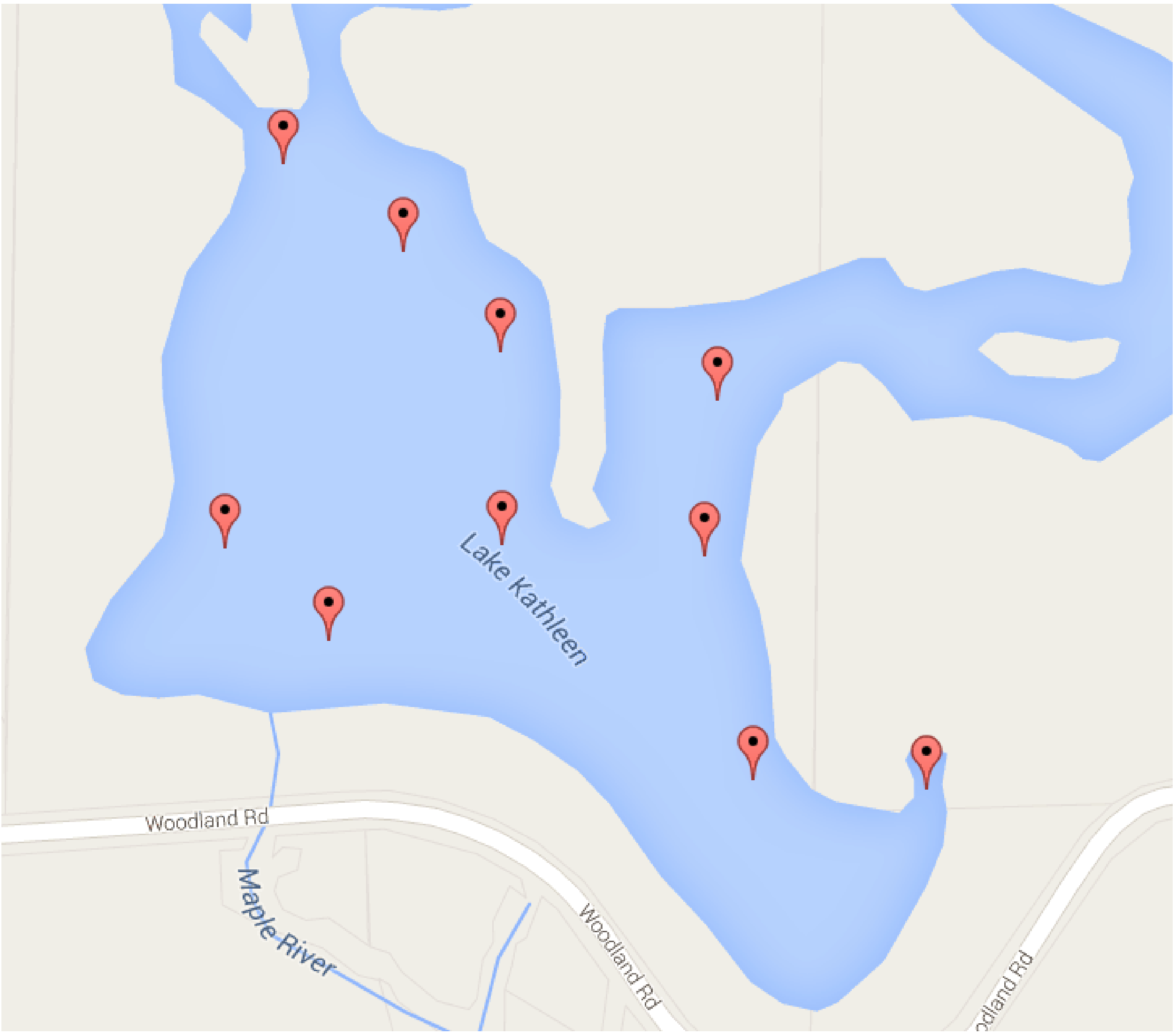


Figure 2

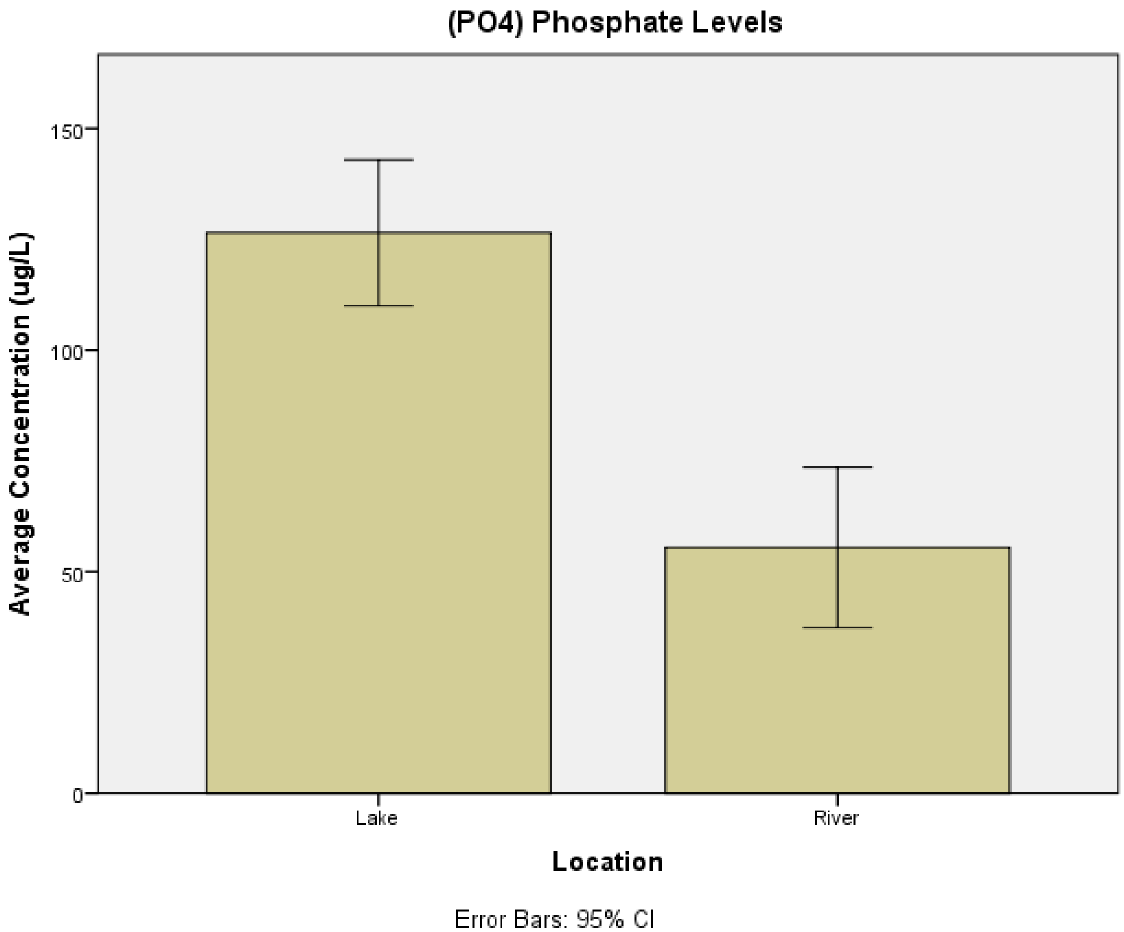

(PO4) Phosphate Levels
150
100
50
0
Average Concentration (ug/L)
Lake
River
Location
Error Bars: 95% CI

Figure 3

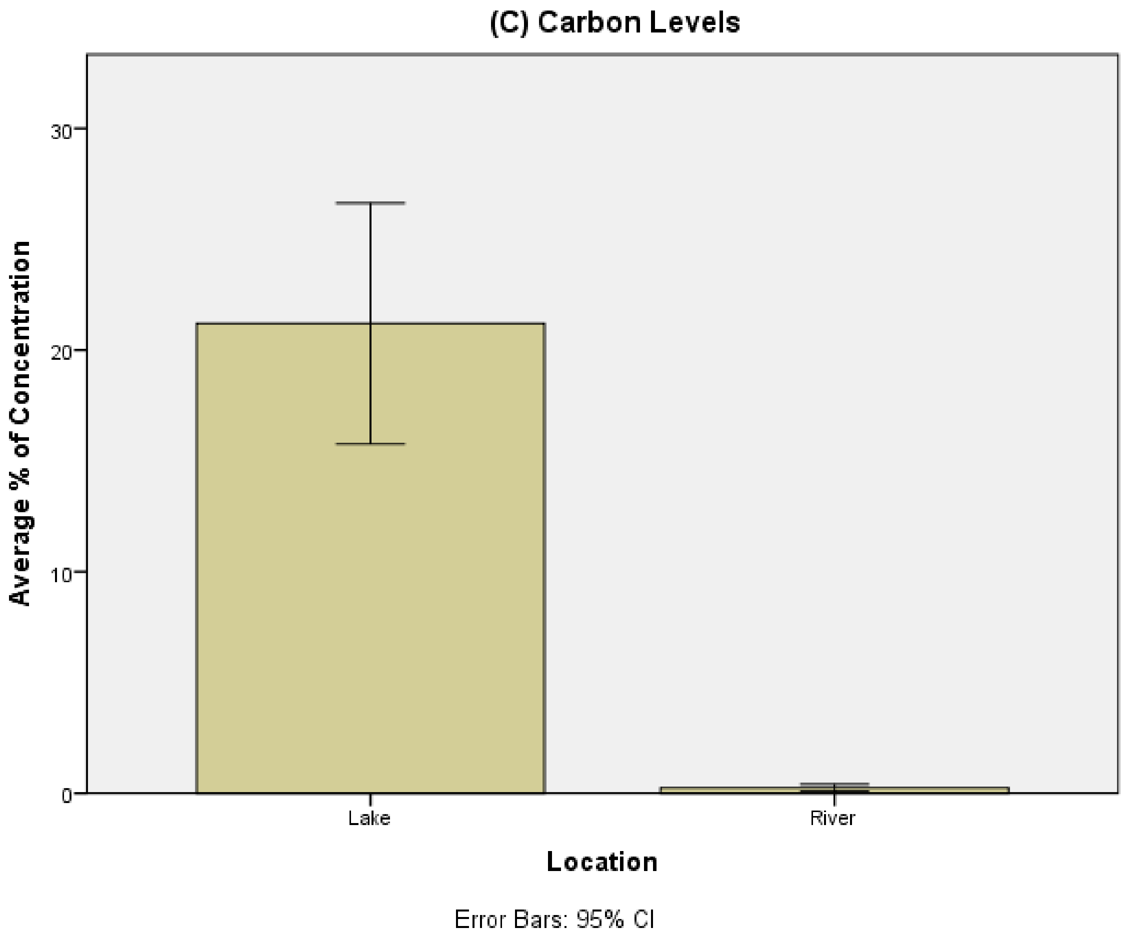

(C) Carbon Levels
Average % of Concentration
30
20
10
0
Lake
River
Location
Error Bars: 95% CI

Figure 4

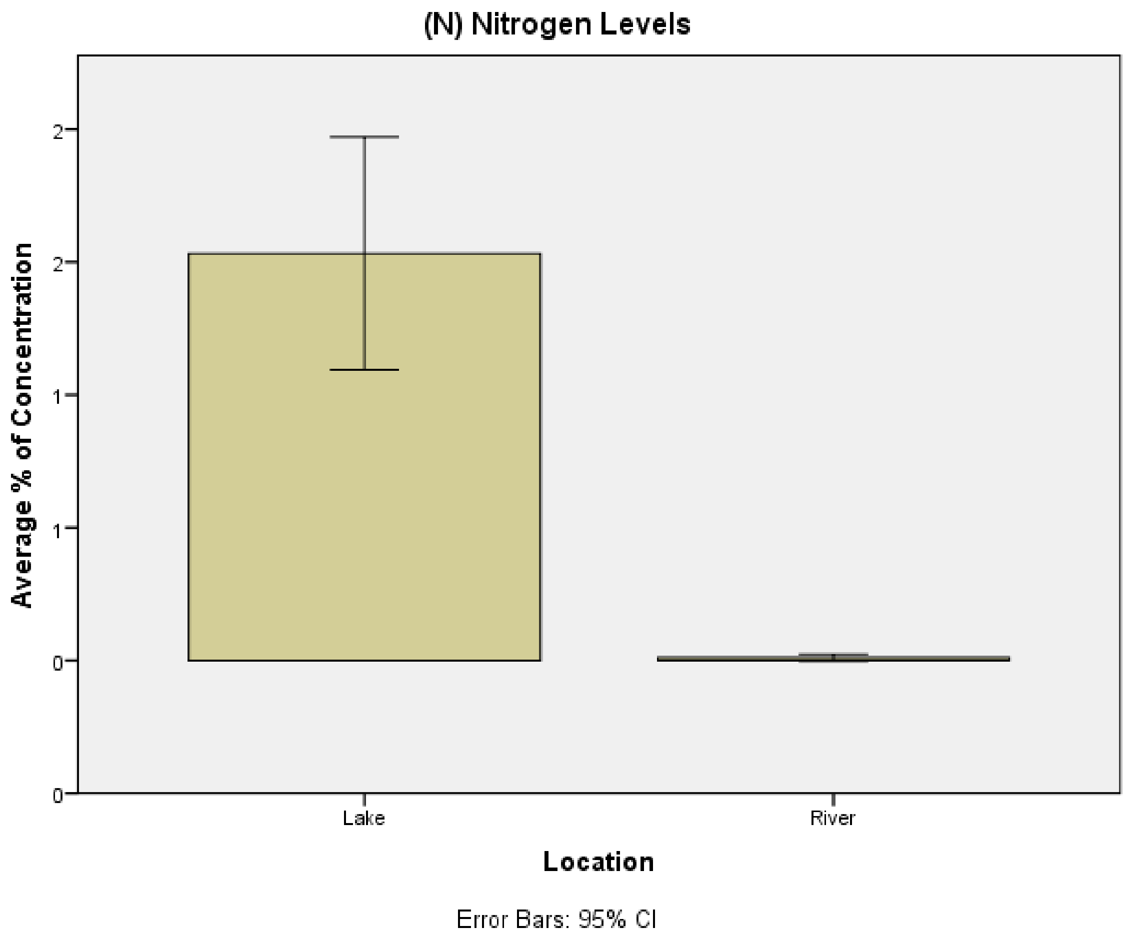

(N) Nitrogen Levels
Average % of Concentration
2
2
1
1
0
0
Lake
River
Location
Error Bars: 95% CI

Figure 5

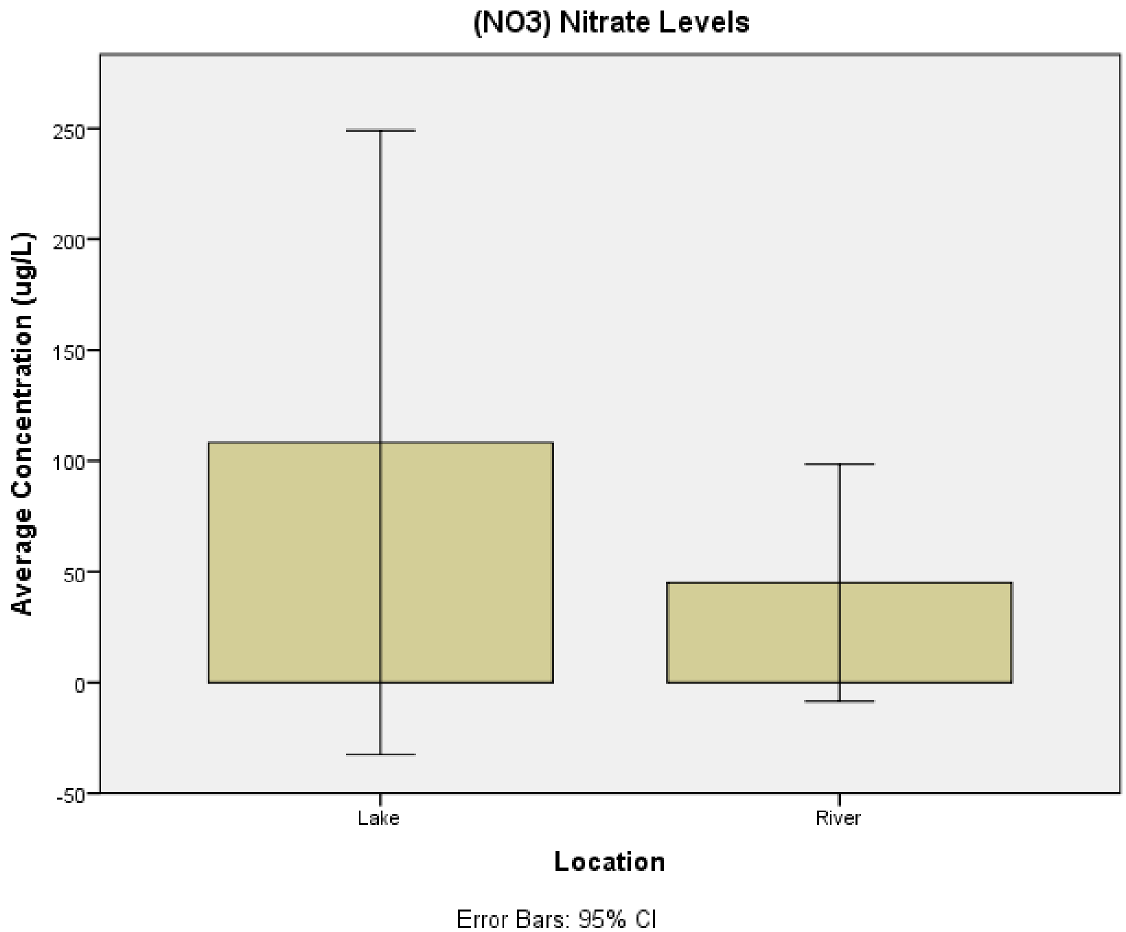

(NO3) Nitrate Levels
Average Concentration (ug/L)
250
200
150
100
50
0
-50
Lake
River
Location
Error Bars: 95% CI

Figure 6

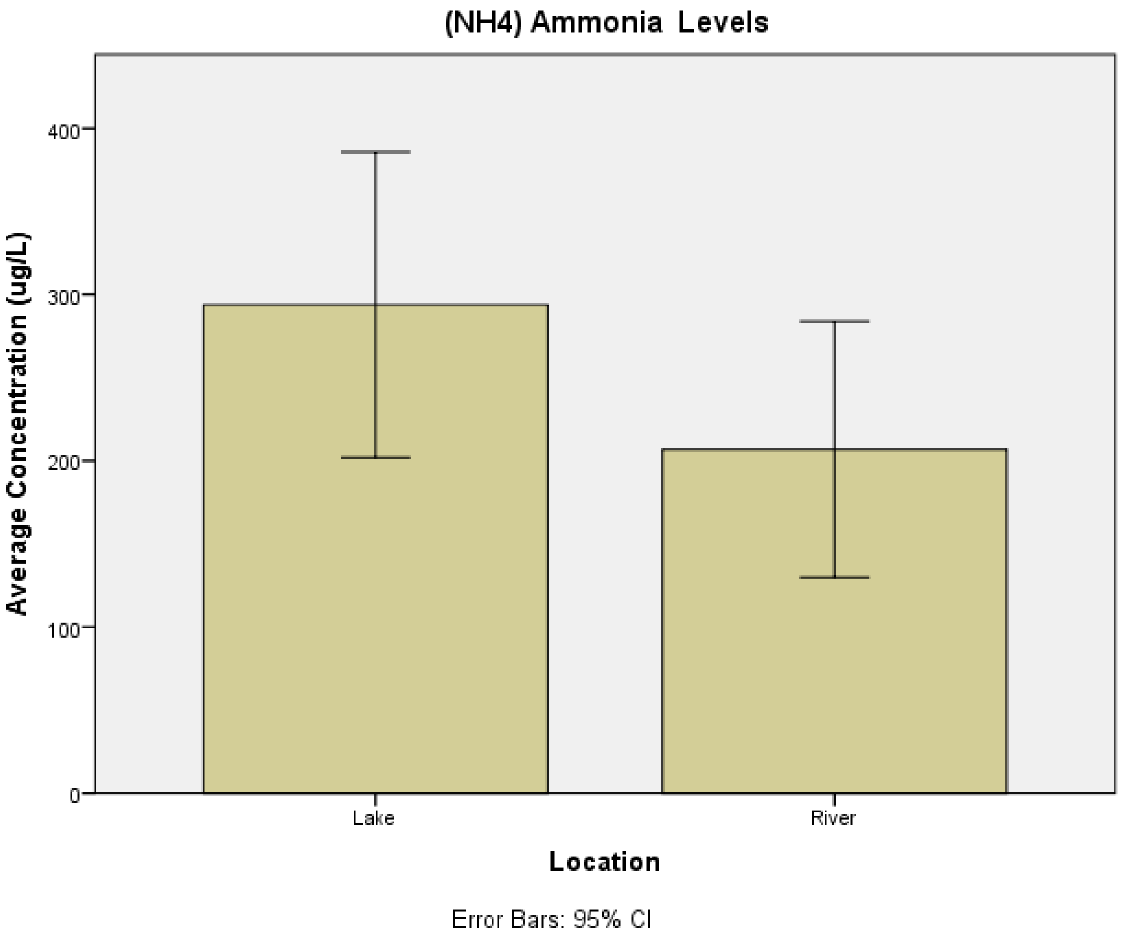

(NH4) Ammonia Levels
Average Concentration (ug/L)
400
300
200
100
0
Lake
River
Location
Error Bars: 95% CI

Figure 7

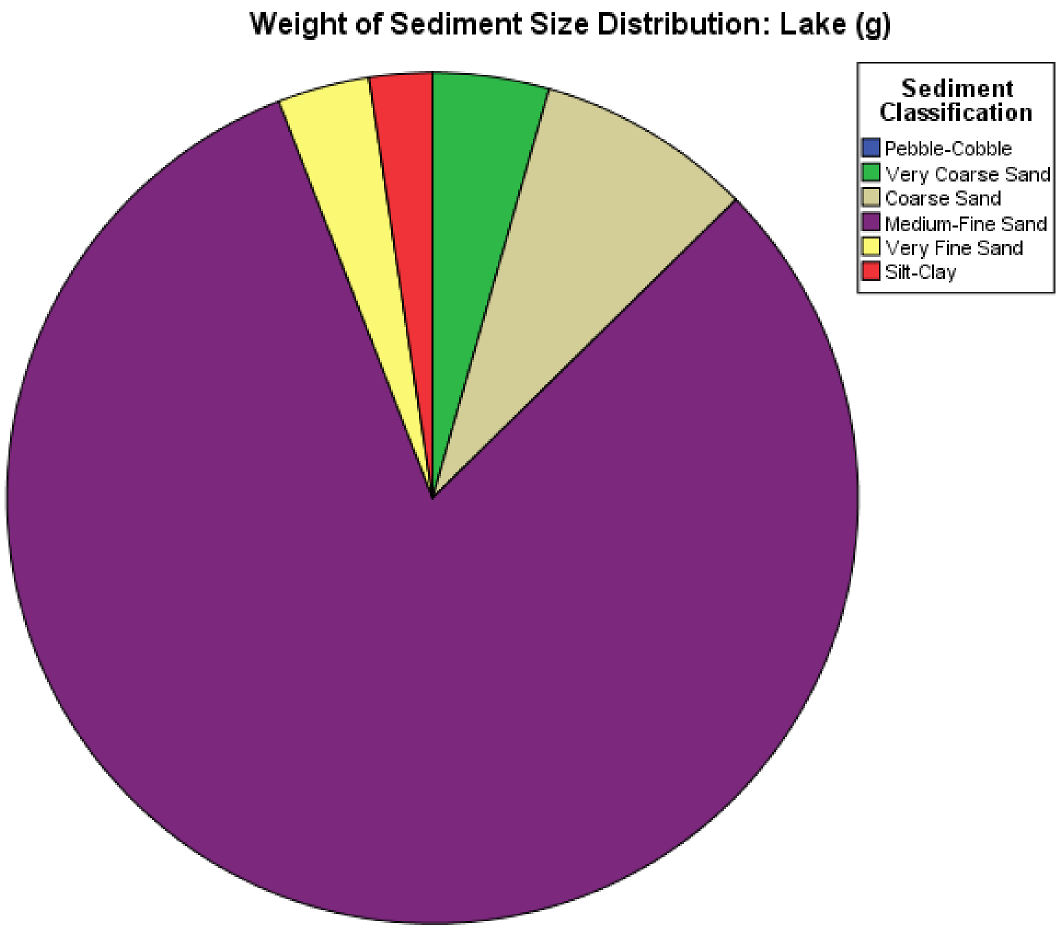
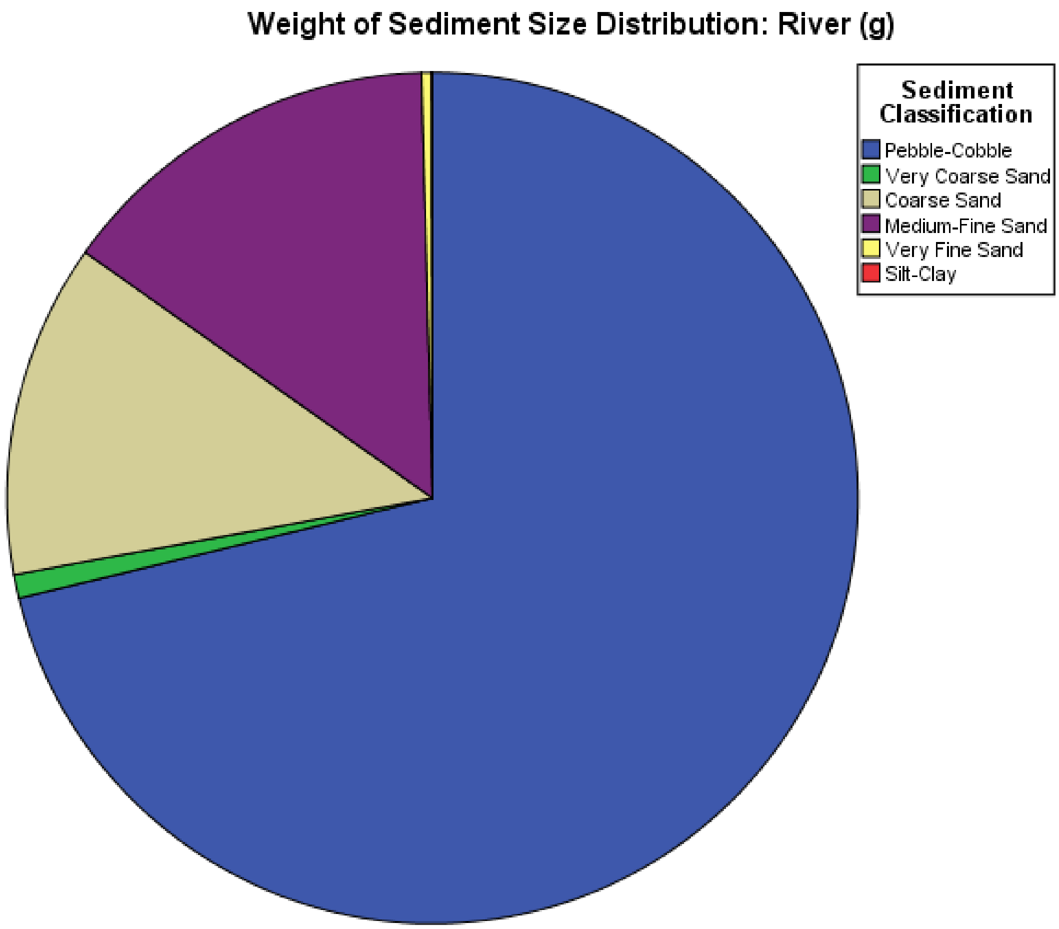

Weight of Sediment Size Distribution: Lake (g)
Sediment Classification
Pebble-Cobble
Very Coarse Sand
Coarse Sand
Medium-Fine Sand
Very Fine Sand
Silt-Clay

Figure 8



References

Doyle, M. W., E. H. Stanley, C. H. Orr, A. R. Selle, S. A. Sethi, and J. M. Harbor (2005) Stream ecosystem response to small dam removal: lessons from the heartland. Geomorphology. 71:227-244.

Hansen, J. F., and D. B. Hays. 2012. Long-term implications of dam removal for macroinvertebrate communities in Michigan and Wisconsin rivers, United States. River Res. Applic. 28: 1540-1550.

Hart, D. D., T. E. Johnson, K. L. Bushaw-Newton, R. J. Horwitz, A. T. Bednarek, D. F. Charles, D. A. Kreeger, and D. J. Velinsky. 2002. Dam removal: challenges and opportunities for ecological research and river restoration. Bioscience. 52: 669-681.

Oey, M (2015) Effective Mitigation of Sedimentation on Riparian Riverbeds and Salmonid Populations After Dam Removal. *Master's Projects.* Paper 132. http://repository.usfca.edu/capstone/132

Stanley EH, Doyle MW (2003). Trading off: the ecological effects of dam removal. *Frontiers in Ecology and the Environment* 1: 15–22.

Tullos DD, Finn DS, Walter C (2014) Geomorphic and Ecological Disturbance and Recovery from Two Small Dams and Their Removal. PLoS ONE 9(9): e108091. doi:10.1371/journal.pone.0108091