Impact of Beaver Dams on the Maple River West Branch

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Abstract

Beavers alter ecosystems through building dams. To determine if and how beaver dams affect stream ecosystems, we surveyed seven beaver dams in the West Branch of the Maple River (Emmet Co., MI), a cold water trout stream. We measured dissolved oxygen and water temperature at all dams and sampled macroinvertebrates above and below six active beaver dams. We found no statistical difference in temperature, dissolved oxygen, species diversity, and functional feeding groups of macroinvertebrates above and below dams. However, we found different macroinvertebrate communities above and below dams, and greater species richness and abundance downstream. Thus, beaver dams are producing an effect on the West Branch Maple River, and further samples should be taken to determine the extent of this effect and to sufficiently answer management questions in regards to trout populations.

Introduction

Through creating dams, beavers expand their available habitat, increase their food supply, and receive protection from predators (Naiman et al., 1988). Construction of beaver dams in streams clearly alters the surrounding environment; however, their impact has been argued as both positive and negative. Documented effects of beaver dams include retention of sediment, organic matter and water within impoundments, changes in nutrient cycling, increase in stream surface area and alterations to the riparian zone (McDowell and Naiman, 1986). These habitat modifications can influence the biota found in the stream. The beaver's large impact on the ecosystem classifies it as a keystone species, or a species with a great impact relative to its abundance (Naiman et al., 1986).

Beaver dams mainly alter streams through impounding water, which affects discharge. Stream velocity decreases above the dam and conditions change from lotic to lentic (Collen and Gibson, 2001). Accompanying this reduction in velocity is increased deposition, as the sediment carrying capacity is reduced. Sediment, both mineral and organic, is deposited within the pond resulting in less sediment transport and deposition downstream. The slower flow also results in a lower dissolved oxygen concentration upstream from dams, because of less circulation and more benthic respiration consuming oxygen (Bledzki et al., 2011).

Beavers change the riparian landscape through felling trees and changing the forest species composition (Collen and Gibson, 2001). Flooding can occur as a result of impoundment, which can create wetlands and kill woody species (Collen and Gibson, 2001). Loss of riparian cover increases the amount of light reaching the stream, resulting in an increase in temperature in beaver ponds relative to downstream water temperature (Naiman et al., 1988). Changes in riparian landscape also affect the amount and type of nutrients taken up from the groundwater by riparian vegetation, and thus change the input of nutrients into the stream (Johnston et al., 1988). Construction of dams also increases the water level, thus increasing the width of the river around the dam (Gurnell, 1998).

Changes in geomorphology, sedimentation, and water flow caused by beaver dams can affect the distribution of macroinvertebrates. Alteration in river flow induces a change from lotic taxa to more lentic forms, and increases the importance of collectors over shredders and scrapers within impounded sites (McDowell and Naiman, 1986). The reduction of flow reduces the amount of course particulate organic matter, by burying it under the sediment as well as preventing it from flowing downstream. The amount of fine particulate organic matter (FPOM) increases, decreasing the food source for shredders and scrapers, while increasing that for collectors. Meanwhile, changes in substrate and available habitats downstream along with increased flow and less sediment flow, relative to upstream impoundments, creates a different collection of organisms. Habitat homogeneity dominates upstream, compared to downstream, resulting in a greater diversity of macroinvertebrates below the dam. Also, the increased flow and rocky substrate often seen downstream of dams, favors individuals in the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). The EPT index provides insight into the water quality of the stream, with a higher value indicating higher water quality. In the case of beavers, the EPT index allows a quick comparison between upstream and downstream habitats (Gerritsen, 1995).

Beaver dams also impact the abundance and diversity of fish found in a stream. As with macroinvertebrates, the main impact on fish communities is the alteration in stream flow and creation of lentic pools. Hagglund and Sjoberg (1999) suggested beaver ponds might enhance fish species diversity due to an increase in habitat diversity downstream and the structure of the beaver dams providing fish protection from adverse environmental condition. However, other studies show that beaver can negatively affect trout streams (Collen and Gibson, 2000). Trout, as a cold water species, would be most affected by a warming in temperature due to beaver impoundments (McRae and Edwards, 1994). Although it would appear beaver dams would hinder migration, they have shown to be passable by trout (Burchsted et al., 2010).

Our study seeks to examine the impacts of beaver dams on water quality and macroinvertebrates in a cold-water trout stream in northern Michigan. In our sample area, the West Branch of the Maple River (Emmet Co., MI), considered a high quality trout stream, the dominant fish species is brook trout, which is a naturally reproducing population (Godby, 2010). This makes the beaver dams in the Maple River West Branch a major concern, as they could negatively affect the trout population in the river. The West Branch Maple River, which is in the Cheboygan River Watershed, originates from the Pleasantview Swamp, meets with the East Branch of the Maple River at Lake Kathleen, and then flows out as the Maple River into Burt Lake.

We hypothesized that beaver dams would affect both water quality and macroinvertebrate community. Specifically, we predicted the slower flow and reduced riparian cover to increase temperature upstream in comparison to below the dams. In contrast, dissolved oxygen should be lower upstream from the dams, also attributable to slower flow, which creates an accumulation of decomposing matter that consumes oxygen. Downstream from the dams should show a greater EPT Index than upstream, due to a faster flow and a higher concentration of oxygen. Other changes in macroinvertebrate community include a greater proportion of gathering collectors above the dams due to increased amounts of fine sediment. Overall, we expected macroinvertebrate diversity to be greater below the dams because of the larger variation in habitat. The observed differences should provide insight into the effects of beaver dams on water quality and macroinvertebrates in the West Branch Maple River, giving some indication of the overall impact on the stream.

Methods

We conducted our beaver dam survey on the West Branch of the Maple River (Emmet Co., MI) from Camp Road to East 31 throughout the end of July 2012 (Figure 1).

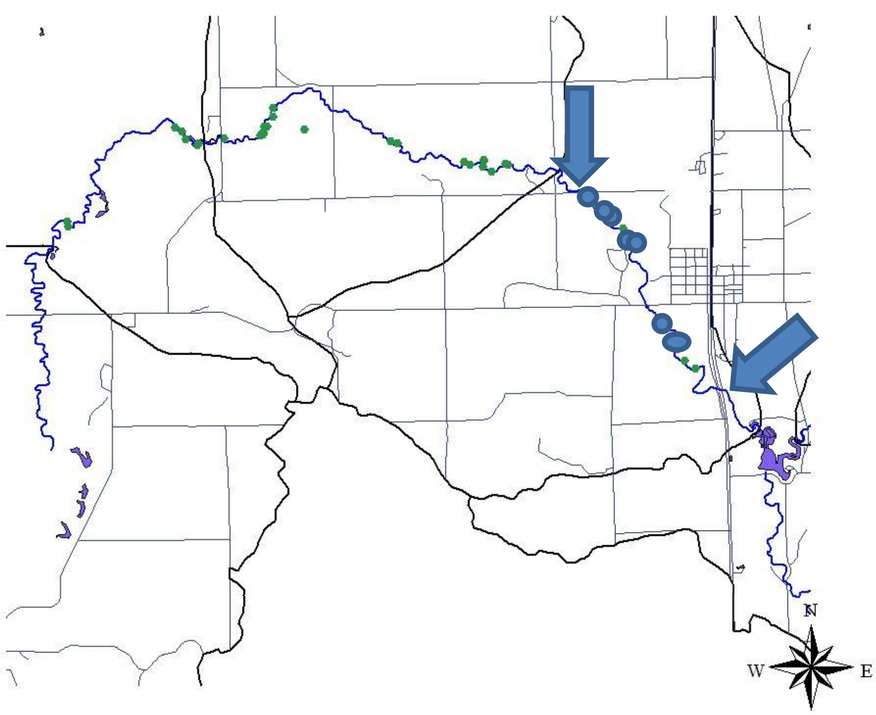

Figure 1. We sampled the W. Branch Maple River (Emmet Co., MI) between the two blue arrows; the blue dots indicate the dams we sampled.

At each beaver dam, we first assessed its activity status. If a dam had freshly cut wood and looked recently built, we defined it as active. If there was a breach in the dam, we assumed it was inactive. Next, regardless of the dam's activity status, we measured the width and height of the dam. To measure width, we used measuring tape and found the distance between the endpoints of the dam, from bank to bank, across the river. To measure height, we used a meter stick and found the distance from the surface of the water to the highest point of the dam. We also measured the water level downstream of the dam, using a meter stick. Using a thermometer, we measured the water temperature (°C) upstream and downstream of the dam. We took dissolved oxygen (mg/L) above and below the dams using a YSI dissolved oxygen meter. We measured dissolved oxygen and temperature within one meter upstream and downstream of the dam.

At active dams, we sampled for macroinvertebrates upstream and downstream within 3 meters from the dam. Two people sampled for invertebrates downstream and two people sampled upstream simultaneously over a ten-minute period. One person scraped the bottom with a kick net while the other disturbed the substrate upstream from net. At the end of the sampling period, we emptied the contents into Whirlpaks. At the biological station, we sorted through the samples, picked out macroinvertebrates, and identified them to functional feeding group and family. Collected macroinvertebrates were kept and preserved in 95% ethanol.

Statistical Analyses

To compare dissolved oxygen and temperature values upstream and downstream from the dam, we calculated the average values across seven dams and compared them with one-tailed t-tests comparing the values. Our null hypotheses were that dissolved oxygen should be lower downstream and temperature should be higher.

To assess the overall diversity of macroinvertebrates upstream and downstream, we used the Shannon Diversity Index. We calculated the H' above and below each dam, calculated the average across six dams and compared them with a one-tailed t-test. Our null hypothesis stated we would find greater macroinvertebrate diversity below, rather than above, the dams. We also calculated the average abundance, species richness, above and below six dams. We compared these values using two-tailed t-tests.

We also calculated the average total number of each functional feeding group (gathering collectors, filtering collectors, scrapers, shredders, and predators) found above and below the dams. We compared the average abundance of each functional feeding group above and below the dams using t-tests. For all groups except for gathering collectors, where our null hypothesis that we would find a greater amount upstream allowed us to use a one-tailed t-test, we used two-tailed t-tests.

Results

Dam width ranged from 7.1 to 14.4 meters and height ranged from 19 to 98 centimeters (Table 1). The average width across all dams, active and inactive, was 10.7 meters, with a standard error of 1, and the average height was 67 centimeters, with a standard error of 10. Water height ranged from 18 to 54 centimeters and the average was 34 centimeters with a standard error of 6.

The difference between the average dissolved oxygen concentration above the dams (8.56 mg/L) and below the dams (8.62 mg/L) was not significant (Table 2; $t=1.78$, $df=12$, $p=0.29$). The difference in average water temperature above (19.56°C) and below (19.24°C) was also not significant ($t=1.78$, $df=12$, $p=0.41$). EPT index tended to be higher downstream but this difference was not statistically significant (Figure 2; $t=1.81$, $df=10$, $p=.08$). One of the EPT orders, Trichoptera, appeared more abundant than Diptera downstream but the difference was not significant (Figure 3; $t=2.57$, $df=5$, $p=.11$). Specifically, filtering-collector Trichoptera tended to be greater downstream, but this difference was also not significant (t=2.02, df=5, p=.10), although variance was high, particularly below the dams where the standard deviation was 21.71 (Figure 4).

Average species diversity tended to be higher below the dams, at 2.10 compared to 1.81 above the dams (Figure 5), but the difference was not significant (t=1.81, df=10, p=0.07). However, we found a significantly greater average abundance downstream (Figure 6; t=2.23, df=10, p=0.03) along with greater average species richness downstream (Figure 7; t=2.23, df=10, p=0.02). We found 13 families exclusively downstream, 5 families only upstream, and 20 families both above and below (Table 3). Two Trichoptera families, Hydropsychidae and Helicopsychidae, were found exclusively downstream and another, Brachycentridae, was found predominantly below the dams. On the contrary, mayflies from the Caenidae family were only found upstream.

Overall, gathering collectors made up the largest proportion of macroinvertebrates found, both above and below the dams (Figures 8, 9). For every functional feeding group, including gathering collectors (t=1.81, df=10, p=0.10), filtering collectors (t=2.45, df=6, p=.12), scrapers (t=2.57, df=5, p=.12), shredders (t=2.45, df=6, p=.45), and predators (t=2.36, df=7, p=.52) the difference up and downstream of dams was not significant (Figure 10). However, there were significantly more collectors (filtering and gathering combined) downstream of beaver dams (Figure 11; t=2.23, df=10, p=.04). Oligochaeta made up the largest portion of collectors found upstream and Trichoptera made up the largest portion of collectors found downstream (Figures 12, 13).

Table 1. Location, activity status, and physical measurements of the beaver dams sampled in the West Branch of the Maple River (Emmet Co., MI) in July 2012.

Dam #	Location	Active/Inactive	Water Height (cm)	Dam Width (m)	Dam Height (cm)
1	45.54807N, 84.79326W	Active	54	14.4	56
2	45.54787N, 84.79290W	Inactive	27	13.2	98
3	45.56033N,84.67720W	Active	18	9.6	68
4	45.56343N, 84.80125W	Active	45	7.1	19
5	45.56058N, 84.80013W	Active	20	10.4	63
6	45.56053N, 84.80022W	Active	48	8.9	85
7	45.55891 N, 84.79823W	Active	24	11.4	86
	Average		34	10.7	67
	Standard Error		6	1.0	10

Table 2. Average dissolved oxygen concentration and water temperature above and below all beaver dams sampled in the Maple River West Branch (Emmet Co., MI).

	Above	Below	p-value
Dissolved Oxygen (mg/L)	8.56	8.62	0.28
Standard Error	0.81	0.06	
Water Temperature (°C)	19.56	19.24	0.41
Standard Error	0.92	0.97	

Table 3. Taxa found only above, only below, and both above and below beaver dams sampled in the Maple River West Branch (Emmet Co., MI).

Above		Both		Below	
Order	**Family**	**Order**	**Family**	**Order**	**Family**
Decapoda	Decapoda	Bivalvia	Sphaeriidae	Amphipoda	Amphipoda
Ephemeroptera	Caenidae	Coleoptera	Elmidae	Diptera	Althoricidae
Gastropoda	Lymnaeidae	Diptera	Ceratopogonidae	Diptera	Tipulidae
Gastropoda	Planorbidae	Diptera	Chironomidae	Ephemeroptera	Siphluridae
Megaloptera	Sialidae	Ephemeroptera	Ephemeridae	Gastropoda	Gastropoda
		Ephemeroptera	Leptohyphidae	Hemiptera	Corixidae
		Ephemeroptera	Baetiscidae	Megaloptera	Corydalidae
		Gastropoda	Aplexa	Megaloptera	Corydalidae
		Gastropoda	Physidae	Odonata	Aeshnidae
				Plectopera	Perlidae
		Hirudinea	Hirudinea		
		Isopoda	Asellidae	Trichoptera	Helicopsynchidae
		Odonata	Calopterydigae	Trichoptera	Hydropsychidae
		Odanata	Cordulegastridae	Trichoptera	Phryganeidae
		Odonata	Gomphidae		
		Oligiochaeta	Oligochaeta		
		Trichoptera	Brachycentridae		
		Trichoptera	Glossosomatidae		
		Trichoptera	Leptoceridae		
		Trichoptera	Limnophilidae		
		Trichoptera	Philopotamidae		

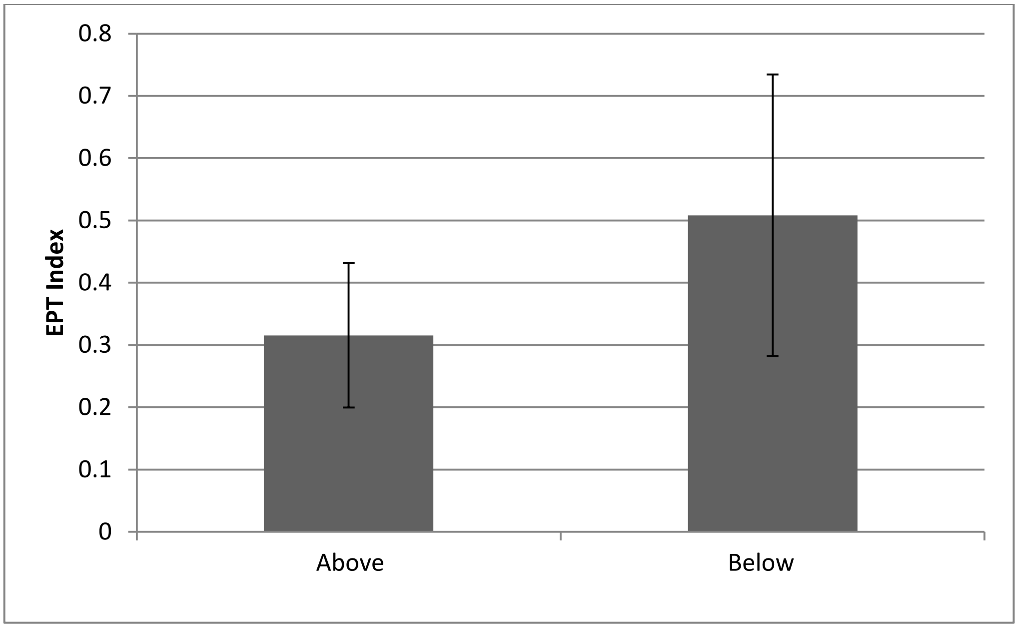

Figure 2. Average %EPT above and below beaver dams sampled in the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and differences were not significant (t=1.81, df=10, p=.08).

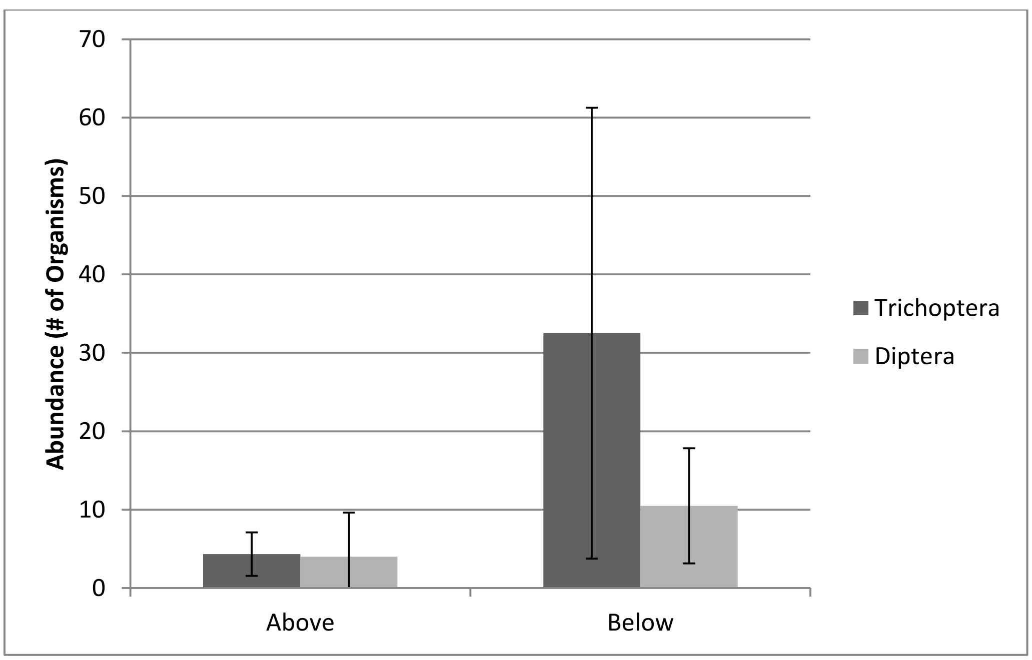

Figure 3. Average number of Trichoptera and Diptera found above and below beaver dams sampled in the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and differences between Trichoptera and Diptera were not significant (above: t=-0.11, df=10, p=.92; below: t=-1.48, df=10, p=.19)

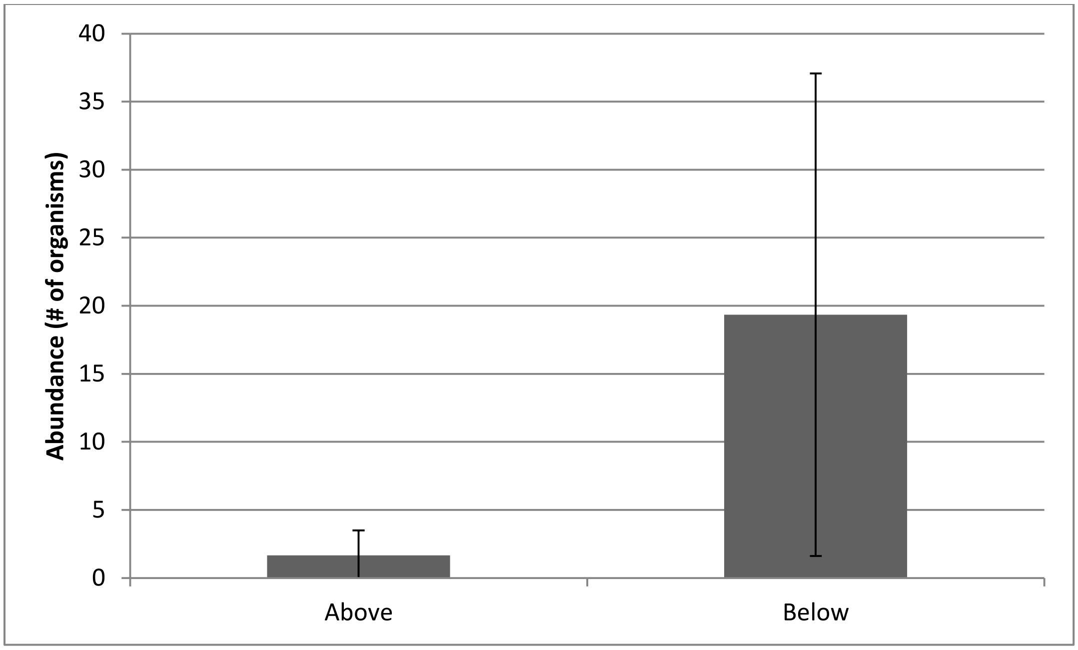

Figure 4. Average number of filtering collector Trichoptera found above and below beaver dams sampled in the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and differences were not significant (t=2.02, df=5, p=.10).

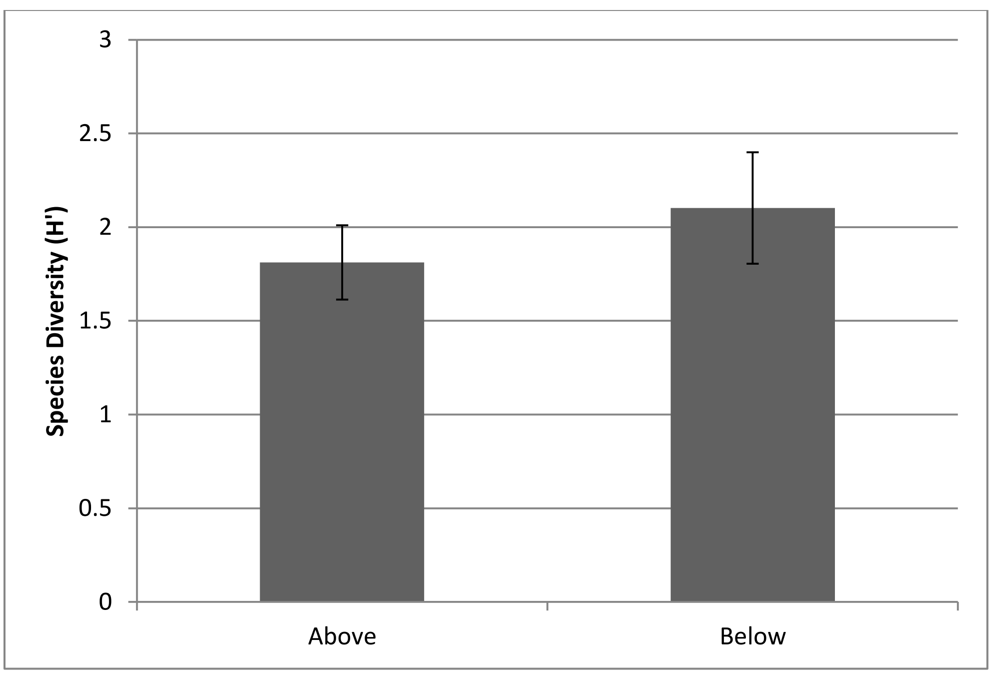

Figure 5. Average species diversity above and below dams sampled in the Maple River West Branch (Emmet Co., MI) in July 2012. Bars indicate 2 standard errors and difference was not significant (t=-1.63, df=10, p=.07**)**.

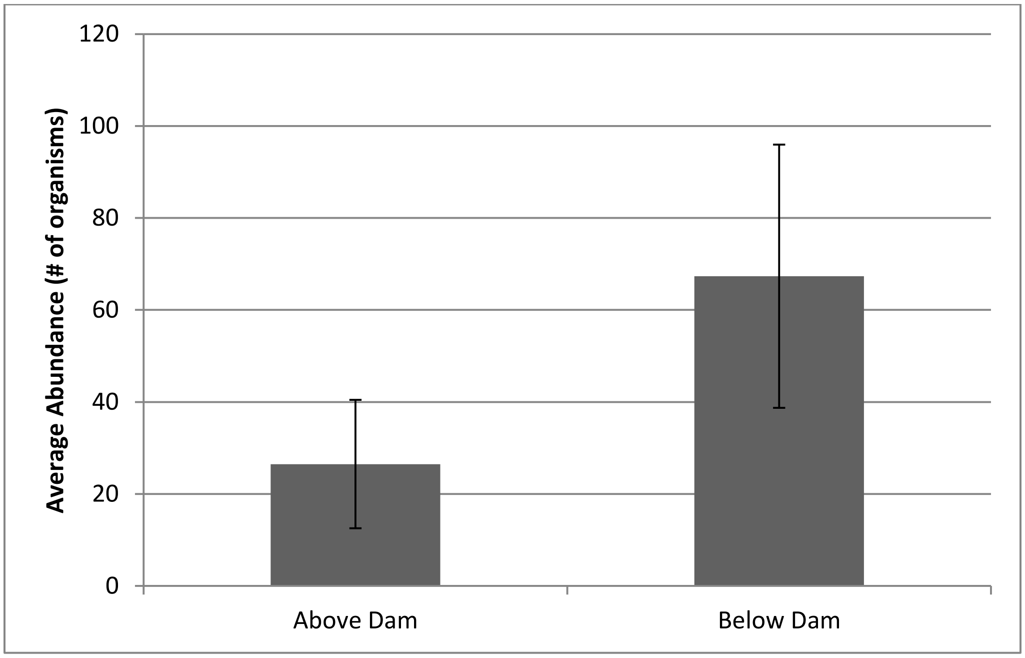

Figure 6. Average total abundance above and below dams sampled on the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and difference was significant (t=1.81, df=10, p=.03).

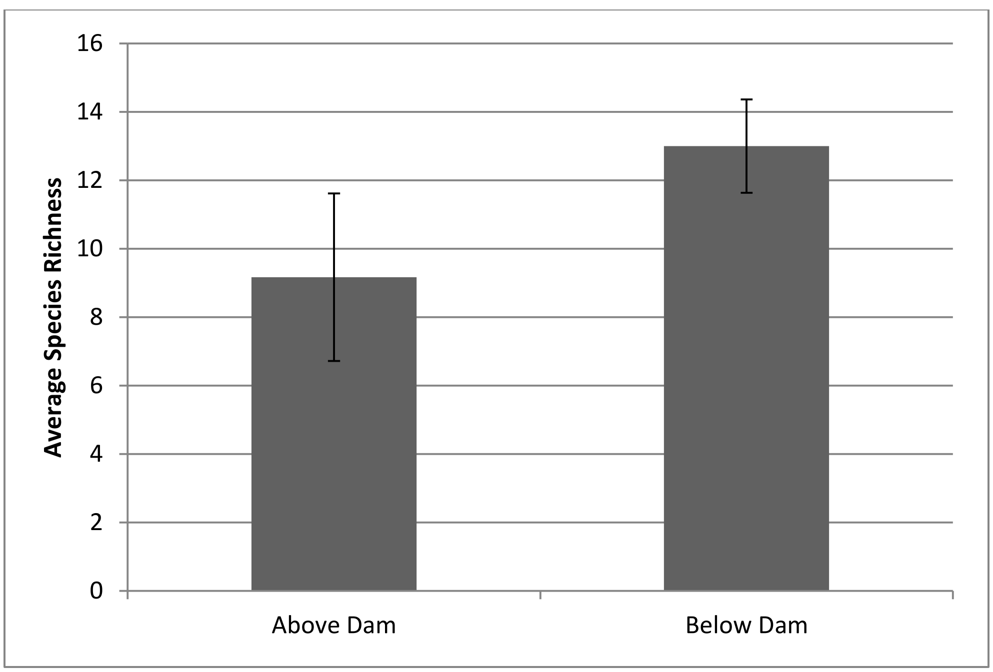

Figure 7. Average species richness above and below dams sampled in the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and difference was significant (t=2.23, df=10, p=.02)

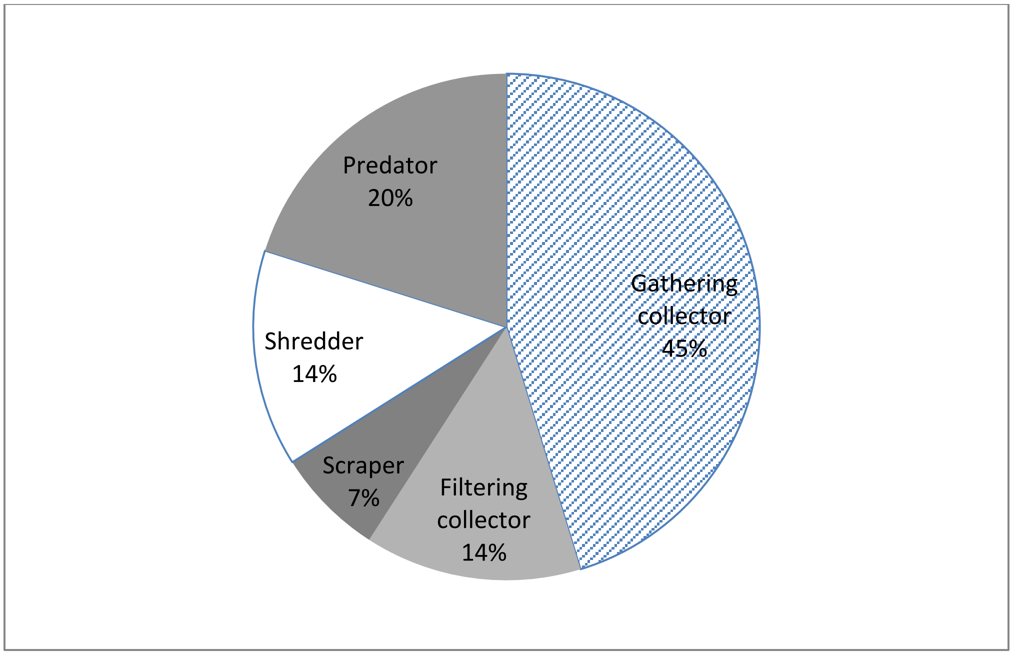

Figure 8. Average proportion of macroinvertebrate functional feeding groups found above the dams sampled in the Maple River West Branch (Emmet Co., MI).

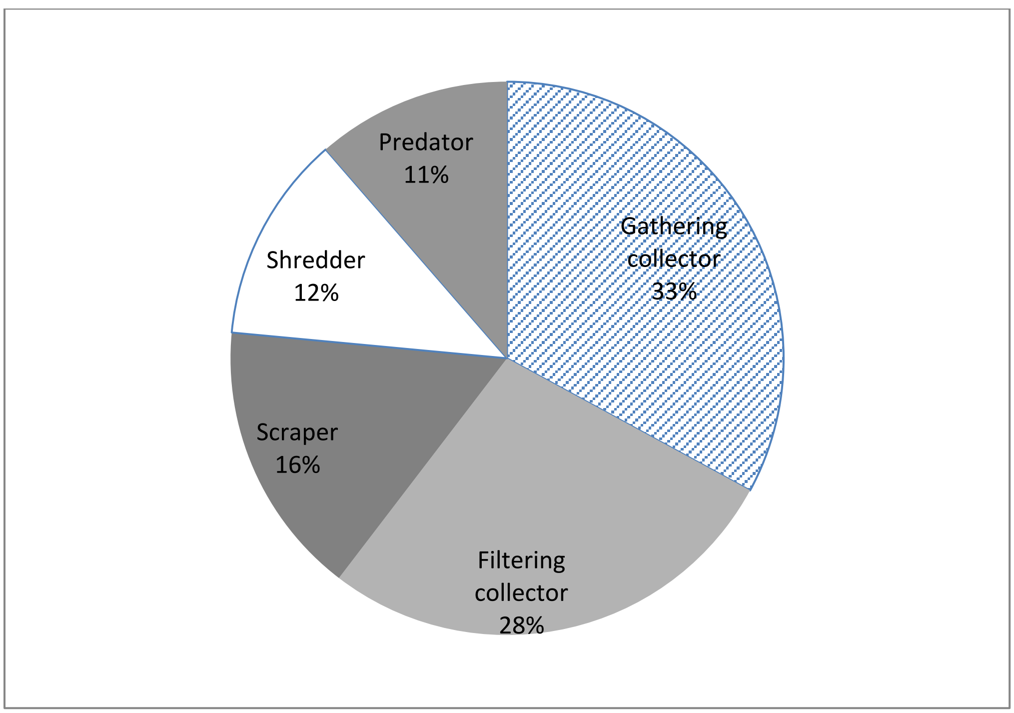

Figure 9. Average proportion of macroinvertebrate functional feeding groups found below the dams sampled in the Maple River West Branch (Emmet Co., MI).

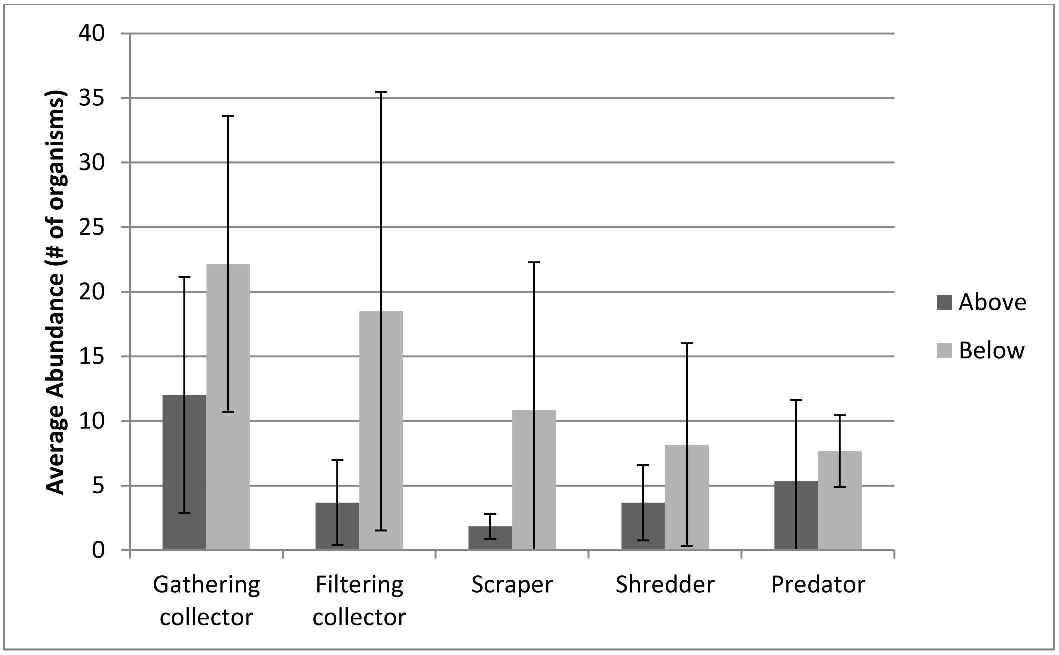

Figure 10. Average number of each functional feeding group of macroinvertebrates found above and below the beaver dams sampled on the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors, and differences were not significant (see text for details).

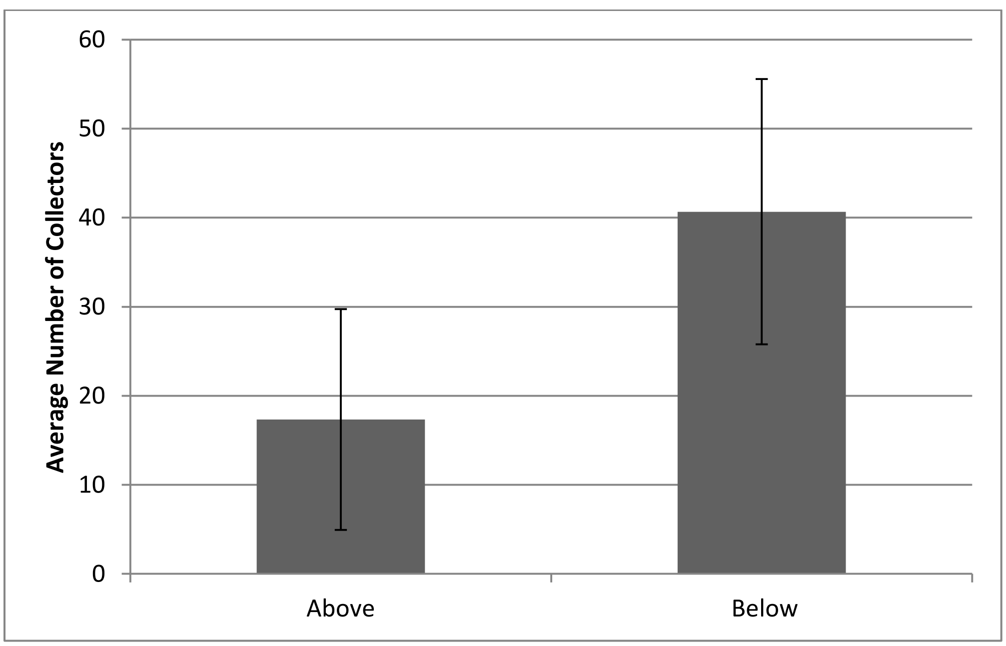

Figure 11. Average number of total collectors (gathering and filtering combined) found above and below beaver dams sampled on the Maple River West Branch (Emmet Co., MI). Bars indicate two standard errors and differences were significant ($t=-2.41$, $df=10$, $p=.04$).

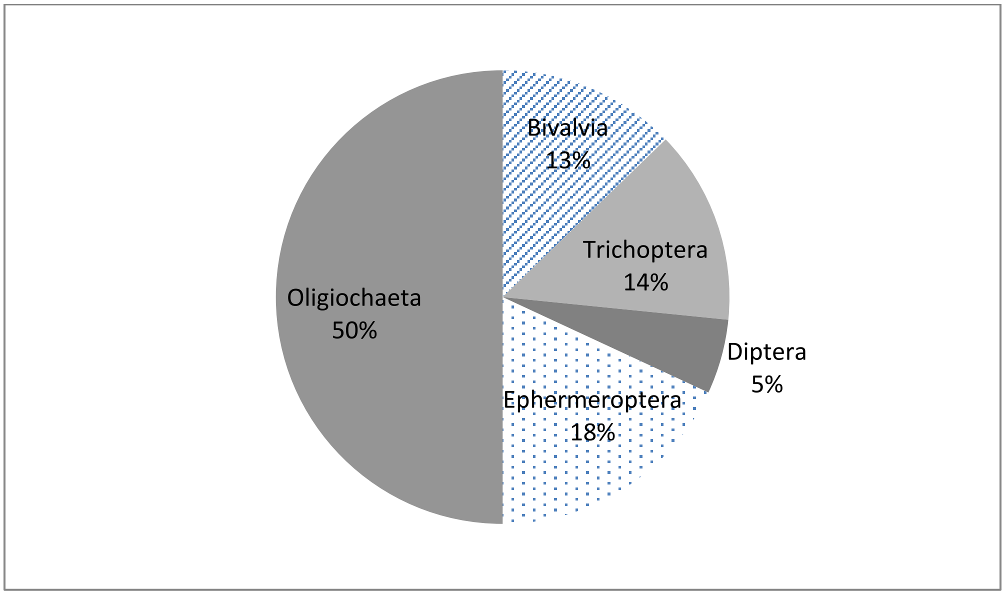

Figure 12. The community of collectors found upstream from beaver dams in the Maple River West Branch (Emmet Co., MI) is shown.

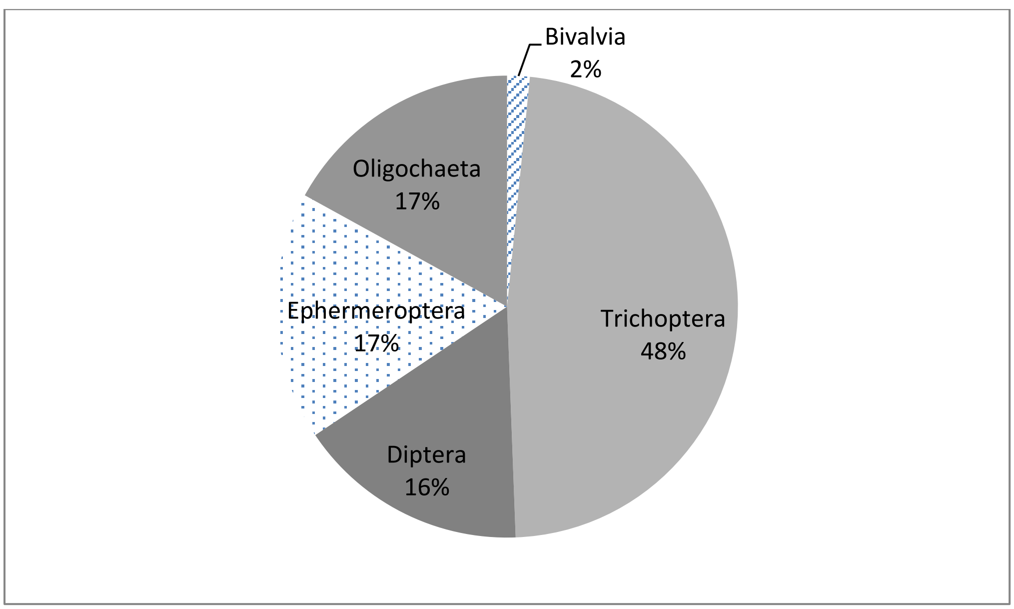

Figure 13. The community of collectors found downstream from beaver dams in the Maple River West Branch (Emmet Co., MI) is shown.

Discussion

We predicted a significant difference in temperature, dissolved oxygen, EPT index, species diversity, and gathering collectors upstream and downstream, but our data failed to support these hypotheses. However, our data indicate other unpredicted trends. We found a greater abundance and species richness of macroinvertebrates downstream, and we also saw a shift in macroinvertebrate community. We found significantly more collectors downstream reflecting a change in macroinvertebrate community as a result of the beaver dams. Overall, our data suggest that water quality in the West Branch Maple River is not affected by beaver dams, but macroinvertebrate community is.

The dams sampled were small, and did not have the far reaching affects seen by larger, more established dams like those mentioned in Naiman et al. (1988). This could explain the lack of change in temperature. Riparian coverage was still prevalent and prevented sunlight from reaching the stream, resulting in no increase of water temperature in beaver impoundments. Also, the beaver ponds of dams sampled were fairly shallow and not deep enough to accumulate decomposing matter, to create the nearly anoxic conditions seen in some cases of larger beaver ponds (Gurnell, 1998).

Little difference was also seen in water quality, as measured by the EPT index, above and below the dams, and the slightly greater value downstream can be attributed to the differing substrate. The percent of Ephemeroptera, Plecoptera, and Trichoptera found in a sample typically provides a good estimate of the water quality of a stream, since all three species are fairly intolerant of changes to the environment (Gerritsen, 1995). The greater number of filtering collecting Trichoptera downstream helps explain the increased EPT value downstream, as the rocky substrate and increased flow downstream is more conducive to Trichoptera families such as Brachycentridae, Hydropsychidaae and Helicopsychidae, than upstream. The difference in number of Dipetera and Trichoptera organisms downstream, compared to the difference seen upstream, emphasizes the creation of a habitat more favorable to caddisflies.

Besides being more suited to Trichoptera, the habitat downstream showed more heterogeneity, allowing the development of more species and explaining the greater species richness found downstream. This also explains the increased abundance, as with more available habitat and more species, there is more opportunity form more organisms to thrive downstream. With greater abundance and species richness, you would also expect to see a difference in diversity. Perhaps our lack of difference is attributable to our sampling technique, and we didn't sufficiently sample the varying habitats downstream to give us enough organisms of the different species to produce a higher diversity value. Also, our sample size of only 6 may not have been large enough to show a significant difference.

Although the diversity values do not prove a difference in macroinvertebrates found upstream and downstream from dams, looking at the specific taxa found show a shift in macroinvertebrate community structure, which can be explained by a difference in habitat, thus emphasizing changes caused by the dam. Upstream typically had more sediment build-up, while downstream had more cobble and clear, faster flowing water. These differences explain the greater amount of collectors found downstream. A large proportion of the collectors found downstream were the aforementioned Trichoptera, Brachycentridae and Hydropsychidae. Hydropsychidae, net-spinning caddisflies, are restricted to flowing waters and prefer areas of cobble to which they can attach their nets (Bouchard, 2004). The common forms of Brachycentridae larvae attach to a hard substrate such as a rock, and use their legs to filter food from the water (Bouchard, 2004). The increased flow and abundance of cobble found downstream would explain why these Trichoptera would prefer the area below the beaver dams. While not a collector, the substrate also explains why Helicopsychidae was found exclusively downstream. As a scraper, it benefited from the cobble downstream from which it scrapes algae and other microorganisms off (Bouchard, 2004).

Whereas downstream of dams, Trichoptera dominated the collector community, upstream, nearly 50% of the collector community was composed of Oligochaetes. Oligochaetes are commonly found in soft sediments and stream pools, reflective of the conditions seen upstream from the beaver dams (Bouchard, 2004). Caenids, found only upstream, also prefer still waters, and even have special coverings that protect their gills from sediment deposition (Bouchard, 2004). Both families are fairly tolerant of polluted water and can live in low dissolved oxygen conditions (Bouchard, 2004). In contrast, Brachycentrid caddisflies have a very low tolerance level for low oxygen concentrations (Bouchard, 2004). Since we saw no significant difference in dissolved oxygen above and below, we must assume the difference in community is mainly due to changes in sediment deposition and substrate.

These differences in macroinvertebrate communities pose some questions about the affects on trout in the Maple River West Branch. Protecting and maintaining the brook trout population is a main goal of the Michigan Department of Natural Resources in the West Branch Maple River (Godby, 2010). Brook trout feed on macroinverterbrates, so the changes in community seen between above and below the stream could affect them. However, brook trout show no preference to certain macroinvertebrate taxa to others when presented with different communities (Reice and Edwards, 1986). Thus, the change in macroinvertebrate species will have few strong effects on brook trout population.

Our results showed little difference in dissolved oxygen and temperature above and below the dam, implying that beaver dams change few of the basic characteristics in the stream that would impact trout populations. Plus, McRae and Edwards (1994) showed that removing a beaver has little impact on water temperature. Removing the dam could actually be more harmful than beneficial, due to the destruction involved disrupting the macroinvertebrate communities (McRae and Edwards, 1994).

In summary, beaver dams altered macroinvertebrate communites, abundance, and species richness on the West Branch Maple River, but had little affect on dissolved oxygen, temperature, and water quality. The differences in macroinvertebrates can be attributed to variance in flow and substrate above and below the dams. In another study, it would be interesting to see if flow was significantly different above and below, as we did not measure water velocity. Another study should also sample the macroinvertebrates on the dam, as that could also show a difference in community. Trout, the main concern of the river, have little preference in macroinvertebrates and will eat regardless of the taxa available, so from our survey, we conclude they are only slightly affected by the beaver dams on the West Branch. Yet, we cannot make assumptions on the trout populations in the river without a thorough assessment. Perhaps a future study can look at the trout populations of the portion of the Maple River West Branch affected by beavers, and this will provide a broader picture of the effects of beaver dams and give more insight into whether removal is necessary. Right now, with no reference to the previous condition of the river before the addition of beaver dams, and with only a change seen in macroinvertebrate community, we have no reason to assume that the river will be more ecologically sustainable without the dams.

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