Potential reintroduction of Arctic grayling, *Thymallus arcticus,* into the West Branch of the Maple River: An assessment of abiotic factors, salmonid diet and community

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Abstract

Arctic grayling were once abundant species in northern Michigan that have since been extirpated. Logging, destruction of habitat, overfishing, and introduction of non-native trout species contributed to the decline of the grayling population in Michigan. Habitat restoration and a recent resurgence of interest and funding for reintroduction of grayling has led many groups to investigate rivers in Michigan for grayling suitability. In this study, we investigated the west branch of the Maple River, located in Emmet County, Michigan, as a potential site for reintroduction of grayling. Our study consisted of habitat assessment, macroinvertebrate community study, and fish community study. We found that the west branch of the Maple River is a high quality cold-water river with suitable substrate for grayling. Additionally, there are abundant macroinvertebrate prey items for grayling. Grayling would be able to coexist with other fish species such as Brook trout, *Salvelinus fontinalis,* in some upstream areas due to the to low abundance competitor trout like Brown trout, *Salmo trutta*, and Rainbow trout, *Oncorhynchus mykiss*. More studies must be done on other sites, but we have concluded that the reintroduction of grayling into the west branch of the Maple River would be an achievable effort.

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Introduction

Arctic grayling (*Thymallus arcticus*) historically had a small natural habitat in Northern Michigan, which included most rivers and streams in the lower peninsula from the 44th to 46th parallel (Fig. 1) (Vincent 1962). Its only other range in the contiguous United States is in Montana, where it still survives today, but in a smaller range compared to its historical range. Though there was only a small range in Michigan, the grayling crowded the rivers they inhabited, and they were an easy fish to catch (Michigan Grayling 2018). They were so intertwined with the culture of Northern Michigan, and the then unspoiled wilderness, that the city of Grayling, Michigan was named after the fish.

Overfishing, introduction of competitors such as Brown, *Salmo trutta,* and Rainbow trout, *Oncorhynchus mykiss*, and logging led to the grayling's demise. Fishing reports said that grayling were not frightened by boats or fishermen, and that "inexperienced fishermen has little difficulty making large catches" (Vincent 1962). Logging destroyed river bottoms, clouded up and choked the water, and removed the bank-side trees that provided the much-needed shade for the small streams (Hartman et. al. 1996). There were attempts from 1880-1925 to extend grayling range to less human populated areas by moving adult fish to several lakes and streams. Additionally, over 3 million fry were stocked in rivers and lakes to replenish the declining populations, but these efforts failed in saving the fish from local extinction (Nuhfer 1992).

In the past few decades, fisheries management have changed their stance to a more holistic approach, including reintroduction of species such as grayling. Stricter regulations on fishing and exploitation of the environment were created and enforced, and habitats were restored to create a more welcoming environment (Whelan 2004).

There were stockings of grayling into several inland lakes and streams from 1987-1991, but they were unsuccessful (Nuhfer 1992).

Reintroducing a species back to its native habitat isn’t straightforward, especially if a species hasn’t inhabited that area in nearly 100 years. There are many variables to consider when introducing grayling to a habitat, including water temperature, flow, substrate, macroinvertebrate population, and other fish species. For example, Arctic grayling in the Big Hole River can survive in temperatures of up to 25°C (Lohr et al. 2011). But, Arctic grayling are considered a coldwater species with an optimal water temperature below 16°C (Danhoff et al. 2017). Tolerance and sensitivity to temperatures are based on geographical location and acclimation.

Grayling spawn in interstitial spaces between rocky substrate. Therefore, streams and rivers must have large particle sizes of 0.22cm-10cm with a small amount of sand and silt (~20%) (Shepard & Oswald 1989). Grayling also live, spawn, and feed in relatively fast streams, with a velocity ranging from 0.1-0.9 m/s (Danhoff et al. 2017).

Another important factor to consider is macroinvertebrate population. Grayling are opportunistic drift feeders that feed primarily on terrestrial and aquatic insects such as Diptera and Ephemeroptera (Stewart 2007). Higher water velocities are preferred by the fish for better feeding stations (Stewart 2007).

Species that compete with grayling are other benthic/drift feeders such as Brook trout, *Salvelinus fontinalis,* Rainbow trout, Brown trout, and Sculpin, *Cottidae spp.* The trout and grayling both choose and rank positions for feeding in a similar hierarchical manner (Hughes NF. 1992). Sculpin are abundant in northern Michigan streams and rivers and feed on benthic invertebrates, which affects the food availability of drift feeders. Research on Brook trout and Arctic grayling suggest that they can survive in the same habitat due to microhabitat partitioning, and there is little evidence that Brook trout negatively influences the growth of Arctic grayling (Byorth PA, Magee JP. 1998). On the other hand, juvenile grayling and Brown trout have been shown that the strongly compete for food and habitat in sympatry (Degerman, et al. 2000).

It has been found that Brown trout also outcompete Brook trout and can lead to reduction of Brook trout populations and an increase of Brown trout habitat range and populations (Fausch & White 1981). This research, and past interactions of Arctic grayling, Brown trout, and Rainbow trout (Vincent 1962), suggest that the grayling decline in the presence of Brown and Rainbow trout.

There has been increased support for another stocking and reintroduction event. As of June 18th, 2018, the Michigan Department of Natural resources has raised almost $425,000 to fund the $1.1 million project to reintroduce grayling. Most of this money has come from public foundations (Arctic grayling reintroduction… [Internet]). Due to this new-found public interest in grayling reintroduction, we decided to survey the fish communities, macroinvertebrate communities, and habitat characteristics of the west branch of the Maple River. Located in Emmet County, Michigan, U.S.A., the west branch of the Maple River is a high-quality, coldwater stream that houses mainly Brook trout with smaller proportions of nonnative, Rainbow and Brown trout (Maple River). It was also a historic habitat for Arctic grayling (Vincent 1962). This research was done to investigate whether the introduction of *Thymallus arcticus* would be viable in the west branch of the Maple River considering competition with other species, habitat suitability, and available food sources.

Materials and Methods

This study was divided into 3 parts: fish community study, macroinvertebrate and prey community study, and habitat assessment. There were 4 sites within the west branch of the Maple River that were investigated. They include Robinson Road (coordinates: 45°33'02.6"N 84°47'47.2"W), Cold Creek (coordinates: 45°34'45.8"N 84°50'54.1"W), US 31 (Simpson Street) (Coordinates: 45°32'24.3"N 84°47'01.2"W), and Pine Trail **(**Coordinates: 45°30'51.1"N 84°46'18.3"W) (Fig. 2). Cold Creek is a shallow, silty creek that is less than 2 meters wide. It was chosen because it is a potential rearing site for young and is a tributary that feeds into the Maple River. The other three sites are similar as they are all wider streams with medium depth and flow that could be potential habitats for adult grayling. Pine trail is a site in the main branch of the Maple River that is below the Lake Kathleen dam, which is currently being removed in 2018 (Fortino 2017). At each site, we chose a 100 meter transect as our sampling area.

Abiotic factors: We measured the discharge, depth, temperature, and substrate of each site to evaluate habitat. Temperature was measured every time we went to a site (every site was visited at least 3 times) and averaged. Temperatures were taken between July 24, 2018 and August 7, 2018. We used an ANOVA to determine if there were any significant differences in mean temperature among the sites. Flow was taken 10 times across the width of the stream/river at 60% depth to calculate the discharge of each site. Substrate was defined by particle size using the Modified Wentworth

Classification scheme and a consensus survey was done by estimating percent cover per 20 meters. We averaged the percent cover per 20 meters to make a percent cover for the entire 100 meters for each site. We made pie charts to compare the percent cover at the different sites.

Macroinvertebrates: We sampled macroinvertebrates by collecting benthic samples. For every 20 meters of river, we collected 5 macroinvertebrate samples with Surber samplers. These samples were in proportion to the substrate at the river bottom. For example, if the river bottom was 60% cobble, 20% sand, and 20% wood, we would do three Surber samplers in cobble, one in sand, and one in wood. Each sample was collected for 2 minutes for a total of ten person-minutes per 20 meters. We used brushes to disturb sediment and brush macroinvertebrates into the Surber samplers. We then picked the macroinvertebrates for 30-person minutes and placed them in ethanol to be counted and sorted back at the lab. A total of 25 different samples was collected for each site. We made hierarchical constellation plot from Pearson Correlation Coefficients to compare similarity of sites based on macroinvertebrate communities. We used the Shannon Diversity Index of macroinvertebrates to compare diversity among site.

Fish: We used both backpack electrofishing and seining to sample fish communities and reduce sampling bias. We seined in calmer and more open pools. Electrofishing was used to capture fish in places with more cover or faster flowing water that seine nets couldn’t catch. Seining was done for 45 minutes at each site. Electrofishing varied with time due to varying habitat, such as depth and pools at each site, but equal effort was kept the same (Table 3). Duty cycle was set at 25% and pulse was set at 50Hz for every site. Only one backpack electro shocker was used at Cold Creek since it was too narrow to use two. At the other three sites, we used two backpack electro shockers due to the width of the river. Every fish that was caught was noted by species and placed back into the water. Up to 10 salmonids were taken from each site to be dissected and have stomach contents recorded. These fish were placed into an MS222 solution to be anesthetized and then euthanized with a 10% formalin solution. Slimy sculpin (*Cottus cognatus)* Mottled sculpin (*Cottus bairdii)* and Mudminnows (*Umbra limi*) were also removed in the same manner as an outgroup to compare feeding to salmonids, but we did not have enough feeding data for these outgroup fish to do statistical analysis. Constellation plots and Peterson correlation matrices were made to examine similarity of species abundance among sites. A Shannon Diversity Index was made for each site. We created a hierarchical cluster plot to show Pearson correlations between fish species. A dendrogram was created using the same correlations to show similarity of fish communities among sites.

Food and Feeding: We separated and recorded the stomach contents of each fish by order. We used these data to make frequency of occurrence index, numerical index, and Ivlev's Electivity index for each site. We chose to highlight Diptera and Ephemeroptera because they are preferred prey by grayling. We chose to discuss Odonata because they were highly selected in the environment.

Results

Abiotic factors: Mean water temperature was different across sites. (ANOVA: F=11.530, df=14, p=0.001) WMCC, our tributary site, had a significantly higher average water temperature compared to the other sites (Tukey's: p=0.001, 0.007, 0.003, table 1)

WMUS was the coldest site, with an average temperature of 16.2°C (Table 2). WMRR and WMPT were similar to each other and slightly higher than WMUS, with an average temperature of 16.8°C and 17.3°C, respectively (Table 2). WMCC had a much higher temperature, with an average water temperature of 20.7°C (Table 2).

Discharge at WMCC was very low at 0.032m^3/s. WMRR, WMUS, and WMPT had similar discharge, but WMPT was higher, 1.650m^3/s, since it was the most downstream site (Table 2).

WMCC was composed of mostly sand/silt and wood (Fig. 3). The substrate at WMCC was also stirred up and became cloudy easily when disturbed. WMRR had a diverse mix of sand, wood, and pebble substrate (Fig. 4). WMUS had a considerable amount of rocky substrate such as 20% pebble and 29% cobble (Fig. 5). WMPT had a majority pebble substrate (Fig. 6). We noticed that sand/silt and wood substrate decreased downstream, while rocky material like pebble and cobble increased downstream.

Fishes Populations: *Salvelinus fontinalis* was the most abundant salmonid species caught, accounting for 25.95% of the total catch. *Salvelinus fontinalis* was caught at every site. *Salmo trutta* was more abundant than *Oncorhynchus mykiss* accounting for 11.14% of the total catch compared to 2.54% of the catch. Both species were caught at WMRR, WMUS, and WMPT. *Cottus spp,* which was composed of

Cottus bairdi and *Cottus cognatu*s, was the most abundant not-salmonid fish caught, accounting for 32.02% of total catch (Table 3). A total of 14 species were caught between the 4 sites (Table 3).

Salvelinus fontinalis was the only salmonid found at WMCC and the catch was mostly composed of young of the year. The majority of salmonids caught were *Salvelinus fontinalis* for both WMRR and WMUS. *Salmo trutta* were the second-most abundant salmonid caught at those sites. At WMPT, *Salmo trutta* was the most abundant salmonid caught at WMPT, with 75% of the total salmonid catch. *Oncorhynchus mykiss* was the second-most abundant salmonid, with 16% of total salmonid catch, at WMPT. *Salvelinus fontinalis* was the least abundant salmonid caught at WMPT (Table 3) (Figure 7).

WMRR was the most diverse site with H=0.39. WMCC was the second-most diverse, with H=0.31. WMPT diversity was H=0.28. WMUS was the least diverse site, with H=0.19 (Table 4).

There was a positive correlation between both *Salmo trutta* and *Oncorhynchus mykiss* adults and juveniles. There was a positive correlation between *Salvelinus fontinalis* juveniles and *Culaea inconstans* and *Umbra limi*. (Fig. 8). *Salvelinus fontinalis* adults were negatively correlation with both adult and juvenile *Salmo trutta* and *Oncorhynchus mykiss*. *Salvelinus fontinalis* adults were also negatively correlated with *Perca flavescens* and *Micropterus salmoides* (Fig. 8).

WMRR and WMPT were most similar in terms of species abundance and evenness, and that WMUS was similar to those sites as well. WMCC was very different compared to the other three sites (Fig. 9).

Macroinvertebrates: WMCC was the most diverse macroinvertebrate site (table 6). WMRR, WMUS, and WMPT had high amounts of Ephemeroptera and Diptera within the macroinvertebrate communities (table 6).

Food and Feeding: Diptera and Ephemeroptera were avoided for by all salmonid species at every site (Fig. 10, Fig. 11). Odonata were prefered by all salmonid species at WMRR, WMUS, and WMPT (Fig. 12). WMRR and WMPT were similar in macroinvertebrate community. WMUS was more similar to WMRR and WMPT as well. WMCC was very dissimilar from the other three sites (Fig. 13).

Overall trends in numerical indices show that salmonids are opportunistic feeders. It was found that Brook trout prey on mollusca in environments that have a high relative abundance of mollusks, and/or when in presence of Brown or Rainbow trout (Fig. 14). Each salmonid species had a high numerical index of Trichoptera and Odonata at both WMUS and WMCC.

Full tables of numerical index, functional index, and Ivlev's Electivity index for each salmonid species found at each site are located in the appendix.

Discussion

In terms of habitat, WMRR, WMUS, and WMPT were all high-quality cold sites that Grayling could inhabit. WMCC may be too warm to be a rearing site for juvenile grayling, though. It was significantly warmer than other sites, and had a high water temperature of 22°C. This temperature is concerning as juvenile graying can tolerate temperatures of up to 24.5°C (Lohr, et al. 2011).

WMRR, WMUS, and WMPT also had an optimal amount of substrate. The high percent cover of pebble and cobble indicate Grayling could successfully spawn in the west branch of the Maple river (Shepard & Oswald 1989). WMCC had high levels of silt, which leads to high turbidity of the water when disturbed. The fine sediment can damage fish and reduce growth and feeding (McLeay DJ. et al. 1987).

The hierarchical cluster analysis shows that grayling could coexist with Brook trout while still avoiding Brown trout and Rainbow trout. The relative abundance of Brown and Rainbow trout are lower than the abundance of Brook trout at sites WMRR and WMUS, and is more evidence that grayling could inhabit the upstream sites. WMPT has a large amount of Brown trout and a small amount of Brook trout, which is possible evidence that Brown trout are outcompeting Brook trout, and in turn would outcompete grayling if introduced.

Food and feeding data show that there is an abundant source of grayling-preferred macroinvertebrates such as Diptera and Ephemeroptera (Stewart 2007) . Also, the present salmonid species were avoiding these macroinvertebrates.

These data also show that Brook trout were preying on benthic items such as mollusca, which could be due to competition from other trout. Food resource partitioning may be a mechanism enabling Brook and Brown trout coexistence. A study on food partitioning between coexisting Atlantic salmon and Brook trout show similar results in which sympatric Brook trout feed less often and have a different diet that allopatric Brook trout (Mookerji, et al. 2004).

We have concluded that the main branch of the Maple River isn’t viable for grayling introduction due to large populations of Brown trout which would reduce the fitness of grayling greatly (Degerman, et al. 2000). We have also concluded that the west branch of the Maple River, such as sites WMRR and WMUS, are a suitable environment for grayling, and that reintroduction of grayling would be a viable effort. However, more studies must be done on other sites on the west branch of the Maple River to confirm our findings. To keep a stable population of introduced fish, the population must be self-reproducing, so more studies on habitat and macroinvertebrate communities should be done in the spring, the time in which grayling spawn. (Bishop FG. 1971).

Extensive studies on fish communities must be done post-dam removal. When the Lake Kathleen dam is removed, it will allow fish to move between the west branch of the Maple River and the main branch of the Maple River through Lake Kathleen. Studies show that dam removal increases biotic diversity through the enhancement of new spawning areas and new habitat (Bednarek 2001). This could affect fish populations and community structure.

Reintroduction of grayling into the river would not only have ecological implications, but also have economic and cultural implications. Recreational trout fishing is a direct form of ecotourism and reintroducing a sport fish to Michigan would contribute to its already large ecotourism economy (Ditton et al. 2002).

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Tables and Figures

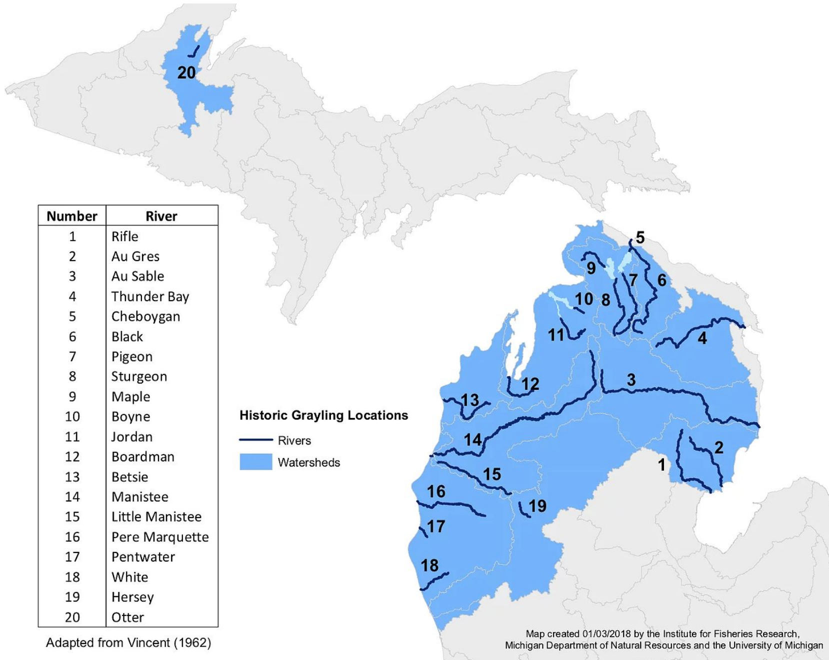

Figure 1: Historic Michigan Grayling locations and watersheds (Vincent 1962).

Figure 2: A map of the four study sites located on the West Branch of the Maple River, Emmet County, Michigan, U.S.A. WMCC=Cold Creek, WMRR=Robinson Road, WMUS=US 31 (Simpson Street), and WMPT=Main Maple River Pine Trail

Table 1: Electrofishing voltage and duration time for all 4 sites.

Site	Voltage(V)	Electroshocker 1 Duration (Seconds)	Electroshocker 2 Duration (Seconds)
WMCC	220	912	N/a
WMRR	225	3216	2145
WMUS	225	1335	1489
WMPT	225	2826	2337

Table 2: A Tukey's post hoc test comparing the temperature at WMCC to WMPT, WMUS, and WMRR, showing a significant different in temperature.

I	J	Sig.
WMCC	WMPT	0.001
	WMUS	0.007
	WMRR	0.003

Table 3: Minimum, maximum, and average water temperature, and discharge of each site. Data for water temperature was taken between July 24th, 2018 and August 7th, 2018.

Site	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Discharge (m^3/s)
WMCC	18.3	22.0	20.7	0.032
WMRR	15.8	17.8	16.8	0.757
WMUS	15.4	16.7	16.2	0.891
WMPT	16.5	17.7	17.3	1.650

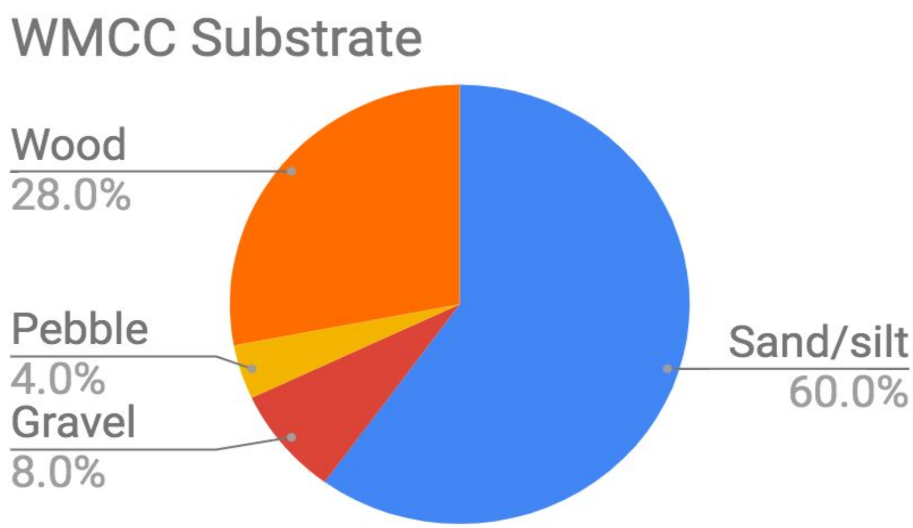

Figure 3: Total percent cover of each substrate type at Cold Creek.

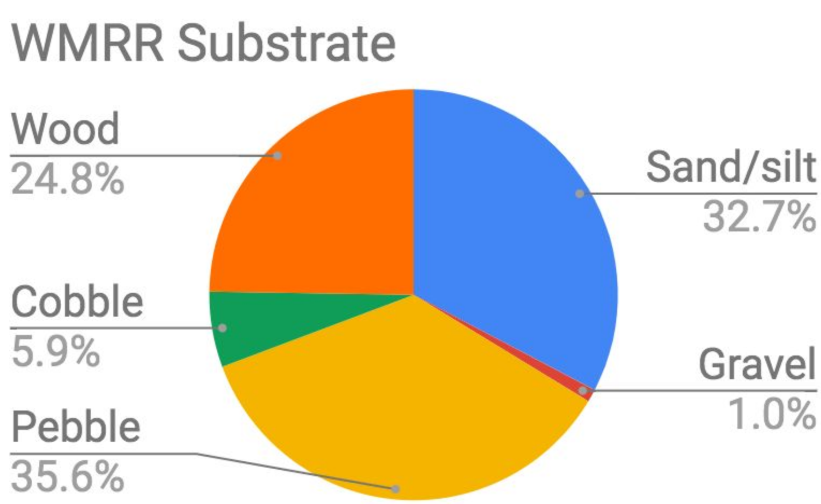

Figure 4: Percent cover of each substrate type at Robinson Road.

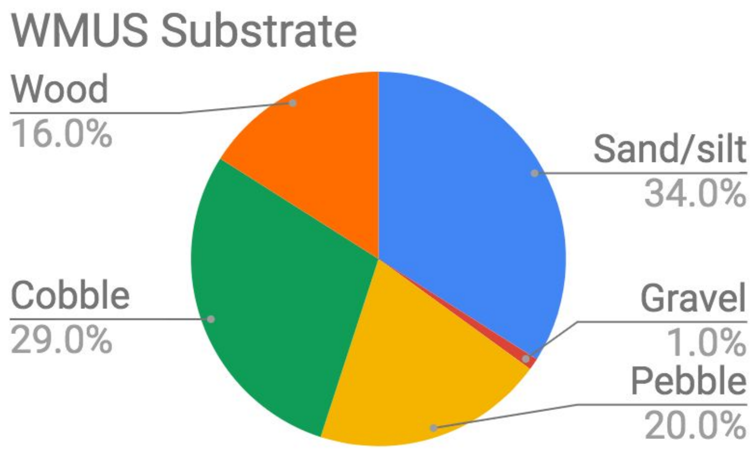

Figure 5: Percent cover of each substrate type at the US31 site.

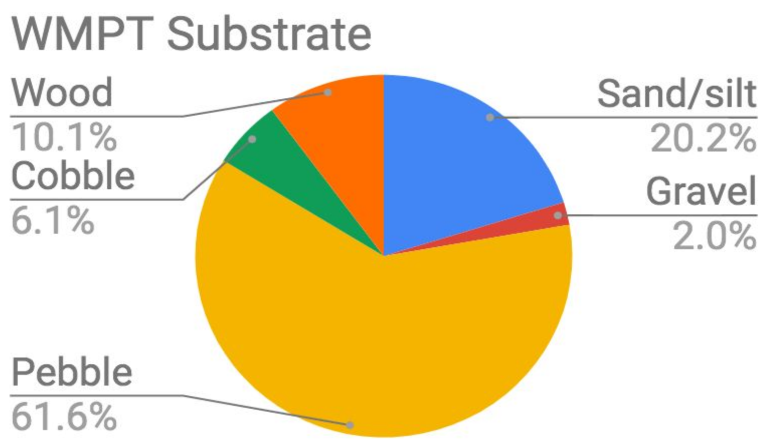

Figure 6: Percent cover of each substrate type at Pine Trail

Table 4: Total amount of fish caught between the four sites separated by species. Stream in which the species was found, method of capture, total count, and percentage of total catch is also included.

Species	Streams	Method of Capture	Count	Percentage of total catch
Salvelinus fontinalis	All	All	184	25.95
Salmo trutta	WMRR, WMUS, WMPT	All	79	11.14
Oncorhynchus mykiss	WMRR, WMUS, WMPT	All	18	2.54
Catostomus comersonii	WMCC, WMRR, WMUS	All	39	5.50
Umbra limi	WMCC, WMRR, WMPT	All	78	11.00
Cottus spp.	WMRR, WMUS, WMPT	All	227	32.02
Semotilus atromaculatus	WMCC, WMRR	All	20	2.82
Phoxinus eos	WMCC, WMRR	All	30	4.23
Pimephales notatus	WMRR	Electrofisher	1	0.14
Pimephales promelas	WMRR	Electrofisher	1	0.14
Culaea inconstans	WMCC, WMRR	All	5	0.71
Lethenteron appendix	WMRR, WMUS	Electrofisher	18	2.54
Perca flavescens	WMPT	Electrofisher	6	0.85
Micropterus salmoides	WMPT	Seines	3	0.42

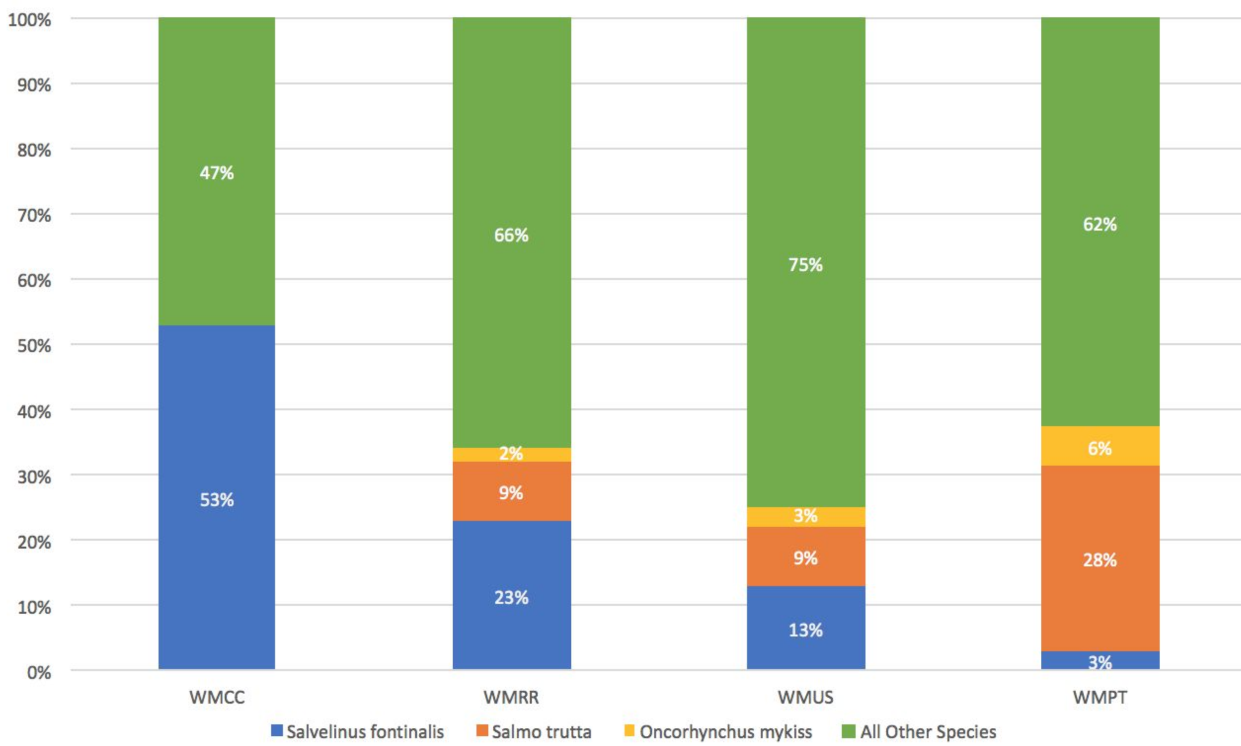

Figure 7: Percentage of *Salvelinus fontinalis, Salmo trutta, Oncorhynchus mykiss,* and all other species abundance between the 4 sites.

Table 5: Percent composition of total salmonids caught for each site. Shannon Diversity Index for all species caught at each site.

Site	Shannon Diversity Index (H)	*% Salvelinus fontinalis*	*% Salmo trutta*	*% Oncorhynchus mykiss*
WMCC	0.31	100%	0%	0%
WMRR	0.39	68%	26%	6%
WMUS	0.19	50%	38%	13%
WMPT	0.28	9%	75%	16%

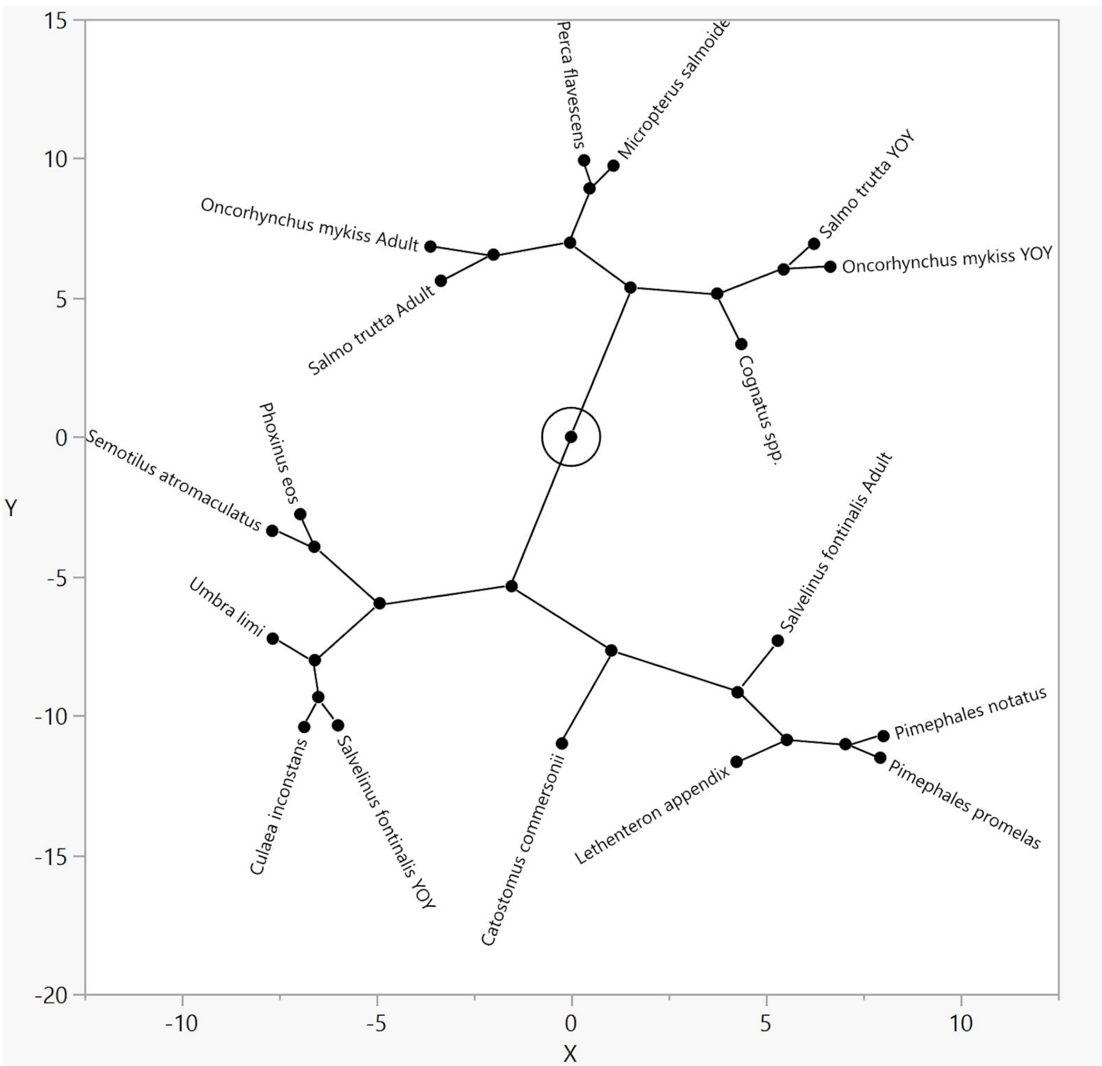

Figure 8: A hierarchical cluster analysis made with Pearson Correlation Coefficient showing correlation of each of the fish species found at the 4 sites.

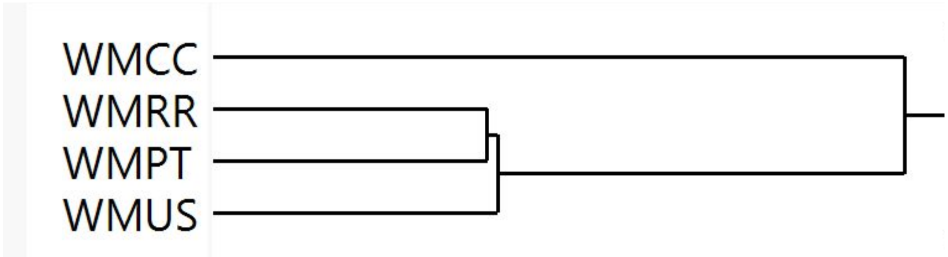

Figure 9: A dendrogram based on a hierarchical cluster comparing similarity between sites in terms of fish communities.

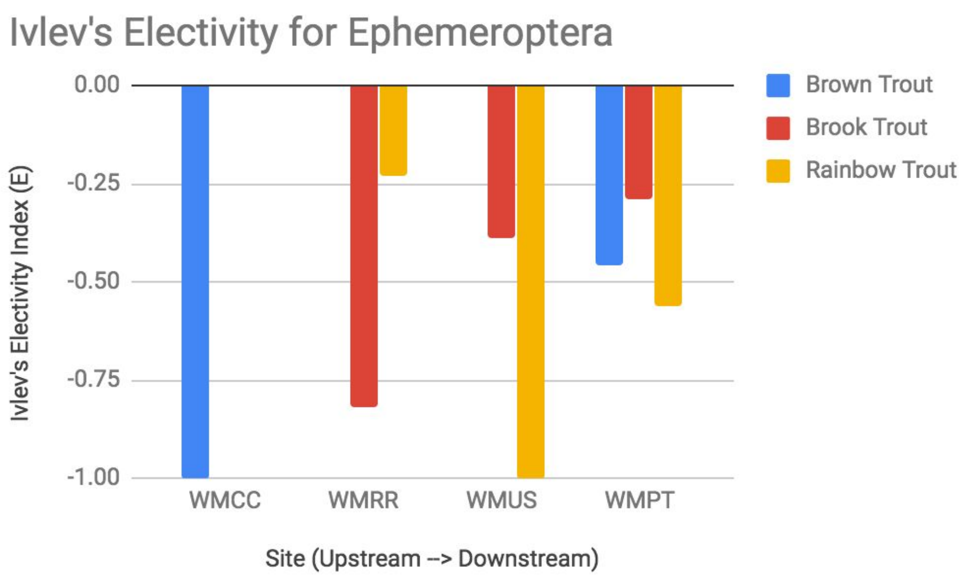

Figure 10: Ivlev's Electivity indices for order Ephemeroptera separated by species and site.

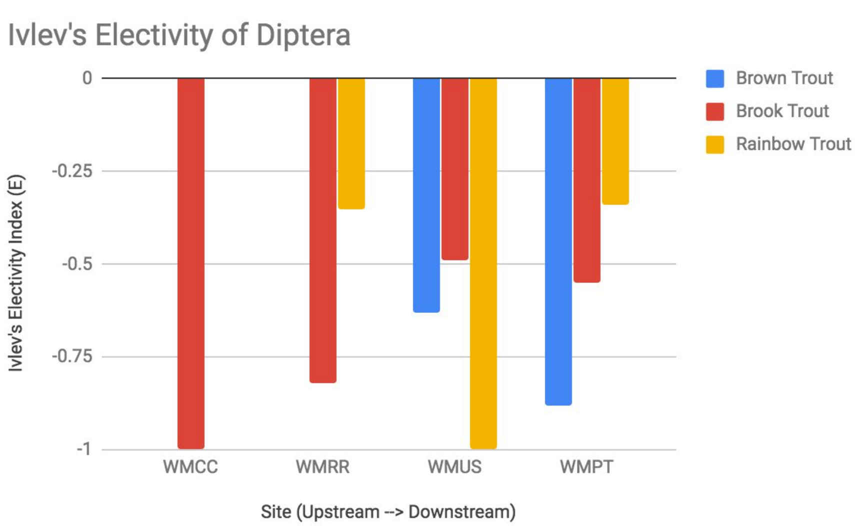

Figure 11: Ivlev's Electivity indices for order Diptera separated by species and site

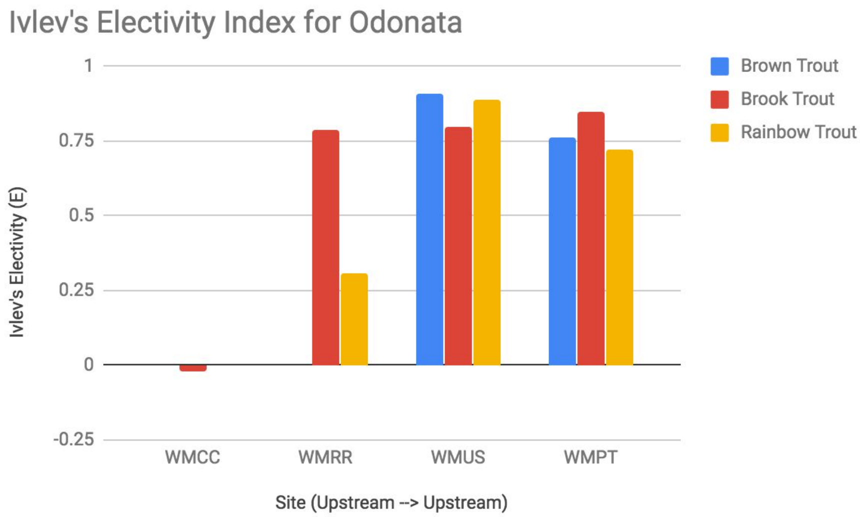

Figure 12: Ivlev’s Electivity indices for order Odonata separated by species and site

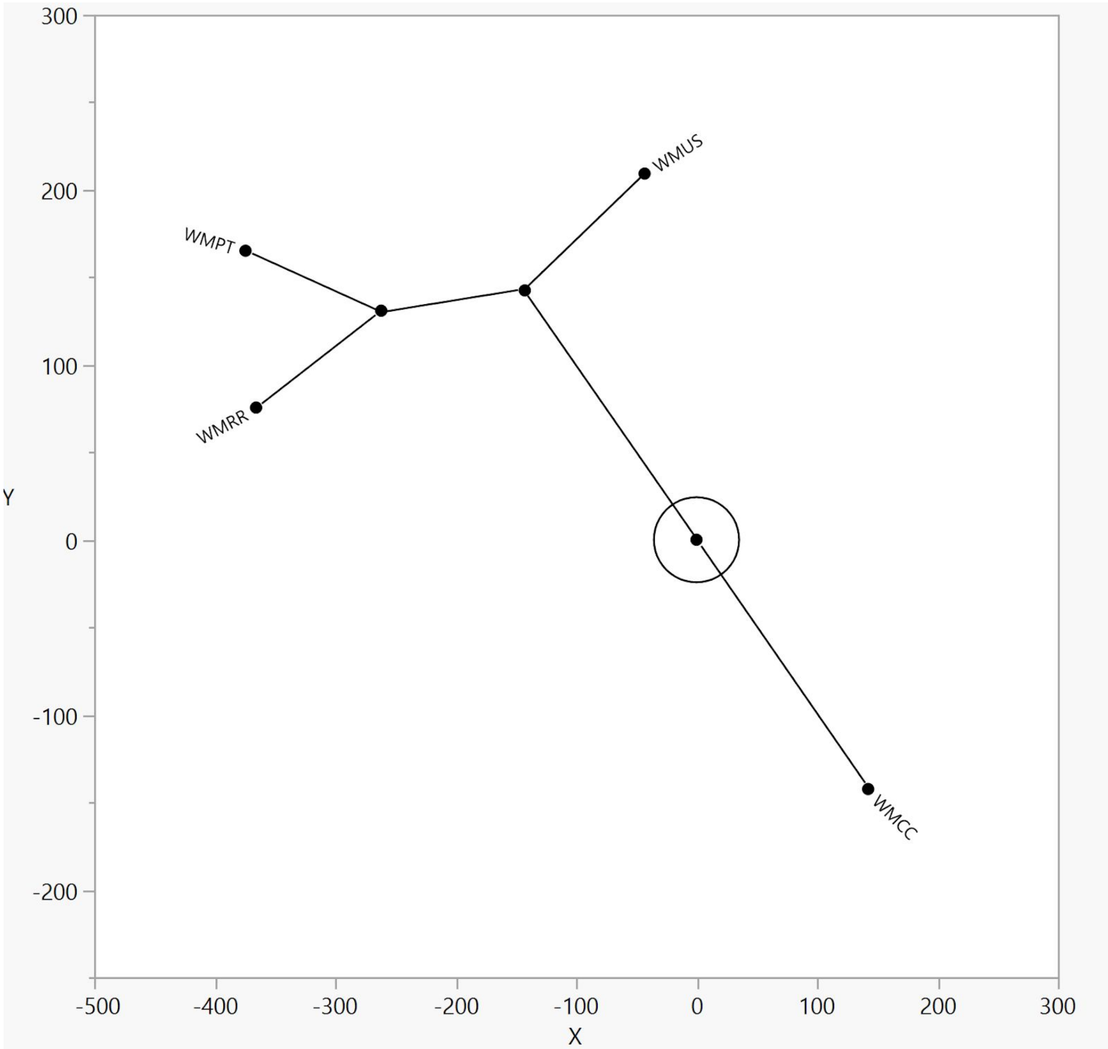

Figure 13: A hierarchical cluster analysis made with Pearson Correlation Coefficient comparing similarity of sites based on macroinvertebrate populations.

Table 6: Shannon diversity of macroinvertebrates at each site, as well as %Ephemeroptera and %Diptera at each site.

Site	Shannon Diversity index	%Ephemeroptera	%Diptera
WMCC	0.87	6	5
WMRR	0.67	27	35
WMUS	0.58	20	33
WMPT	0.70	25	24

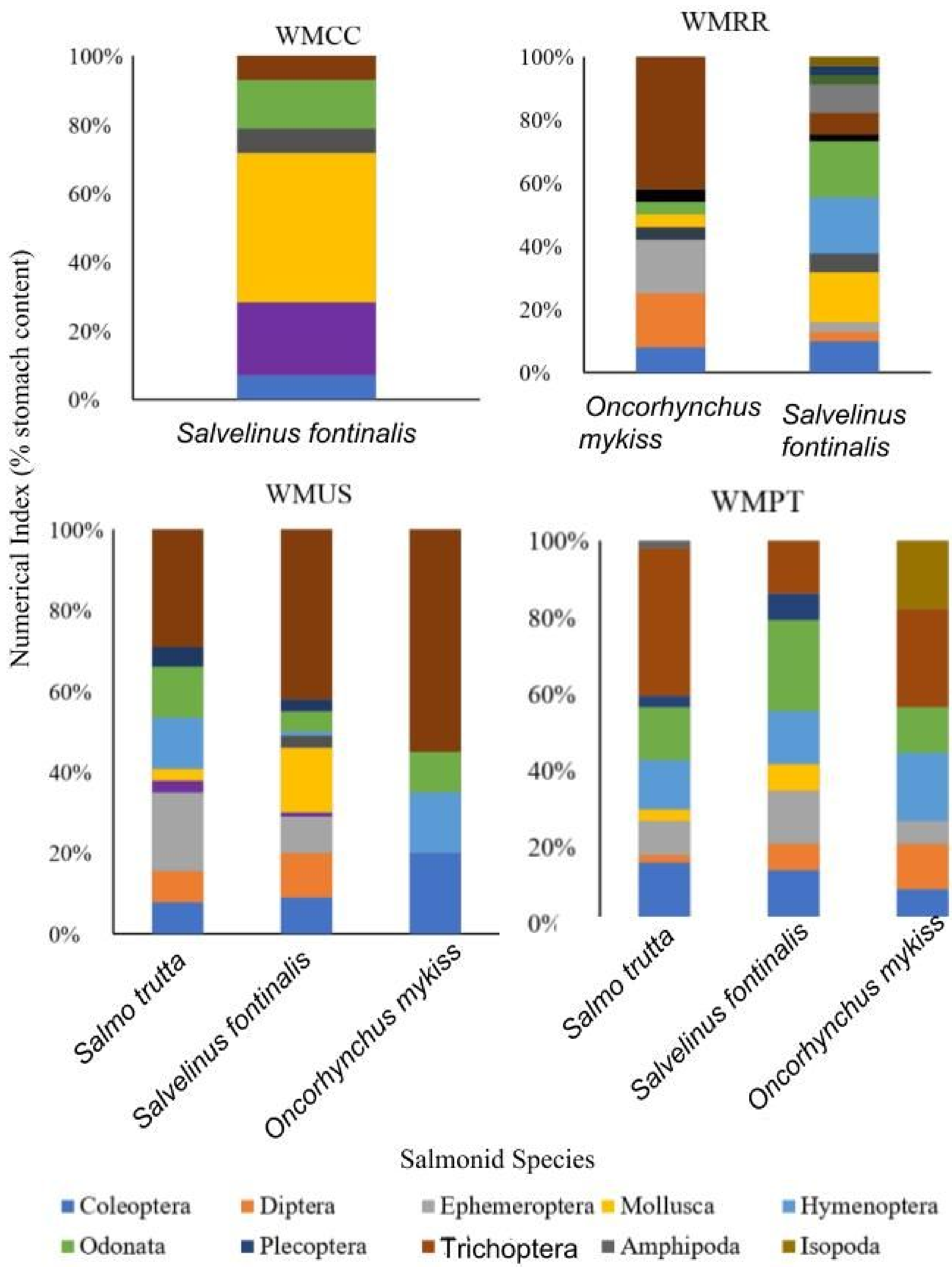

Figure 14: Numerical indices (% stomach content) for each salmonid species found at each site

Appendix

Numerical Index WMUS

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.08	.09	.20	--
Diptera	.08	.11	--	.50
Ephemeroptera	.20	.09	--	.33
Fish	.03	.01	--	--
Mollusca	.03	.16	--	--
Hemiptera	--	.03	--	--
Hymenoptera	.13	.01	.15	--
Odonata	.13	.05	.10	--
Plecoptera	.05	.03	--	--
Tricoptera	.30	.42	.55	--
Isopoda	--	--	--	.17

Frequency of Occurrence WMUS

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.67	.75	.67	--
Diptera	.67	.50	--	1.00
Ephemeroptera	.67	.25	--	1.00
Fish	.33	.25	--	--
Mollusca	.33	.50	--	--
Hemiptera	--	.25	--	--
Hymenoptera	.33	.25	.33	--
Odonata	.67	.50	.33	--
Plecoptera	.33	.25	--	--
Tricoptera	1.00	.75	1.00	--
Isopoda	--	--	--	.50

Ivlev's Electivity WMUS

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.19	.27	.59	-1.00
Diptera	-.63	-.49	-1.00	.21
Ephemeroptera	0.00	-.39	-1.00	.25
Fish	1.00	1.00	--	--
Mollusca	.63	.93	-1.00	-1.00
Hemiptera	-1.00	.80	-1.00	-1.00
Hymenoptera	1.00	1.00	1.00	--
Megaloptera	-1.00	-1.00	-1.00	-1.00
Odonata	.91	.80	.89	-1.00
Plecoptera	1.00	1.00	--	--
Tricoptera	-.13	.03	.17	-1.00
Isopoda	--	--	--	1.00

Numerical Index WMRR

Macroinvertebrate order	*Oncorhynchus mykiss*	*Salvelinus fontinalis*
Coleoptera	.08	.10
Diptera	.17	.03
Ephemeroptera	.17	.03
Arachnida	.04	--
Mollusca	.04	.16
Hemiptera	--	.06
Hymenoptera	--	.18
Odonata	.04	.18
Polydesmida	.04	.02
Tricoptera	.42	.07
Amphipoda	--	.09
Decapoda	--	.03
Plecoptera	--	.03
Isopoda	--	.03

Frequency of Occurrence WMRR

Macroinvertebrate order	*Oncorhynchus mykiss*	*Salvelinus fontinalis*
Coleoptera	1.00	.78
Diptera	1.00	.22
Ephemeroptera	1.00	.11
Arachnida	1.00	--
Mollusca	1.00	.44
Hemiptera	--	.33
Hymenoptera	--	.44
Odonata	1.00	.89
Polydesmida	1.00	.22
Tricoptera	1.00	.56
Amphipoda	--	.44
Decapoda	--	.33
Plecoptera	--	.11
Isopoda	--	.22

Ivlev's Electivity WMRR

Macroinvertebrate order	*Oncorhynchus mykiss*	*Salvelinus fontinalis*
Coleoptera	.35	.44
Diptera	-.35	-.82
Ephemeroptera	-.23	-.82
Amphipoda	--	1.00
Mollusca	.63	.89
Hemiptera	--	1.00
Hymenoptera	--	1.00
Megaloptera	-1.00	-1.00
Odonata	.31	.79
Plecoptera	-1.00	.25
Tricoptera	.24	-.57
Decapoda	--	1.00
Polydesmida	1.00	1.00
Isopoda	-1.00	-.09

Numerical Index WMCC

Macroinvertebrate order	***Salvelinus fontinalis***	***Umbra limi***
Coleoptera	.07	1.00
Diptera	--	--
Ephemeroptera	--	--
Fish	.21	--
Mollusca	.43	--
Hemiptera	.07	--
Hymenoptera	--	--
Odonata	.14	--
Tricoptera	.07	--
Amphipoda	--	--
Decapoda	--	--
Plecoptera	--	--
Isopoda	--	--

Frequency of Occurrence WMCC

Macroinvertebrate order	***Salvelinus fontinalis***	***Umbra limi***
Coleoptera	.17	.50
Diptera	--	--
Ephemeroptera	--	--
Fish	.33	--
Mollusca	.50	--
Hemiptera	.17	--
Hymenoptera	--	--
Odonata	.33	--
Tricoptera	.17	--
Amphipoda	--	--
Decapoda	--	--
Plecoptera	--	--
Isopoda	--	--

Ivlev's Electivity WMCC

Macroinvertebrate order	*Salvelinus fontinalis*	*Umbra limi*
Coleoptera	.33	.93
Diptera	-1.00	-1.00
Ephemeroptera	-1.00	-1.00
Amphipoda	-1.00	-1.00
Mollusca	.06	-1.00
Hemiptera	.57	-1.00
Megaloptera	-1.00	-1.00
Odonata	-.02	-1.00
Plecoptera	-1.00	-1.00
Tricoptera	-.30	-1.00
Decapoda	.86	-1.00
Annelida	-1.00	-1.00
Hirudinea	-1.00	-1.00

Numerical Index WMPT

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.16	.14	.09	--
Diptera	.02	.07	.12	.14
Ephemeroptera	.09	.14	.06	.09
Mollusca	.03	.07	--	--
Hymenoptera	.13	.14	.18	--
Odonata	.14	.24	.12	--
Plecoptera	.03	.07	--	--
Tricoptera	.39	.14	.26	.77
Amphipoda	.02	--	--	--
Isopoda	--	--	.18	--

Frequency of Occurrence WMPT

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.33	.50	.50	--
Diptera	.17	.50	.50	.67
Ephemeroptera	.50	1.00	1.00	.33
Mollusca	.17	.50	--	--
Hymenoptera	.67	1.00	1.00	--
Odonata	.67	1.00	50	--
Plecoptera	.17	.50	--	--
Tricoptera	.83	1.00	1.00	.67
Amphipoda	.17	--	--	--
Isopoda	--	--	.18	--

Ivlev's Electivity WMPT

Macroinvertebrate order	*Salmo trutta*	*Salvelinus fontinalis*	*Oncorhynchus mykiss*	*Cottus spp.*
Coleoptera	.41	.35	.14	-1.00
Diptera	-.88	-.55	-.34	-.28
Ephemeroptera	-.46	-.29	-.62	-.47
Amphipoda	.13	-1.00	-1.00	-1.00
Mollusca	.18	.52	-1.00	-1.00
Hymenoptera	.96	.96	.97	-1.00
Megaloptera	-1.00	-1.00	-1.00	-1.00
Odonata	.76	.85	.72	-1.00
Plecoptera	-.04	.34	-1.00	-1.00
Tricoptera	.06	-.43	-.13	.38
Isopoda	--	--	1.00	--