Analysis of Four Maple River Sites for Proposed Re-Introduction of *Thymallus arcticus*

Mikela Dean

University of Michigan Biological Station
EEB 486: Biology and Ecology of Fishes
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Dr. Amy Schrank

The historically abundant Arctic Grayling (*Thymallus arcticus*) is a native Michigan Salmonid was extirpated due to many abiotic and biotic factors. Renewed interest in reintroducing *T. arcticus* to Northern Michigan Rivers by the DNR led to an investigation of viability on four sites of the Maple River in Emmett County, Michigan. We evaluated the abiotic factors and components of Salmonid competition to assess if *T. arcticus* reintroduction could be viable. Analysis of temperature, substrate, macroinvertebrates, fish communities and diet showed that suitable habitat characteristics were present in the two West Branch sites of the Maple River. In these two sites, there was ample preferred food sources, lower percentages of non-native Salmonids and suitable substrate compositions. While two sites were deemed viable, removal of a Dam on the Maple River may change river composition. Thus, more research is needed on fish communities, diet, and competition post-Dam removal to determine if *T. arcticus* should be reintroduced.

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Abstract:

The historically abundant Arctic Grayling (*Thymallus arcticus*) is a native Michigan Salmonid that was extirpated due to many abiotic and biotic factors. Renewed interest in reintroducing *T. arcticus* to Northern Michigan Rivers by the DNR led to an investigation of viability of four sites of the Maple River in Emmett County, Michigan. We evaluated the abiotic factors and components of Salmonid competition to assess if *T. arcticus* reintroduction could be viable. Analysis of temperature, substrate, macroinvertebrates, fish communities and diet showed that suitable habitat characteristics were present in the two West Branch sites of the Maple River. In these two sites, there was ample preferred food sources, lower percentages of non-native Salmonids and suitable substrate compositions. While two sites were deemed viable, removal of a Dam on the Maple River may change river composition. Thus, more research is needed on fish communities, diet, and competition post-Dam removal to determine if *T. arcticus* should be reintroduced.

Keywords: Arctic grayling, Michigan, competition

Introduction:

The Arctic Grayling (*Thymallus arcticus*) is a native Salmonid species that historically inhabited waterways throughout Michigan and the Great Lakes Region (GLERL 2018). In the late 1800s, populations of *T. arcticus* began to significantly decline due to multiple interacting abiotic and biotic factors (Vincent 1962). Factors such as increased logging and agricultural practices caused a multitude of abiotic changes to Arctic Grayling habitat. (Vincent 1962). Additionally, overfishing and competition from introduced non-native Brown (*Salmo trutta*) and Rainbow (*Oncorhynchus mykiss*) trout caused declines in *T. arcticus* abundance (Vincent, 1962). This native salmonid persisted in Michigan until approximately 1936, when its presence was last known (McAllister and Harington 1969).

The decline of *T. arcticus* populations in Michigan did not go unnoticed, as the State of Michigan attempted to stabilize the population by stocking rivers with over 3 million Montana sourced *T. arcticus* from 1900-1933 (Nuhfer 1992). Unfortunately, these stocking efforts were not sufficient to save the population. The DNR attempted to restock several Northern Michigan rivers yearly from 1987-1991, but populations of *T. arcticus* did not survive due to many factors including competition, predation and illegal fishing (Nuhfer 1992). While populations have been unsuccessful in Michigan waters, fluvial *T. arcticus* still persist in Big Hole river in Montana (Lohr et al. 1996). As of 2016, the DNR has expressed renewed interest in re-introducing *T. arcticus* into historical Northern Michigan habitats such as the Maple River (Michigan.gov).

Currently in Michigan, there are two native (*Salvelinus fontinalis* and *Salvelinus namaycush*) and seven introduced (*Oncorhynchus gorbuscha, Oncorhynchus kisutch, Oncorhynchus nerka, Oncorhynchus tshawytscha, Oncorhynchus mykiss, Salmo salar and Salmo* *trutta)* salmonid species (GLERL 2018). The salmonid species that would potentially share river habitat with *T. arcticus* include *S. trutta*, *S. fontinalis* and *O. mykiss* (GLERL 2018). In Montana where *T. arcticus* are currently found, they coexist and compete with *S. fontinalis* for resources (Vincent 1962). While they coexist with *S. fontinalis*, the effects of non-native *O. mykiss* and *S. trutta* on *T. arcticus* survival have been negative in the past (Vincent 1962)

Adult Arctic Grayling have optimal temperature ranges between 2.7 ˚C-22 ˚C, with an upper incipient lethal temperature of 25˚C (Danhof 2017; Lohr et al. 1996). Juvenile Arctic Grayling have a slightly narrower optimal temperature range from 4.3-17.3˚C (Dion & Hughes 2004; Mallet et al. 1999). During spawning, *T. arcticus* rely heavily on gravel substrate to both lay and fertilize their eggs upon (Bishop 2011). Additionally, they typically associate with coarse sand and gravel as adults (Vincent 1962). Their diet is compromised primarily from drift, with some preference for Ephemoptera (mayfly) and Diptera (true flies) (Stewart et al 2007).

The possibility of reintroducing *T. arcticus* into Northern Michigan sparked interest in evaluating potential habitats. Given the known historical population of *T. arcticus* in the Maple River, we decided to assess abiotic and biotic variables at four different sites along the Maple River. Particularly, we were interested in how competition with other Salmonid species may affect *T. arcticus* survival should they be reintroduced. While Salmonid species are widely studied, very little research has been conducted on competition between salmonids in the Great Lakes Region. Our question was to determine if introduction of *T. arcticus* would be viable in sites along the Maple River considering competition with other species (Salmonidae), habitat suitability, and available food sources.

Materials and Methods:

Sites

Four sites along the Maple River in Emmett County near Pellston, Michigan were chosen for evaluation of suitability for *Thymallus arcticus* re-introduction. The four sites that were chosen based on accessibility were Cold Creek (CC) located at 45˚34’45.793” N, 84˚50’54.221” W, Robinson Road (WMRR) at 45˚33’2.901” N, 84˚47’47.167” W, US 31 (WMUS) at 45˚32’24.244” N, 84˚47’1.048” W, and Pine Trail (MMPT) 45˚30’50.998” N, 84˚46’16.684” W (See inset). Each site was flagged every ten meters for a total of 100m to assess. Robinson Road, US 31, and Pine Trail were chosen as possible year-round habitats and Cold Creek was chosen as a potential rearing tributary.

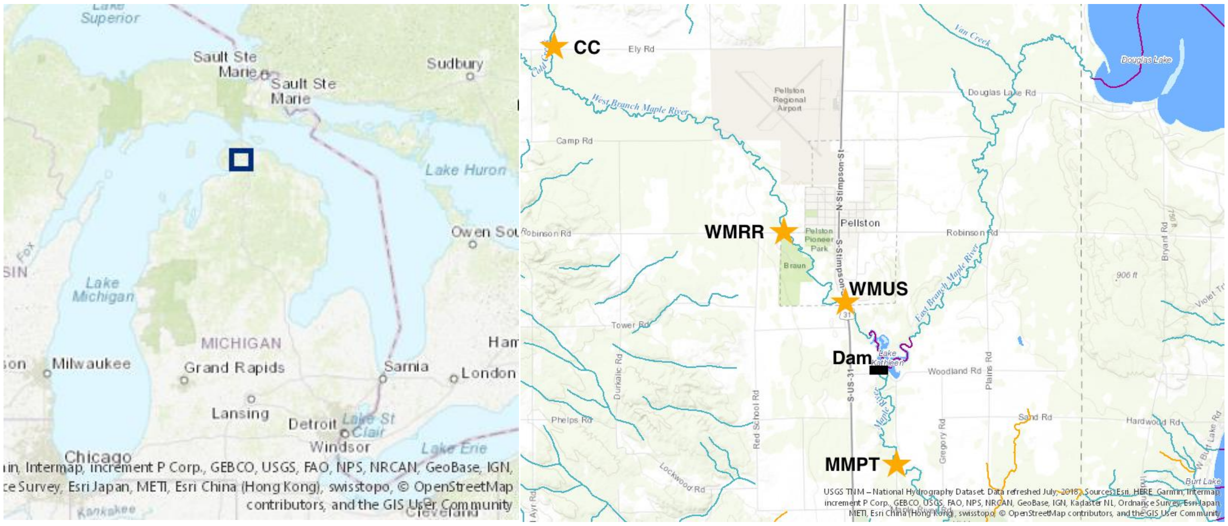

Figure 1: Map of Michigan with Emmet county depicted by the black box (left). Map of Emmett county with approximate locations of CC, WMRR, WMUS, and MMPT marked on the Maple River (blue) by yellow stars (right). Note the Dam marked at the mouth of the Maple River from Lake Kathleen. Exact GPS coordinates of sites listed above.

Abiotic Factors

Each time we visited a site, we recorded time, air temperature, water temperature, and general weather conditions. Water temperature was measured with a Hach pocket pro digital conductivity meter and air temperature was recorded with a glass thermometer. Temperature data was compiled per site and high, low and average temperatures were recorded. After the assumptions of normality and homogeneity of variance were tested, ANOVA tests were performed to determine differences in mean temperatures among sites. We also measured discharge at each of the four sites using a Hach flow meter. At one open and straight portion of each site, we stretched a measuring tape across the river and recorded width. We then assembled the flow meter and split the width into ten equally spaced points. At each of the ten points, depth was measured and the flow was recorded at 60% depth. Weather conditions were recorded by type of cloud cover, sun presence, and precipitation type.

DNR Data Sheets

To efficiently help the DNR assess possible habitat for *T. arcticus* reintroduction, we decided to use a selection of their premade data sheets. At one visit for each site, we filled out the DNR survey sheet. This survey sheet assessed physical appearance & instream cover characteristics for each site. DNR data sheets filled out during habitat analysis were compiled for possible DNR use.

Substrate

To measure substrate, sites were split into five 20-meter transects. Within a single transect, we estimated substrate type (sand/silt, gravel, pebble, cobble, and wood) and abundance to the nearest 5 percent based on visual comparisons of substrate types. To estimate percentage, each group member quickly walked the transect estimated substrate types and percentages. After all three field crew estimated, we announced our estimate simultaneously for a given substrate type. We came to consensus on substrate type and percentage.

Macroinvertebrates

To analyze available prey for *T. arcticus,* we collected benthic macroinvertebrates using Surber samplers. For every 20 meter transect of each site, we first evaluated percent abundance of different substrates to the nearest 20 percent to ensure representative sampling of benthic invertebrates (more accurate substrate evaluation performed during habitat assessment as described above). For each 20% of substrate in a transect, one two-minute macroinvertebrate collection was performed with a 30 x 30 cm Surber sampler (5 samples per 20 meters, 25 samples per site). During each two-minute sample, bottom sediments were kicked/moved around and rocks/wood were brushed with toothbrushes into the Surber samplers. After each transect collection, samples were combined into an enamel pan and macroinvertebrates were sorted with forceps for 30 person-minutes. Any macroinvertebrates sorted were placed in transect-labeled jars of 85% isopropyl alcohol for later analysis. Any unsorted material was released directly back into the transect, as we moved upstream to the next transect. We later analyzed Shannon Diversity Indices of macroinvertebrates diversity and percent abundance of both Ephemoptera and Diptera for each site. A hierarchical constellation plot based on centroid distance was created using the JMP statistical program to illustrate relatedness of macroinvertebrates communities among sites.

Fish Sampling

To evaluate community diversity and competition in the four sites, fish were sampled using both single pass backpack electroshockers, and six and ten foot seines. Backpack electroshockers were set to 220V with a duty cycle of 25% and a pulse of 50Hz across all sites.

Conductivity was measured before sampling to ensure electrofishing settings were appropriate. These two methods were chosen to both minimize gear bias and maximize number of species captured. At each site, a maximum of 10 salmonids (*S. trutta*, *S. fontinalis,* and *O. mykiss*) were collected for stomach analysis. When applicable, one or two larger individuals of abundance (*Umbra limi, Cottus bairdii, or Cottus cognatus*) were collected for diet comparison to salmonids. Collected species were first anesthetized in MS 222 and then transferred to 10% Formalin while operculation was still occurring. After at least 24 hours in Formalin, collected species were transferred to 50% isopropyl alcohol to preserve stomach contents if they were not already dissected. All other fishes were released after being counted and recorded by species (except overly-shocked fish that would not survive). At Cold Creek, a single backpack electroshocker (too narrow & shallow for two) was used for a total of 912 seconds. Robinson Road, US 31, and Pine Trail were all double backpack electroshocked for combined shocking times of 5,361, 2,824, and 5,163 seconds respectively. Shocking times varied due to differences in width, depth, woody debris cover, and maneuverability of sites. A Shannon diversity index measuring fish diversity and percent *S. trutta, S. fontinalis,* and *O. mykiss* composition (out of all species) for each site were compared. Using the JMP statistical program, correlations between sites based on hierarchical cluster analyses of fish species diversity were mapped onto a dendrogram. Fish count data was assembled using JMP into a centroid-based hierarchical constellation plot that illustrated correlations between different species based on Pearson correlation coefficients.

Diet Analysis

After collection, fishes were dissected and their stomach contents were analyzed under microscopes. Each macroinvertebrate or fish was counted, recorded and identified to order using the STROUD Water Research Center Identification Guide to Freshwater Macroinvertebrates (STROUD 2018). Fish stomach data and macroinvertebrate data was combined to determine the numerical, frequency of occurrence and Ivlev's Electivity indices (See appendix).

Results:

Abiotic Factors

CC had a mean temperature of 20 ˚C, WMRR had a mean temperature of 16.8 ˚C, WMUS had a mean temperature of 16.2 ˚C, and MMPT had a mean temperature of 17.3 ˚C (Table 1). ANOVA tests between CC and WMRR, WMUS and MMPT showed that WMCC had a statistically significant ($p<.05$) difference in mean temperature. The p-values of the ANOVA teste between CC and WMRR, WMUS and MMPT were .003, .007, and .001 respectively. Discharge for CC was .03 m^3, WMRR was .76 m^3 WMUS was .89 m^3 and MMPT was 1.7 m^3 (Table 1).

Substrate

Substrate analyses at each site showed differing substrate compositions along the Maple River. WMCC had especially high wood (28%) and sand/silt (60%) composition. WMRR had large amounts of sand/silt (32.7%), pebble (35.6%) and wood (24.8%). WMUS was mostly composed of sand/silt (34%), cobble (29%) and pebble (20%). Lastly, WMPT was compromised of mostly pebble (61.6%) and sand/silt (20.2%). Moving downstream, pebble and cobble composition increased significantly while sand and wood substrates decreased in abundance (Figure 1).

Macroinvertebrates

Hierarchical centroid-distance based cluster analysis displayed as a constellation plot depicts similarity of macroinvertebrate community composition among sites. CC was the most dissimilar site, while WMUS and WMRR had the most similar macroinvertebrate communities (Figure 2). Shannon diversity indices showed macroinvertebrate community diversity was highest at CC (.87) and lowest diversity at WMUS (.58) (Table 2). Percent Ephemeroptera of macroinvertebrates was highest at WMRR (27%) and MMPT (25%) while percent Diptera was highest at WMRR (35%) and WMUS (33%) (Table 2).

Fish Sampling

Fish sampling yielded 14 different species among all sites. Electrofishing yielded the highest number of fishes, but did not capture all species (*Micropterus salmoides*). Both *S. fontinalis* and *Cottus spp.* made up most of the yield, at 26% and 32% respectively (Table 3). Dendogram analyses of fish communities showed that MMPT and WMRR were most closely related, with WMUS slightly less related and CC being even less similar (Figure 3). Constellation plot depictions of species relatedness sites based on Pearson correlations showed interesting relationships. While *O. mykiss* and *S. trutta* clustered closely as both juveniles and adults, *S. fontinalis* was not closely related to the non-native salmonids as juveniles or adults (Figure 4). Shannon diversity indices showed WMRR was the most diverse in fish catch (.39), then CC (.31), MMPT (.28) and lastly WMUS (.19) (Table 4). Percentages of total catch showed the highest percentage of *S. fontinalis* at CC (53%) and decreased linearly at each site downstream, with their lowest abundance at MMPT (3%). Both *S. trutta* and *O. mykiss* abundance increased moving downstream, with lowest abundance at CC (0%) and highest abundance at downstream MMPT (28% and 6%) (Figure 5).

Diet

Based on calculations of Ivlev's Electivity for each site and species (See appendix), bar graphs were constructed comparing electivity of Ephemeroptera, Diptera and Odonata by species and site (Figures 6a-6c). Across all sites and species, there were strong (negative) values of avoidance for both Ephemoptera and Diptera. For Odonata, except for *S. fontinalis* at CC, all species across all sites showed a strong (positive) preference for this prey order. Based on calculations of Numerical indices for each site and species (See appendix), stacked bar graphs indicated diversity and percent composition of prey order for each species and site. At CC, *S. fontinalis* consumed mainly Mollusca and fish. At WMRR, *O. mykiss* consumed primarily Trichoptera while *S. fontinalis* showed high variability in diet with Mollusca still prominent. At WMUS, all three Salmonid species consumed a variety of prey, but prominently Trichoptera. At MMPT, Trichoptera and Odonata were consumed heavily by all three species. Notably, *S. fontinalis* consumed a large proportion of Mollusca when compared to *S. trutta* and *O. mykiss* at WMRR, WMUS and MMPT.

Discussion:

Abiotic factors and substrate showed possible habitat for *T. arcticus* reintroduction to the Maple River. All four sites had average, minimum and maximum temperatures that were within the known range for *T. arcticus.* Since these temperatures were recorded during one of the hottest months of the year, these temperatures are likely towards the maximum water temperatures for the Maple River. In terms of substrate, the more downstream sites of WMRR, WMUS, and MMPT with less silt and higher pebble or gravel composition were more appropriate for *T. arcticus* spawning and year-round habitation. CC was warmer and had high wood and sand/silt composition, which is not ideal for *T. arcticus.*

Macroinvertebrate composition differed between sites, although WMRR and WMUS were very similar. MMPT was also closely related to these two sites while CC differed. Interestingly, CC had the highest Shannon Diversity Index due to the presence of many macroinvertebrate orders not observed elsewhere. Overall, all four sites had relatively high Shannon Diversity Indices (>.50) of macroinvertebrate composition. In terms of known prey items of *T. arcticus* (Stewart et al 2007), WMRR, WMUS, and MMPT had macroinvertebrate compositions of more than 50% combined Diptera and Ephemoptera.

Fish sampling of the four Maple River sites showed varying community diversity among sites. WMRR had the most diverse fish community while WMUS had the least diverse fish community. Hierarchical constellation plots based on Pearson correlation coefficients depicted promising data for *T. arcticus* reintroduction. Adult and juvenile *O. mykiss* and *S. trutta* clustered closely and were far away from *S. fontinalis*. This shows that there may be room for *T. arcticus* to associate in fish communities with *S. fontinalis*, while avoiding *O. mykiss* and *S. trutta.* Salmonid composition by species of total catch further indicated which communities would be favorable for *T. arcticus*. CC, WMRR and WMUS had higher percentages of *S. fontinalis* and lower percentages of both *O. mykiss* and *S. trutta.* WMPT had a very small percentage of *S. fontinalis* and a high percentage of *S. trutta*, which is not a good indicator for *T. arcticus* reintroduction.

Diet analysis using Ivlev’s Electivity at CC, WMRR, WMUS and MMPT showed ample preferred food resource availability for *T. arcticus.* All three Salmonid species heavily avoided both Ephemeroptera and Diptera, while instead preferring macroinvertebrates such as Odonata. Numerical indices showing diet composition of *S. trutta, S. fontinalis* and *O. mykiss* indicated highly variable diets between species and sites. At CC, *S. fontinalis* had a diet consisting primarily of Mollusca. At WMRR, *O. mykiss* consumed Coleoptera and Ephemeroptera while *S. fontinalis* had a much more varied diet. At WMUS and MMPT, *O. mykiss* and *S. trutta* consumed largely Coleoptera, Odonata and Hymenoptera while *S. fontinalis* again had a highly variable diet of mainly Coleoptera, Mollusca and Odonata. Overall, the trend of *S. fontinalis* consuming Mollusca was observed at all sites of the Maple River. Previous studies investigating resource partitioning between *S. fontinalis* and other sympatric salmonid species indicated that *S. fontinalis* effectively broadened their diet and relied on alternative prey sources in the face of competition (Mookerji et al., 2004). Thus, competition with other Salmonids is likely the cause of increased Mollusca consumption by *S. fontinalis.* Consumption of Mollusca by *S. fontinalis* in more downstream sites may indicate that *T. arcticus* may not be very successful there, since Mollusca were not abundant in downstream macroinvertebrate collection.

Considering temperature, substrate, macroinvertebrates, fish communities and diet, we believe that reintroduction of *T. arcticus* to the Maple River would be viable. In particular, the West Branch sites of WMRR and WMUS would be most appropriate. WMRR and WMUS have relatively diverse fish and macroinvertebrate communities with high percentages of both Ephemeroptera and Diptera composition. These sites also fall within the known temperature range of *T. arcticus*. In terms of competition, WMRR and WMUS have relatively low percentages of *O. mykiss* and *S. trutta*, and relatively high percentages of *S. fontinalis*. All three salmonids showed heavy avoidance of both Diptera and Ephemeroptera. Given these factors combined, there appears to be suitable habitat for *T. arcticus* in the West Branch of the Maple River.

While some Maple River sites appear to be suitable for *T. arcticus* reintroduction, the suitability may change as the Dam separating MMPT from the upstream sites is being removed. This removal may change abiotic and biotic factors in the Maple River. In previous studies, removal of dams has caused fish to distribute themselves differently along rivers and show increased habitat partitioning (Burroughs et al., 2010). We do not know how the Dam removal will change fish communities and competition in the Maple River as future research will be needed to assess new habitat composition along the Maple River. It is possible that reintroduction of the native Salmonid *T. arcticus* may become more viable with the removal of the dam, but only time will tell.

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Figures and Tables:

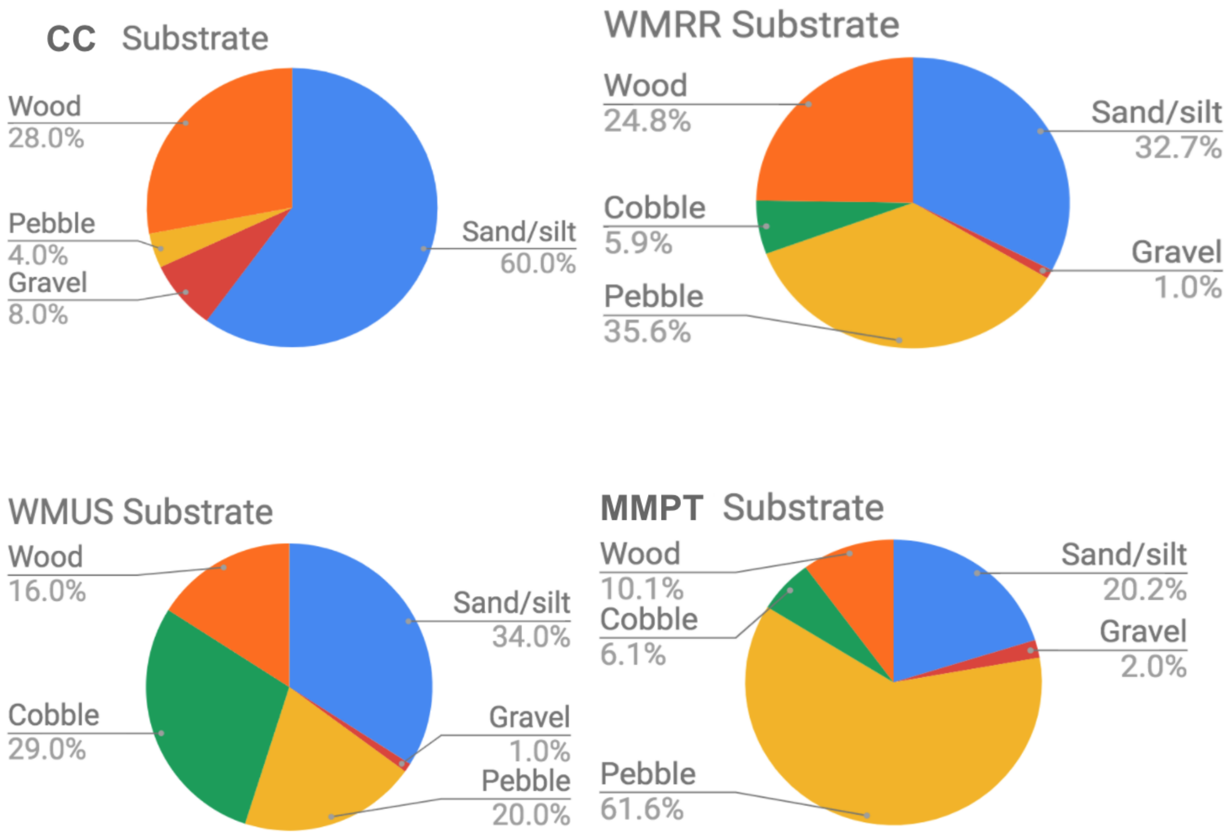
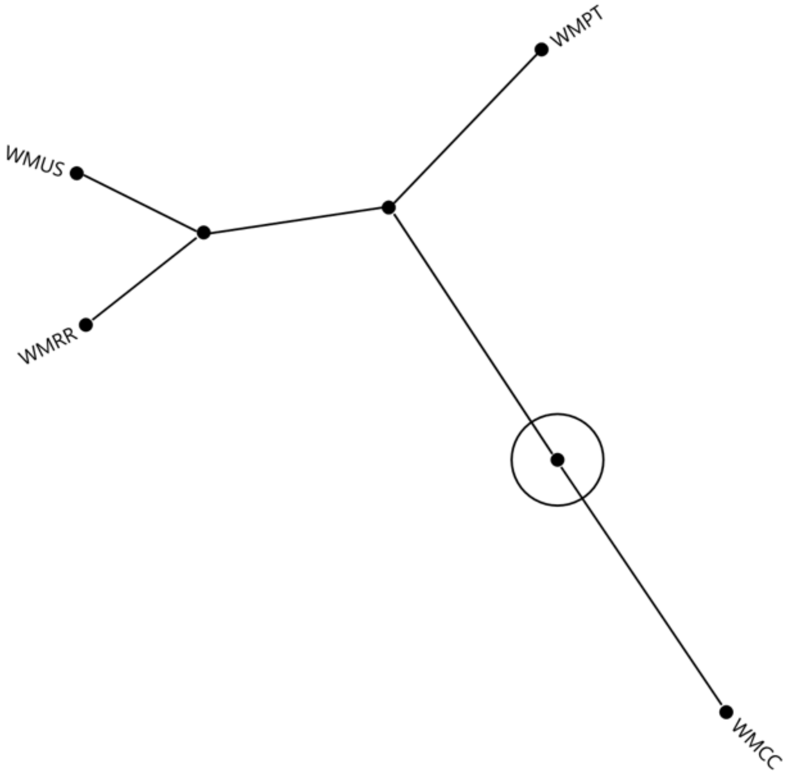


Figure 1: Pie charts displaying substrate composition estimates of each Maple River site. Upstream sites (CC and WMRR) were composed primarily of wood and sand/silt, while downstream sites (WMUS and MMPT) were composed primarily of pebble and cobble substrates.



<u>Figure 2:</u> Hierarchical constellation plot of relationships between macroinvertebrate communities among sites, based on centroid distance. CC was the most distantly related community, while WMUS and WMRR had tightly related communities. MMPT was pretty closely related to both WMUS and WMRR.

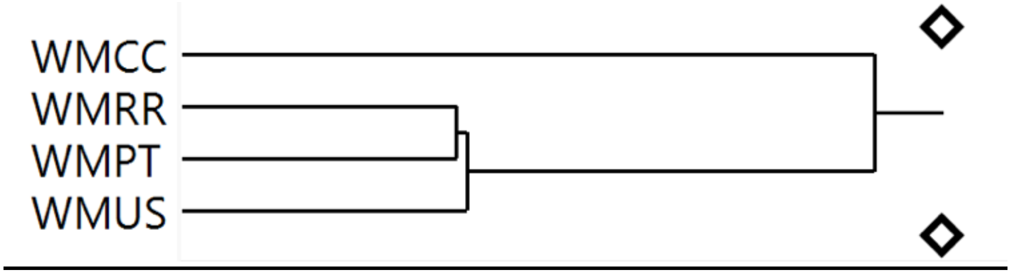


Figure 3: Dendogram based on hierarchical centroid-distance relationships illustrating similarities in fish communities among sites. WMRR and MMPT were tightly related along with WMUS, while WMCC was not similar.

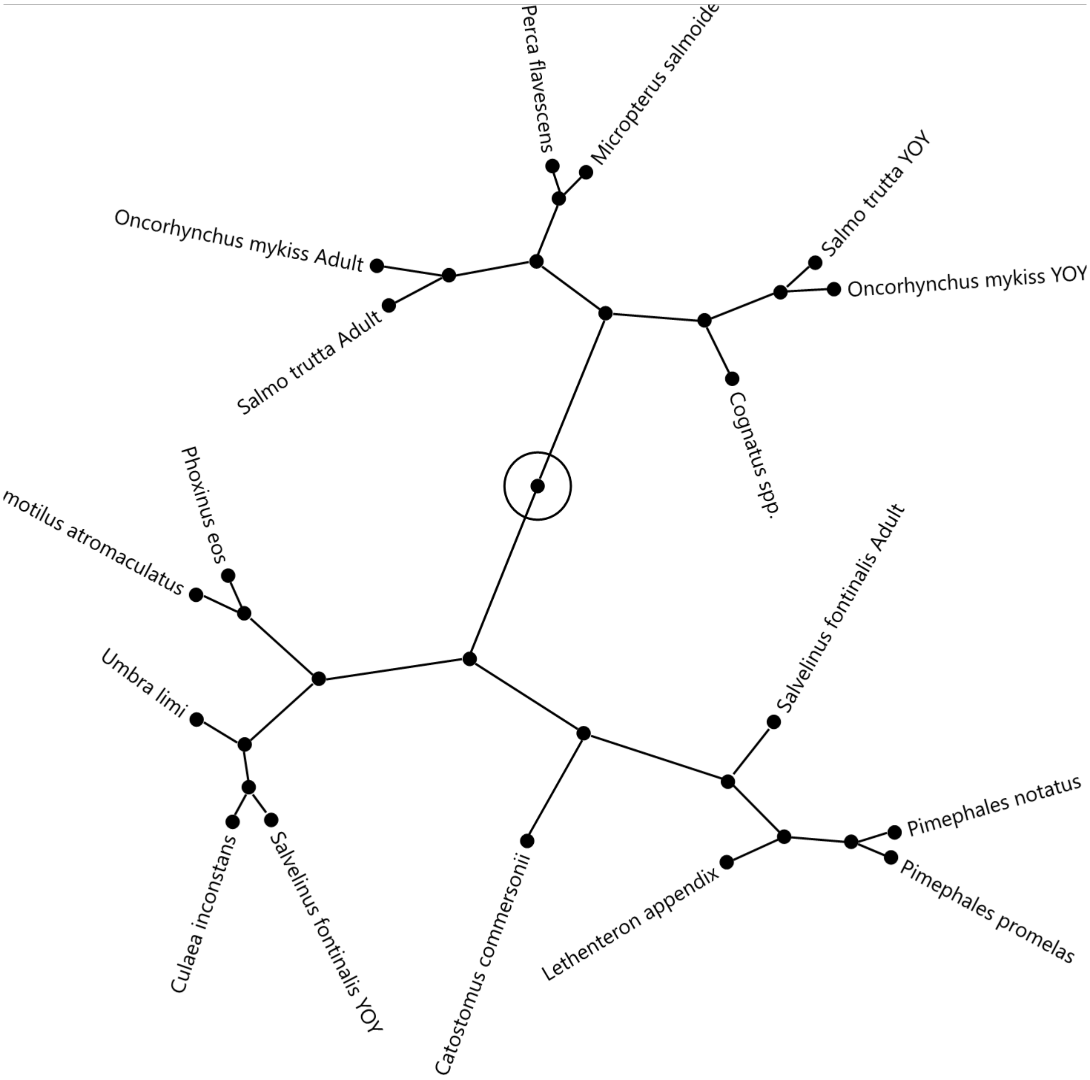


Figure 4: Hierarchical constellation plot of species relatedness based on Pearson correlations. Closer dots indicate closer relatedness in habitat use and the circle shows the point of origin. *O. mykiss* and *S. trutta* were closely correlated as both adults and young of year, while *S. fontinalis* was not closely related to *O. mykiss* or *S. trutta* as young of year or adults. *S. fontinalis* also showed differences in fish community association as young of year and adults.

Percent Composition of Fish Communities Among Sites

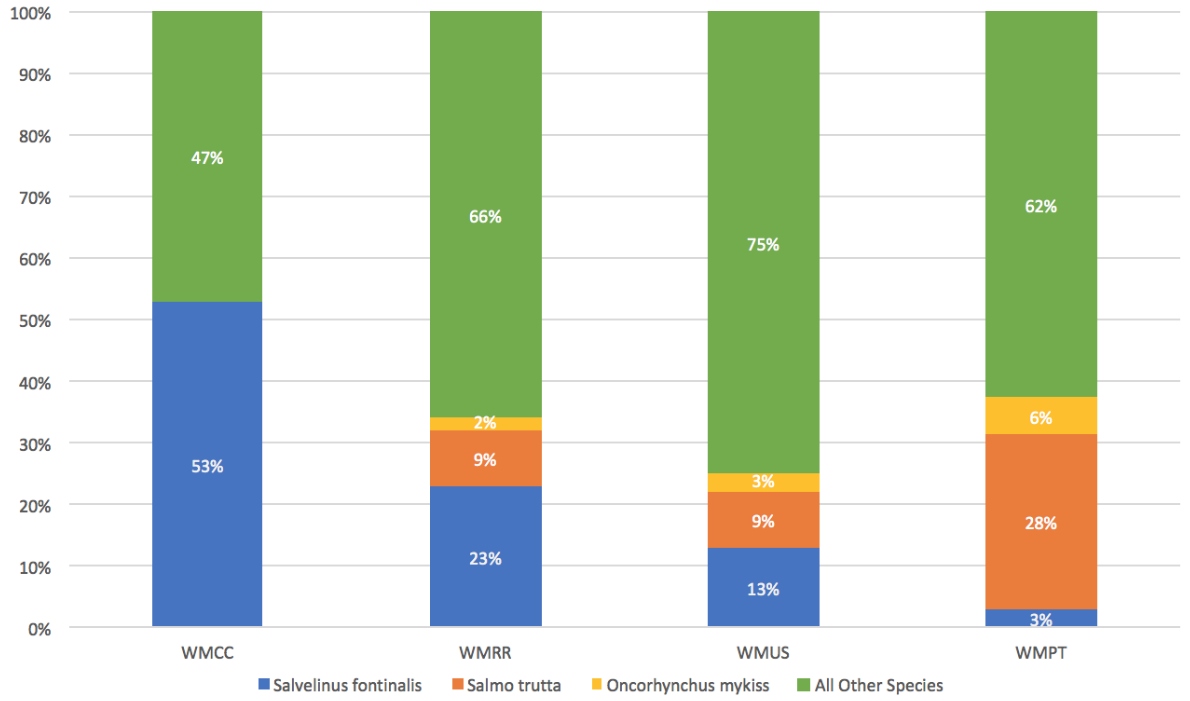


Figure 5: Stacked bar graph illustrating percent composition of all species versus each *S. fontinalis*, *O. mykiss*, and *S. trutta* at each site. Percentage of *S. fontinalis* was highest at CC, and decreased moving downstream. Conversely, percentage composition of *O. mykiss*, and *S. trutta* increased moving downstream.

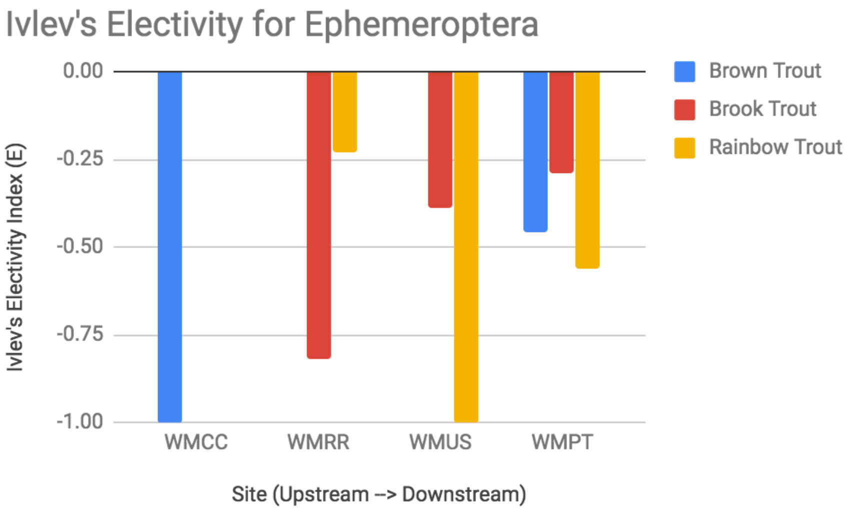


Figure 6a: Bar graphs depicting Ivlev's Electivity for Ephemoptera for each species at each site. Negative values show avoidance of prey items. All species at all sites showed avoidance for Ephemoptera.Tables with all calculated values can be found in the Appendix.

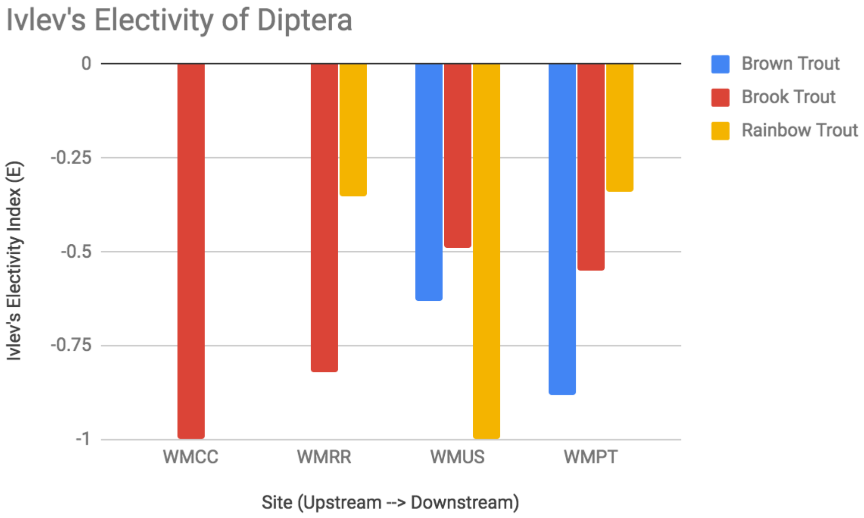


Figure 6b: Bar graphs depicting Ivlev's Electivity for Diptera for each species at each site. Negative values show avoidance of prey items. All Salmonid species at all four sites showed avoidance for Diptera. Tables with all calculated values can be found in the Appendix.

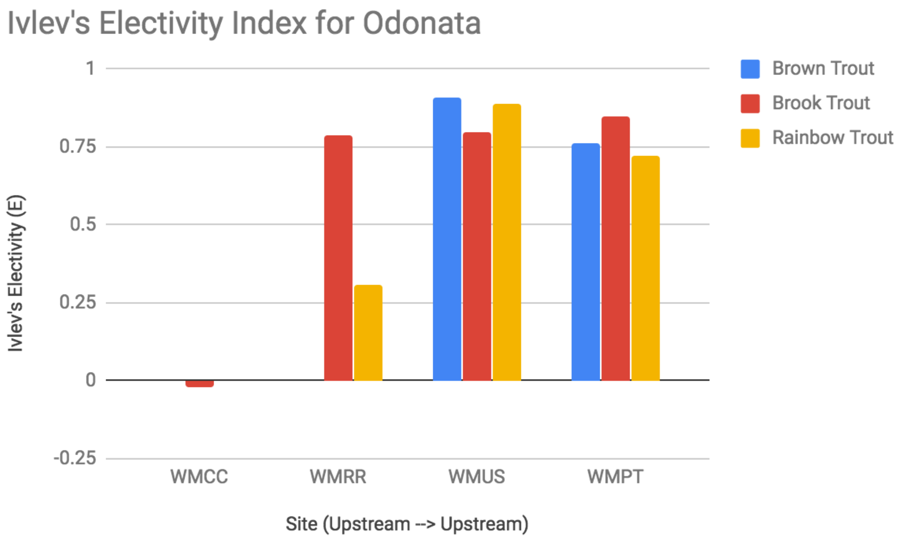
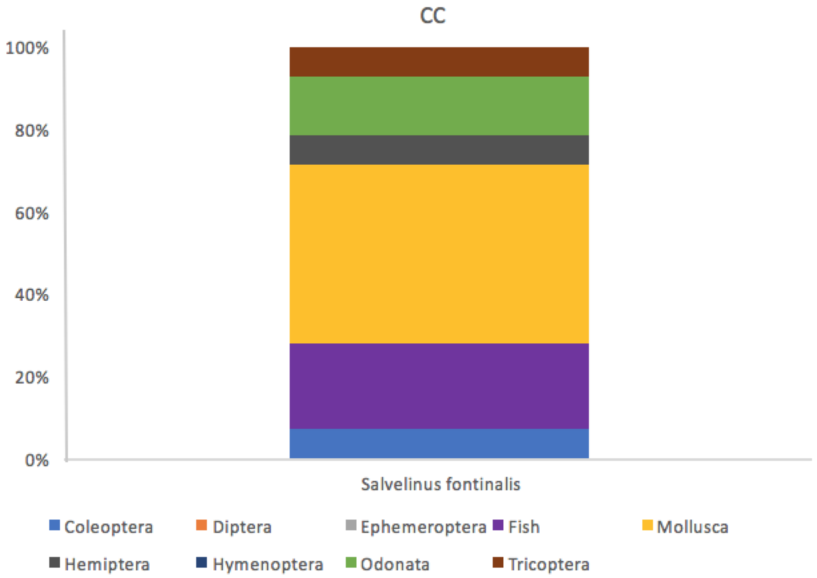
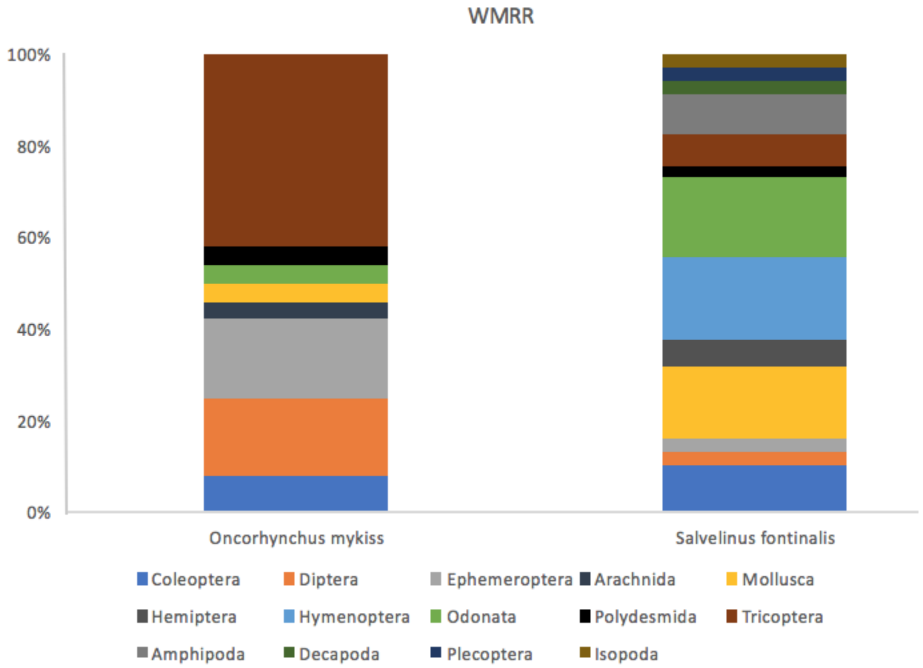


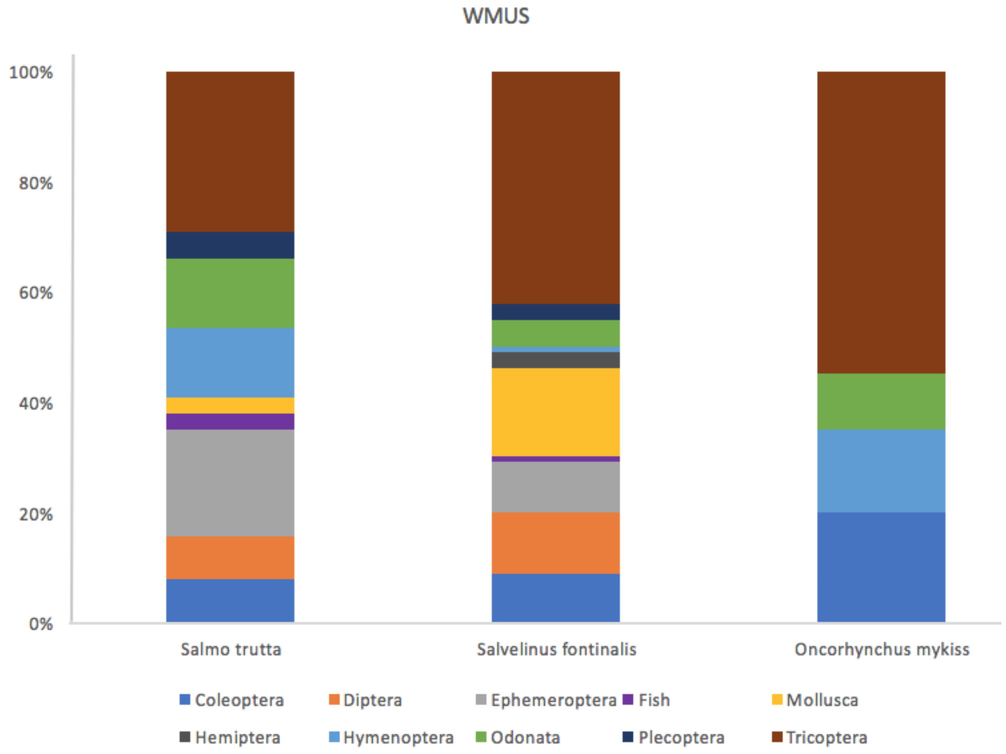
Figure 6c: Bar graphs depicting Ivlev's Electivity for Odonata for each species at each site. Positive values show preference while negative values show avoidance of prey items. All species at all sites showed preference for Odonata, with the exception of the slight avoidance by *S. fontinalis* at CC. Tables with all calculated values can be found in the Appendix.



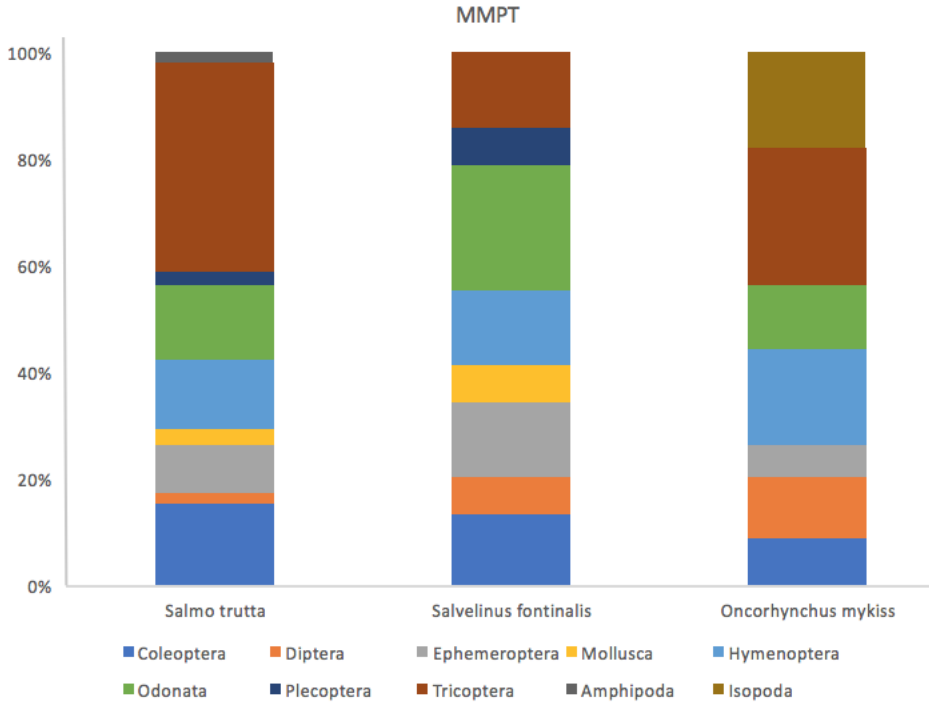
<u>Figure 7a:</u> Stacked bar graph depicting numerical indices of *S. fontinalis* (N=6) at CC, with different colors representing different macroinvertebrate orders. *S. fontinalis* consumed mainly Mollusca (yellow) and fish (purple). Tables with all calculated values can be found in the Appendix.



<u>Figure 7b:</u> Stacked bar graph depicting numerical indices of *S. fontinalis* (N=9) and *O. mykiss* (N=1) at WMRR, with different colors representing different macroinvertebrate orders. *S. fontinalis* consumed mainly Mollusca (yellow), Odonata (green) and Hymenoptera (light blue). *O. mykiss* consumed primarily Trichoptera (red/brown), Ephemoptera (light gray) and Diptera (orange). Tables with all calculated values can be found in the Appendix.



<u>Figure 7c:</u> Stacked bar graph depicting numerical indices of *S. trutta* (N=3) , *S. fontinalis* (N=4) and *O. mykiss* (N=3) at WMUS, with different colors representing different macroinvertebrate orders. *S. trutta* consumed primarily Trichoptera (red/brown), Ephemoptera (light gray), Hymenoptera (light blue) and Odonata (green). *S. fontinalis* consumed mainly Trichoptera (red/brown), Mollusca (yellow) and Diptera (orange). *O. mykiss* consumed primarily Trichoptera (red/brown), Coleoptera (blue) and Hymenoptera (light blue). Tables with all calculated values can be found in the Appendix.



<u>Figure 7d:</u> Stacked bar graph depicting numerical indices of *S. trutta* (N=6), *S. fontinalis* (N=2) and *O. mykiss* (N=2) at WMUS, with different colors representing different macroinvertebrate orders. *S. trutta* consumed primarily Trichoptera (red/brown), Odonata (green), Hymeoptera (light blue) and Coleoptera (blue). *S. fontinalis* consumed mainly Odonata (green), Trichoptera (red/brown), Mollusca (yellow) and Hymenoptera (light blue). *O. mykiss* consumed primarily Trichoptera (red/brown), Hymenoptera (light blue) and Isopoda (mustard). Tables with all calculated values can be found in the Appendix.

Tables:

Site	Mean Temp (°C)	High Temp (°C)	Low Temp (°C)	Discharge (m^3/s)
CC	20.7	22.0	18.3	.032
WMRR	16.8	17.8	15.8	.757
WMUS	16.2	16.7	15.4	.891
MMPT	17.3	17.7	16.5	1.65

Table 1: Table showing mean, high and low temperatures, along with discharge for all four Maple River sites.

Site	Shannon Diversity Index	% Ephemeroptera	% Diptera
CC	0.87	6	5
WMRR	0.67	27	35
WMUS	0.58	20	33
MMPT	0.70	25	24

Table 2: Table depicting Shannon Diversity Indices for macroinvertebrate communities at each site. Larger decimals of Shannon Diversity represent higher species diversity. Percent Ephemoptera and Diptera out of all macroinvertebrates collected for each site are also shown.

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

Table 3: Table showing species caught, location, method of capture, number, and percentage of total catch for all fishes collected during sampling.

Site	Shannon Diversity Index
CC	0.31
WMRR	0.39
WMUS	0.19
MMPT	0.28

Table 4: Table showing Shannon diversity indices of fish communities at each site. Larger decimals of Shannon Diversity represent higher species diversity.

Appendix:

Numerical Index CC

Macroinvertebrate order	***Salvelinus fontinalis***	***Umbra limi***
Coleoptera	.07	1.00
Fish	.21	--
Mollusca	.43	--
Hemiptera	.07	--
Odonata	.14	--
Tricoptera	.07	--

Table 1: Table showing Numerical Index for CC for *S. fontinalis* and *U. limi*

Frequency of Occurrence CC

Macroinvertebrate order	***Salvelinus fontinalis***	***Umbra limi***
Coleoptera	.17	.50
Fish	.33	--
Mollusca	.50	--
Hemiptera	.17	--
Odonata	.33	--
Tricoptera	.17	--

Table 2: Table showing Frequency of Occurrence Index for CC for *S. fontinalis* and *U. limi*

Ivlev's Electivity CC

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

Table 3: Table showing Ivlev's Electivity Index for CC for *S. fontinalis* and *U. limi.* Positive numbers show preference for a prey while negative numbers show avoidance.

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

Table 4: Table showing Numerical Index for WMRR for *S. fontinalis* and *O. mykiss*.

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

Table 5: Table showing Frequency of Occurrence Index for WMRR for *S. fontinalis* and *O. mykiss*

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

Table 6: Table showing Ivlev's Electivity Index for WMRR for *S. fontinalis* and *O. mykiss.* Positive numbers show preference for a prey while negative numbers show avoidance.

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

Table 7: Table showing Numerical Index for WMUS for *S. trutta, S. fontinalis, O. mykiss and Cottus spp.*

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

Table 8: Table showing Frequency of Occurrence Index for WMUS for *S. trutta, S. fontinalis, O. mykiss and Cottus spp.*

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

Table 9: Table showing Ivlev's Electivity Index for WMUS for *S. trutta, S. fontinalis, O. mykiss and Cottus spp.* Positive numbers show preference for a prey while negative numbers show avoidance.

Numerical Index MMPT

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	--

Table 10: Table showing Numerical Index for MMPT for *S. trutta*, *S. fontinalis*, *O. mykiss and Cottus spp.*

Frequency of Occurrence MMPT

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	--

Table 11: Table showing Frequency of Occurrence Index for MMPT for *S. trutta*, *S. fontinalis*, *O. mykiss and Cottus spp.*

Ivlev's Electivity MMPT

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	--

Table 12: Table showing Ivlev's Electivity Index for MMPT for *S. trutta*, *S. fontinalis*, *O. mykiss and Cottus spp.* Positive numbers show preference for a prey while negative numbers show avoidance.