# Preliminary Biotic and Abiotic Habitat Assessment and Comparison of East and West Branches of the Maple River for the Reintroduction of Arctic Grayling in Michigan

Gregory Cogut

University of Michigan Biological Station
RLW EEB321/ENV331
8/17/2017
Prof. Amy Schrank

## Abstract

The Arctic Grayling *Thymallus arcticus* is a member of the Salmonid family native to Northern Michigan, that has been extirpated since 1936 due to habitat loss, overfishing, and competition by invasive species. In 2016 the DNR proposed reintroducing Grayling to their native habitat, which includes the restocking of the West Branch of the Maple River, MI. This survey collected habitat, water quality, and macroinvertebrate data at 4 sample sites along the East and West branches of the Maple River. Abiotic habitat characteristics such as temperature, water velocity, and percent cover at both West branch Maple sites were more suitable for Grayling than those at the East Branch sites. While the East branch had more drifting macroinvertebrates, the West branch had significantly higher %EPT for both benthic and drifting macroinvertebrate. Based on our data, we believe that the West branch of the Maple River is more suitable for Grayling than the East branch. We also believe that Grayling could survive in the West branch, however further study should be conducted to determine if Grayling could successfully compete with existing fish species.

# Preliminary Biotic and Abiotic Habitat Assessment and Comparison of East and West Branches of the Maple River for the Reintroduction of Arctic Grayling in Michigan

Gregory Cogut

University of Michigan Biological Station
Rivers Lakes and Wetlands
August 17th 2017
Professor: Dr. Amy Schrank

## Abstract

The Arctic Grayling *Thymallus arcticus* is a member of the Salmonid family native to Northern Michigan, that has been extirpated since 1936 due to habitat loss, overfishing, and competition by invasive species. In 2016 the DNR proposed reintroducing Grayling to their native habitat, which includes the restocking of the West Branch of the Maple River, MI. This survey collected habitat, water quality, and macroinvertebrate data at 4 sample sites along the East and West branches of the Maple River. Abiotic habitat characteristics such as temperature, water velocity, and percent cover at both West branch Maple sites were more suitable for Grayling than those at the East Branch sites. While the East branch had more drifting macroinvertebrates, the West branch had significantly higher %EPT for both benthic and drifting macroinvertebrate. Based on our data, we believe that the West branch of the Maple River is more suitable for Grayling than the East branch. We also believe that Grayling could survive in the West branch, however further study should be conducted to determine if Grayling could successfully compete with existing fish species.

# Introduction

The Arctic Grayling *Thymallus arcticus* is a member of the Salmonid family native to Northern Michigan. Since its last sighting in 1936, the Arctic Grayling has been listed as an extirpated species in the state of Michigan (DNR, 2017). The decline of the Arctic Grayling can be attributed to overfishing, the introduction of European Brown Trout and Rainbow Trout, and most significantly, mass anthropogenic deforestation in the 1800 (Danhoff, 2014). Due to ineffectual regulation in the 1800s and early 1900s, overfishing of the Great Lakes and its tributaries resulted in the reduction of many fish species (Bogue, 2000). The introduction of more aggressive European Brown and Rainbow trouts reduced Grayling populations as they outcompeted Grayling for habitat and ate their eggs and young (Danhoff, 2014). Mass deforestation in the 1800's reduced tree cover and resulted in the silting and increases in log jamming of Northern Michigan's rivers. Reduced tree cover raised water temperatures, which stripped Grayling of much of their natural cold water habitat. Since Grayling spawn on bottom rocks, increased embeddedness from silting and log jamming inhibited their reproduction (Danhoff, 2014).

With an increased emphasis of restoration in the Great Lakes region, in 2016 the Michigan Department of Natural Resources proposed an initiative to return the Arctic Grayling to Michigan waterways (DNR, 2017). The DNR's proposed initiative involves the restocking of the West Branch of the Maple River from elsewhere in the US and Canada (DNR, 2017). The 2016 initiative is not the first attempt to restock Grayling in Michigan, as there have been multiple attempts with the most recent being between 1987 and 1991. Based on his assessment of the last attempt to re-stock Grayling in Michigan between 1987 and 1991, Nuhfe (1992) stated that it is possible for Arctic Grayling populations to establish themselves in some Michigan Lakes. However, for Grayling to be reestablished in Michigan's Rivers, restoration and dam removal must first occur (Nuhfe, 1992). The main branch of the Maple River, which is soon to be reconnected to the East and West branches of the Maple River by the Lake Kathleen dam removal, which will provide a restored and uninterrupted river network that once supported Grayling. Nuhfe (1992) noted that one of the problems with previous re-stocking attempts was that Grayling instinctively swam down river during spawning season, which resulted in them swimming into warmer waters where they became disoriented. Increased river restoration since the last attempted restocking has increased the ability to identify more suitable habitats for Grayling in Michigan.

The first step in identifying suitable habitat for Grayling is determining if the water temperature is cool enough. While Grayling populations in the Big Hole River, MT have shown that Grayling can survive in temperatures reaching above 20 C°, populations studied in Alaska begin to show stress as temperatures approach 17 C° (Danhoff, 2014). According to Feldmeth and Eriksen (1978), Arctic Grayling can only compete with, and possibly outcompete, more aggressive Salmonids in colder headwater streams. Adult and juvenile Grayling differ in that adult Grayling are more tolerant of varying temperatures as their habitable range is 2.7-22.0 C°, while juveniles require temperatures between 4.5-17.3 C° (Danhoff et al, 2017). Thus, for Grayling to successfully establish themselves, restocking locations should not exceed 22 C°, and restocking locations for juvenile fish, specifically, should not surpass 17.3 C°.

River morphometry and water characteristics such as dissolved oxygen and flow are important abiotic habitat factors that can influence the suitability of a river for Grayling. Unlike other Salmonidae, Grayling are not oxygen limited so a suitable habitat for Grayling can have dissolved oxygen between 1.3 and 12.6 mg/L (Danhoff et. al, 2017), but optimal dissolved oxygen levels are above 4 mg/L (Tingley , 2010) . Byström (2003) identified predation as one of the main factors influencing differences in habitat requirements for fish species with respect to maturity. Juvenile Grayling require a refuge habitat with calm shallow water between 0.1 and 0.4 meters deep and with a velocity of 0.1-0.4 m/s, which helps them to develop, avoid larger predators, and face less competition (Byström et al, 2003, Danhoff et al, 2017). Adult Grayling are more developed and less susceptible to predation, so they can survive in water between 0.3 and 2.8 meters deep with velocities between 0.1 and 0.9 m/s (Danhoff et al, 2017).

Graylings' ability to spawn is influence based by river bed characteristics, which is why substratum is an important factor determining habitat suitability for Grayling. Unlike many other Salmonidae, such as Brown and Rainbow trouts, Grayling produce egg sacks that adhere to bottom rocks. Not only does this method of reproduction increase the risk of egg predation, but it also means that Graylings require less embedded and larger substratum than other Salmonidae to spawn. For optimal spawning and habitability, the river bed should range from coarse sand to large pebbles, with less than 30% fine substrate (Dannoff, 2017).

Grayling are opportunistic feeders that will consume all life stages of terrestrial and aquatic macroinvertebrates, as well as fish eggs. As a visual predator, Grayling are reliant on the visibility of their prey and prefer to feed at the surface and at midwater depths, where there is the greatest light penetration. Grayling diet is also seasonably variable in correspondence to the availability of prey species (Stewart et al, 2007). In the spring and summer Grayling primarily consume drifting and flying macroinvertebrates that reside on the surface and at mid-depths (Stewart et al, 2007). In fall and winter Grayling become more reliant on benthic macroinvertebrates, and due to decreased food availability tend to consume less than in the spring and summer (Armstrong, 1986). While adult Grayling have a varied diet, Mayfly nymphs and Diptera pupae have been identified as important food sources for juvenile Grayling (Stewart et al, 2007). Given the less opportunistic feeding patterns of juvenile Grayling, identifying sites with high amounts of Ephemeroptera and Diptera pupae are important for the establishment of a self-sustaining population.

For the DNR to successfully reintroduce Grayling to Michigan, a comprehensive biotic and abiotic habitat assessment of potential reintroduction must first occur. This study seeks to preliminarily address the question of habitat suitability for Grayling in the Maple river by surveying sites along the East and West branches. By comparing the abiotic and biotic habitat features such as water temperature, dissolved oxygen, %cover, abundance and % EPT of both drifting and benthic macroinvertebrates, at our sample sites, it will be possible to know if either branch of the Maple River could support the reintroduction of Grayling. We hypothesize that the West branch of the Maple River will be more suitable for Grayling than the East branch of the Maple River. We also hypothesize that the West branch provides the proper habitat characteristics making it suitable for Grayling to be reintroduced

## Materials and Methods

The study was conducted at four sample sites located along the East and West Branches of the Maple River, near the University of Michigan Biological Field Station in Pellston Michigan

(Figure. 1; Table. 1). The West Branch Maple River at Robinson Road (WB1) is a second order stream that is characterized as a cold groundwater fed stream. The East Branch Maple River at Robinson Road (EB1) is also a second order stream, but it is fed by Douglas lake, and therefore has slightly warmer water than the West branch. West branch Maple River at US 31 (WB2) is a cold third order stream that is groundwater fed. East branch Maple River at Douglas Lake road (EB2) is a slightly warmer second order stream, fed by Douglas Lake. All the sample sites located along the East and West branches of the Maple River are all part of a connected system that converge at Lake Kathleen.

At each of the four sample sites, 100 meter reaches were chosen haphazardly based on access to the stream and marked every ten meters with flags to mark transects. At each transect we first measured stream width, and then measured habitat characteristics every two meters across the stream transect. To measure habitat, we used a $0.25m^2$ PVC quadrat to estimate embeddedness and % cover (Table. 2). Data collected from each site transect was averaged, and then sites % covers were graphed for comparison.

Discharge and water quality assessments was taken once at each sample site. Dissolved oxygen (mg/l) and temperature was assessed at the farthest downstream transect using a YSI. Discharge at the beginning and end of each reach was measured using a flow meter, from which averages where calculated.

We sampled benthic macroinvertebrates quantitatively using D-nets. Ten samples were taken at each site in proportion to percent bottom cover (e.g, 10% gravel= 1 gravel samples). Using two meter sticks we measured a square meter and placed a D-net at the downstream side of the square meter. The area in the square was disturbed for two person minutes, for which fine and large sediment was kicked to dislodge resident invertebrates. Once each sample was collected, they were sorted for thirty person minutes in white enamel pans. Using two independent sample t-test to compare sites from the same branches, resulting in no significant difference within branches. Since there was not a significant difference within branches, we grouped sites from the same branches together to compare the East and West branches of the Maple River. For each branch of the river, abundance per square meter of all macroinvertebrates was calculated, and branch means were compared in SPSS using an independent samples t-test. Additionally, since the resulting data was not normally distributed %EPT of all macroinvertebrates caught in D-net sampling at East and West branches were compared in SPSS using a Mann- Whitney U test.

Drifting macroinvertebrates were collected with three evenly placed drift nets set at the farthest downstream transects of WB1 and EB1 at dawn, noon, and dusk. After one hour drift nets were removed and their contents returned to the lab, where they were sorted for 30 person minutes. Drift nets macroinvertebrates were measured by the total number of organisms caught over the course of an hour. After grouping organisms by site a t- test was conducted in SPSS to compare %EPT between WB1 and EB1. Since the data was not normally distributed for total abundance, a  Mann- Whitney U test was used to compare macroinvertebrate abundance between WB1 and EB1.

## Results

Average percent cover was calculated from quadrats at each site, and graphed for comparison between sites (Figure. 2). EB1, WB2 and EB2 have similar sand cover, and WB1 has the lowest (32.1%). WB1 has the highest percent cover of coarse material (gravel, pebble and cobble) with (27.4%) compared to (19.4%) EB1, (20.0%) WB2, and (10.0%) EB2. Total percent cover of woody debris varied most between sites, with WB1 having the highest (23.6%) and EB2 (6.3%) having the lowest total percent coverage. Additionally, West branch sites are notably less embedded than East branch sites. (Table. 3).

Total abundance of benthic macroinvertebrates was found to be normally distributed between the East and West branch sites, so a t-test was used to compare the relative abundance of macroinvertebrates per square meter between the branches. Relative abundance of macroinvertebrates was not significantly different between the two branches (t= 0.371 def= 37.00 p= 0.712) (Table. 4; Graph 1). Percent EPT was not normally distributed so a non-parametric Mann - Whitney U test was conducted, and the West branch had a significantly higher percent EPT than the East branch (Z=-3.190, p=.001) (Table. 5; Graph 2).

Drifting macroinvertebrate data from dawn, mid-day, and dusk from both WB1 and EB1 were used to establish a daily average number drifters per hour for both sites. Since the total abundance of drifting macroinvertebrates at WB1 were not normally distributed, a Mann Whitney U test was conducted to compare WB1 and EB1. EB1 had significantly more drifting macroinvertebrates than WB1 (Z= -2.742, p= 0.006) (Table. 6; Graph 3). Percent EPT of drifters was normally distributed so a d so t- test conducted, and WB1 had a significantly higher % EPT than EB1 (t= 2.940 , df=16, p= 0.024) (Table. 7; Graph 4).

Measurements of temperature and dissolved oxygen were taken on the same day, and just over an hour apart at all sites. Water temperature at West branch sites were found to be cooler than East branch sites. Dissolved oxygen was more at West branch sites than East branch sites (Table. 8).

Average and maximum velocities were higher for WB1 and WB2 than for EB1 and EB2 (Table. 9). The average depths of WB1, WB2, and EB1 are similar, however EB2 is has a lower average depth than the other sites (Table. 10). All four sites have similar maximum depths (Table 10). The average width of WB1 and WB2 are greater than EB1 and EB2, and have a greater variability in width (Table. 10).

## Discussion

Past attempts to re-introduce Grayling in Michigan have failed in part due to a lack of proper habitat assessments (Nuhfe, 1992). This study seeks to prevent such failures from reoccurring with the DNR's 2016 plan for reintroduction of Grayling, by assessing abiotic and biotic factors of habitat suitability.

One of the primary reasons Grayling were extirpated from Michigan was from clear cutting in the 1800's, which increased embeddedness and the amount of fine substrate on river beds. Grayling require coarse grained sediment to spawn, and thus need a less embedded environment with limited fine grain sediment. Grayling habitat in Big Hole Montana is approximately 20% fine sediment, 50% fine gravel and 30 % large Gravel, and in Alaska, the U.S. Fish and Wildlife recommend less than 10% fine sediment (Tingley, 2010). Based on this study's sample quadrats, WB1 was found to have the least amount of sand, but it was still averaged over 32% sand cover (Figure. 2). While WB1's percent sand is higher than the amount typically inhabited by Grayling, it could still potentially be suitable due to the nearly 30% combined average coarse sediment and high degree of woody debris (Figure. 2).   However, since the rivers Grayling historically inhabited in Michigan tended to have a higher amount of fine cover than those found in Montana and Alaska, WB1 could potentially be suitable for Grayling

(Tingley, 2010). While sites EB1 and EB2 contained noticeably high amounts of sand, observations at WB2 noted higher amounts of pebbles, gravel, and cobble than sampled in our quadrats. Based on these observations, additional sampling should be done at WB2 to re-assesses % cover. WB1 had a noticeably greater amount of woody debris than the other sample sites, which is likely due to the presence of downed trees that cut though portions of the sampling area. While the presence of downed trees can create pools, necessary for spawning and can provide a refuge for juvenile fish, if there is too much debris it can restrict Adult Grayling's ability to pass (Nelson, 1954; Everett and Ruiz, 1992). Based on our findings, the West branch of the Maple River appears more variable in percent cover than the East branch of the Maple river, given the variability between WB1 and WB2 in percent cover (Figure. 2). WB1 and WB2 were also less embedded than EB1 and EB2, which would make the West branch sites more suitable for spawning. (Table. 3) .

Benthic macroinvertebrates are an important source of food for Grayling when there are less available macroinvertebrates in the water column (Armstrong, 1986). The difference in abundance per square meter of benthic macroinvertebrates between the East and West branches of the Maple River were not statistically significant, meaning that the East and West branches have similar abundance (Table. 4). Measurements of dietary consumption of Grayling in Alaska found that they proportionally consume the highest amount of EPT macroinvertebrates (O'Brien, 2001). We found that the West Branch of the Maple River contains significantly more %EPT macroinvertebrates than the East Branch (Table. 5). Our data suggest that the West Branch would provide Grayling with a better benthic food base.

Grayling are visual predators that resorts consuming benthic macroinvertebrates in the absence of drifting macroinvertebrates (Danhoff, 2017). We found a significantly higher abundance of drifting macroinvertebrates per hour at EB1 than WB1 (Table. 6). Based on these findings, the East branch of the Maple River has a greater availability of drifting macroinvertebrates than the West Branch. While adult Grayling are opportunistic feeders, juvenile Grayling have been found to prefer Ephemoroptera and Diptera Pupae (Stewart, 2007; Jones et al. 2003). Since only Diptera pupae was found at EB1, and none were found at WB1, we could not compare % Diptera pupae between sample sites. While there was a higher % EPT of drifting macroinvertebrates at WB1 than EB1, it is unlikely that the loss in quantity would outweigh the benefit of higher % EPT for adult Grayling. (Table. 7). Studies in both Alaska and Canada have found that Grayling preferentially choose habitats with more drifting macroinvertebrates, as the presence of more drifting macroinvertebrates is related to increased rates feeding and reduced energy expenditure searching for food (O'Brian et al, 2001; McFarland et al., 2016). We believe that the East branch of the Maple River would be more preferential for adult Grayling solely do to the greater abundance of drifting macroinvertebrates, while West branch would be more preferential for juvenile Grayling due to the higher %EPT drifters.

Both benthic and drifting macroinvertebrates are an important food source in aquatic ecosystems. However, even if there was a higher abundance of macroinvertebrates at one branch, the availability of macroinvertebrates as a food resource is dependent upon the amount of competition in the stream. Given their similar feeding patterns, competition from other fish such as European Brown and Rainbow trouts are likely to reduce the availability of macroinvertebrates as a food source (Feldmeth and Eriksen, 1978). While there appears to be a sufficient abundance of macroinvertebrates at both sites to sustain Grayling, if other trouts are present they will outcompete Grayling for available macroinvertebrates when the environment becomes limiting (Brown, 1938; Cutting et al., 2015)

Abiotic characteristic such as temperature and dissolved oxygen are important in determining if a habitat is suitable for Grayling. The optimal water temperature for Grayling is between 7.5-16 °C (Tillnely, 2010). We found both West branch sites to have water temperatures that are within the upper bound of the optimal temperature range for Grayling (Table. 8). The East branch sites (EB1 and EB2) had higher water temperatures outside the optimal rage for Grayling. Additionally, since water temperatures at or above 20°C have been found to kill Grayling in Alaska, the water temperatures of the East branch sites could be lethal for some populations of Grayling (Hubert et al., 1985). Since the DNR plans to restock Grayling from the more temperature tolerant populations in Montana, Grayling could likely survive under stressed conditions in the East Maple River (Tingley , 2010). Grayling are not as oxygen limited as other salmonids, which allows them to survive in lower dissolved oxygen environments (Tingley , 2010). Dissolved oxygen measurements for all sample sites are considered optimal levels for Grayling, as all measurements were above 4 mg/L and bellow 12.6 mg/L (Tingley ,2010; Danhoff et. al, 2017). We believe that both branches of the Maple River would provide Grayling with optimal levels of dissolved oxygen.

Depth is an important physical abiotic habitat characteristic for determining habitat suitability for Grayling. Adult Grayling use greater depths as means of cover, while juveniles use shallower depths as a means of predator avoidance (Tingley , 2010). Variability of depths at each site resulted in a range of depths that would prevent any site from serving as an optimal refuge habitat for juvenile Grayling, as larger piscivorous fish could be present (Hughes and Dill, 1990). However, it should be noted that this study did not assess smaller upstream sites for both branches that could potentially serve as refuge habitats (Platts, 1979; Heim et al., 2014). Studies on the relationship between adult Grayling and depth have shown Grayling preferred to inhabit the deeper portions of rivers. (Hughes and Dill, 1990). While adult Grayling could survive at any of the sample sites, all four are near the bottom of their habitable range of 0.3 and 2.8 meters deep (Danhoff et al, 2017; Table. 10).

Velocity is an abiotic factor of habitat suitability because it influences the deposition of sediment and is related to feeding on drifting organisms. Drift feeding fish such as Grayling return to the same location to wait for prey, and higher velocity streams increase the rate at which drifting organisms are moved through the stream (Hughes and Dill, 1990). The higher average velocities at WB1 and WB2 than EB1 and EB2, indicate that the West Branch of the Maple River is more suitable for Grayling (Table. 9).

One of the problems with assessing the habitat suitability for the re-introduction of Arctic Grayling is the wide variety of factors that determine suitability. One of the most important factors in deterring habitat suitability for Grayling is water temperature, and based on our findings the East branch of the Maple River may be too warm for Grayling, however the West branch is within their tolerable range. While the West and East branches of the Maple River has similar abundances of benthic macro invertebrates, the West branch has significantly more %EPT benthic macroinvertebrates. While the East Maple has a greater abundance of drifting macroinvertebrates, the West branch has a higher % EPT of drifters. Additionally, the

West branch Robinson Road site had the greatest proportion of course substrate, which is necessary for spawning (Figure. 2). Based on our findings, we believe that the West branch of the Maple River is more suitable than the East branch of the Maple River for the reintroduction of Grayling.

While we also believe that Grayling could survive in the West branch of the Maple River, future studies should assess other aspects of the West branch of the Maple River. While the West Branch of the Maple River has high abundancies of benthic and drifting macroinvertebrates, we did not consider other factors such as competition that could reduce resource availability. Future studies should assess the fish populations in the river as species such as Brown and Rainbow trouts have been found to outcompete grayling when resources become limiting (Brown, 1938; Cutting et al., 2015). Future studies should also look at the amount of Zooplankton the West branch of the Maple River as Cutting et al. (2015) found that seasonal fluctuation in macroinvertebrate availability resulted in Graylings' diet consisting of 34% Zooplankton. Additional studies should also assess the prevalence of riparian vegetation and the population of terrestrial macroinvertebrates along the bank of the Maple River. McFarland (2016) found that of the terrestrial macroinvertebrate taxa sampled in riparian vegetation in Alaska, Grayling consumed over 99% of all surveyed taxa. One the most significant factors we could not study was the impact of the impending removal of the Lake Kathleen on both branches of the River. While we are confident in our study's findings, and our conclusion that Grayling could survive in the West branch of the Maple River, further habitat assessment is necessary to insure a successful reintroduction.

Table 1. Table of site names and with their corresponding numbers and GPS coordinates. The first GPS coordinate for each site marks the first transect (0m) and the second marks the last transect (100m)

| Site Number | Site Name | latitude longitude |
|---|---|---|
| WB1 | West Branch Maple Robinson Road | 45.5511, -84.7966<br>45.5521, -84.7971 |
| EB1 | 2. East Branch Maple Robinson Road | 45.5512, -84.7518<br>45.5526, -84.7505 |
| WB2 | 3. West Branch Maple U.S. 31 | 45.5406, -84.7849<br>45.5401, -84.7838 |
| EB2 | 4. East Branch Maple Douglas Lake Road | 45.5719, -84.7465<br>45.5725, -84.7458 |

Figure 1. Map of the Maple River with marked sample site locations corresponding to their specific sites 1=WB1, 2=EB1, 3=WB2, 4=EB2.

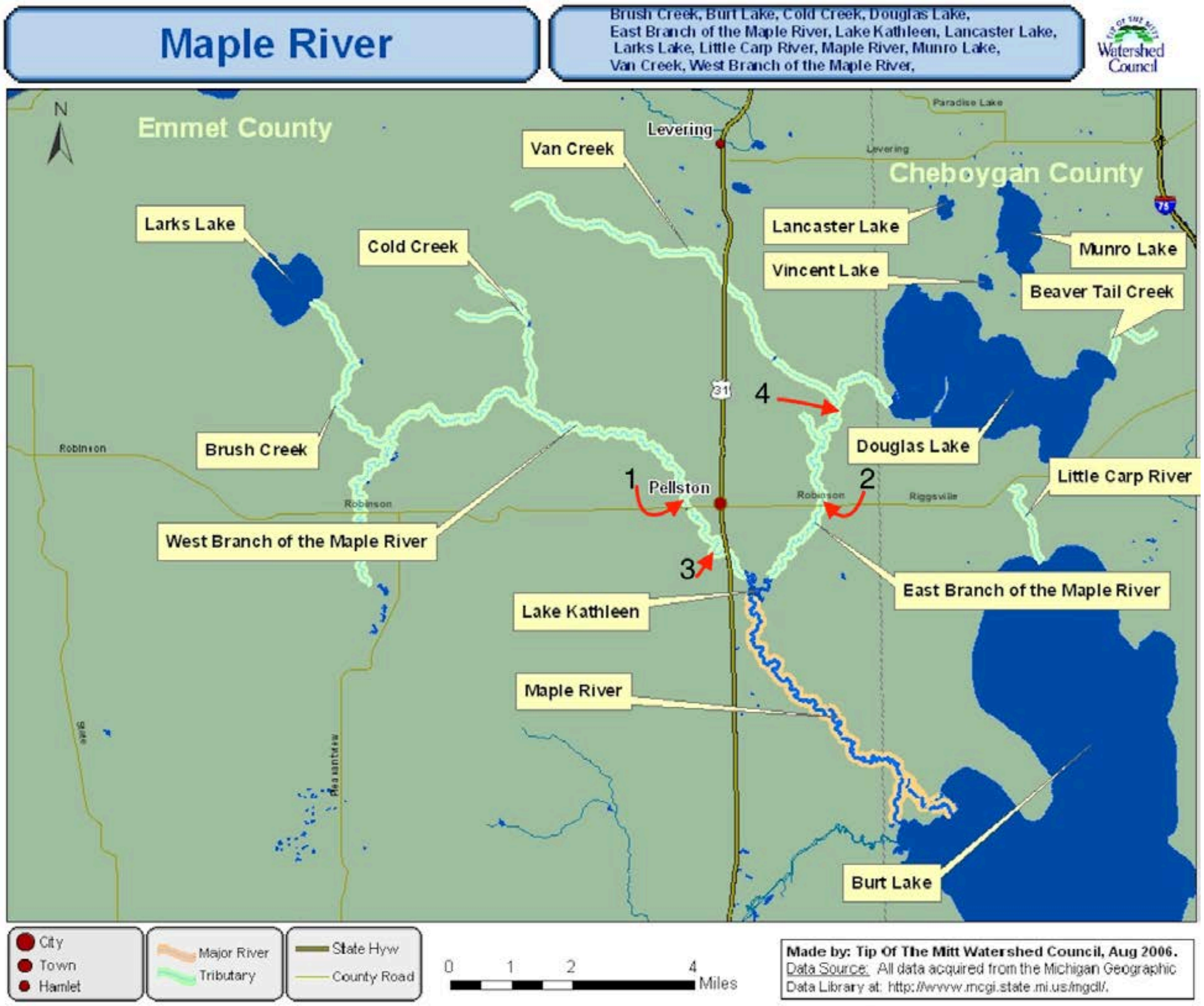


Table 2. Table of Embeddedness and particle percent cover classification size

| Embeddedness Categories | Particle size (mm) |
|---|---|
| 100% covered =1 | Sand: 0.05- 2.00 |
| 75% covered =2 | Gravel: 2-16 |
| 50% covered =3 | Pebble: 16- 64 |
| 25% covered= 4 | Cobble: 64-256 |
| 0% covered =5 | Boulder: >256 |

Figure 2. Graphs of average percent cover of sample sites, measured in habitat quadrats along sample transects. Error bars are representative of 2x the standard error.

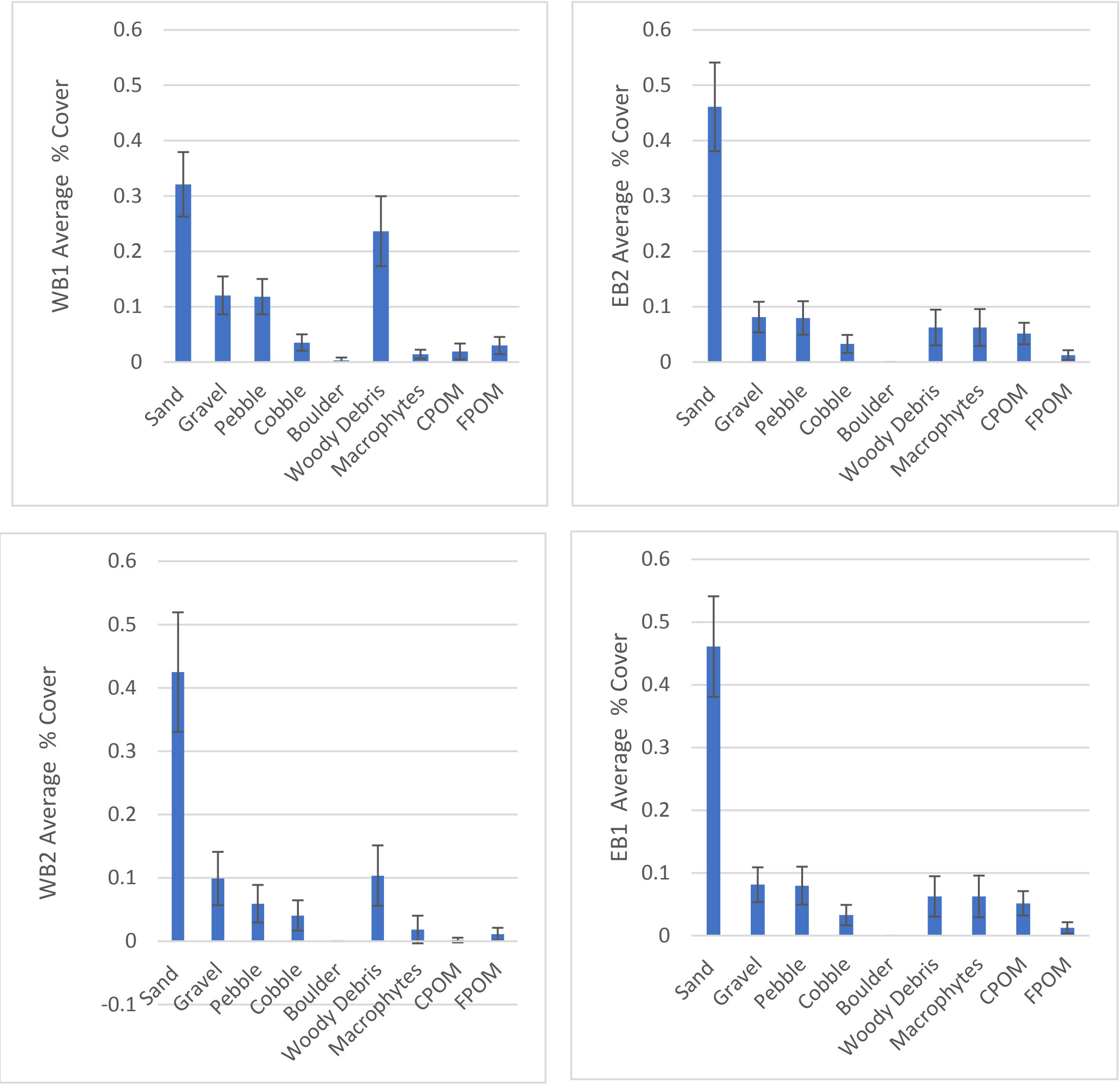


Table 3. Table of average embeddedness and average periphyton based on transect habitat quadrat sampling.

| Site | Average Embeddedness (1-5) | Average Periphyton (0-3) |
|---|---|---|
| WB1 | 2.8 | 0.7 |
| EB1 | 2.2 | 1.4 |
| WB2 | 2.6 | 0.8 |
| EB2 | 2.1 | 1.2 |

Table 4. t-test results for total abundance of benthic macroinvertebrates between the East and West branch of the Maple River.

| Branch | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| West | 19 | 36.26 | 21.65 | 4.97 |
| East | 20 | 33.85 | 18.77 | 4.20 |

Table 5. Mann Whitney U results for % EPT of benthic macroinvertebrates between the East and West branch of the Maple River.

| Branch | N | Mean Rank | Sum of Ranks |
|---|---|---|---|
| West | 19 | 25.97 | 493.5 |
| East | 20 | 14.33 | 286.5 |

Table 6. Mann Whitney U results for abundance of drifting macroinvertebrates between WB1 and EB1.

| Site | N | Mean Rank | Sum of Ranks |
|---|---|---|---|
| WB1 | 9 | 6.10 | 54.50 |
| EB1 | 9 | 12.90 | 116.50 |

Table 7. t-test results for %EPT of drifting macroinvertebrates between WB1 And EB1

| Site | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| WB1 | 9 | 0.55 | 0.29 | 0.10 |
| EB1 | 9 | 0.25 | 0.09 | 0.03 |

Table 8. Table of YSI output taken at the first transect of each site (0m). All measurements were taken on 8/3/17 between 11:40 am to 12:47 pm, and it was cloudy all day with morning sprinkles.

| Site | Temperature C° | Dissolved Oxygen (mg/l) |
|---|---|---|
| WB1 | 16.0 | 8.55 |
| EB1 | 19.3 | 7.00 |
| WB2 | 15.1 | 9.04 |
| EB2 | 21.4 | 7.90 |

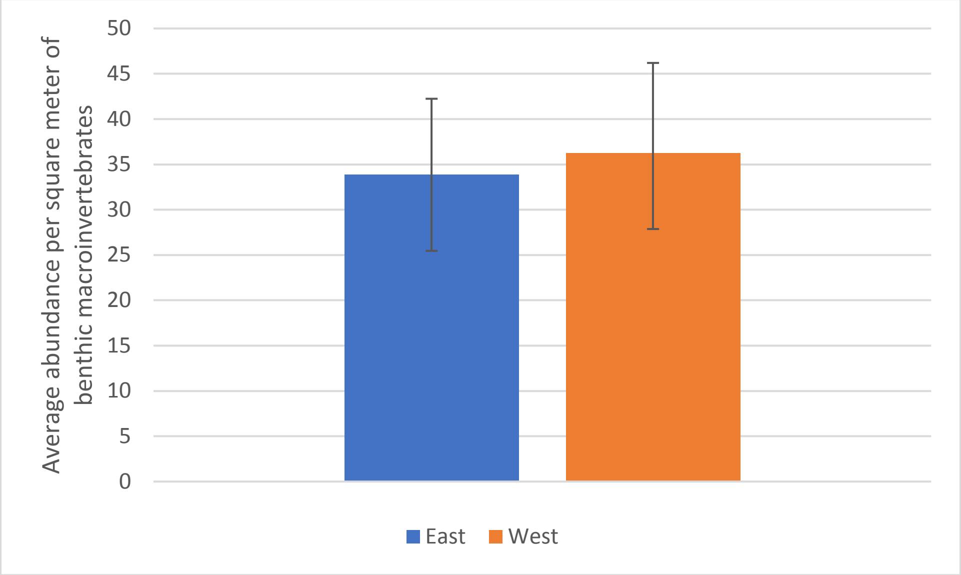
Table 9. Table of average discharge and velocity for each sample site. Average Discharge was found by averaging discharge from the first (0m) and last (100m) transects. Ten equidistant velocity measurements were taken at the beginning and end of each transects, and average, minimum and maximum velocity measurements were found for each site.

| Site | Average Discharge (m^3/ S) | Average Velocity (m/S) | Min Velocity (m/S) | Max Velocity (m/S) |
|---|---|---|---|---|
| WB1 | 1.15 | 0.32 | 0.00 | 0.70 |
| EB1 | 0.51 | 0.19 | 0.00 | 0.32 |
| WB2 | 1.31 | 0.33 | 0.08 | 0.75 |
| EB2 | 0.58 | 0.25 | 0.01 | 0.46 |

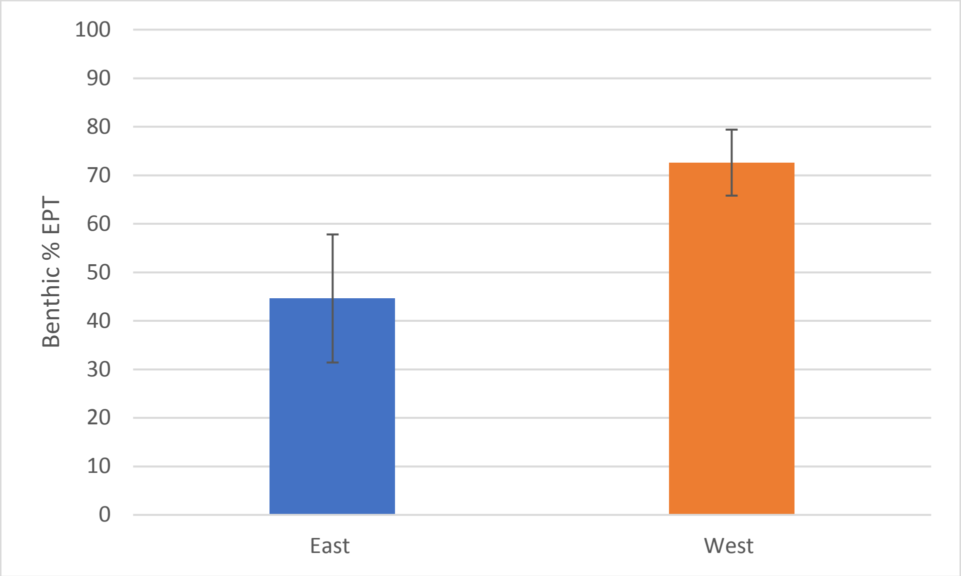
Table 10. Table of average, minimum, and maximum depth and width of sample sites. Depth measurements were taken in ten equidistant points along each sample transect and width measurements we taken at every transect.

| Site | Average Depth (m) | Min Depth (m) | Max Depth (m) | Average Width (m) | Min Width (m) | Max Width (m) |
|---|---|---|---|---|---|---|
| WB1 | 0.40 | 0.08 | 0.80 | 8.03 | 4.40 | 10.50 |
| EB1 | 0.45 | 0.12 | 0.87 | 6.23 | 4.40 | 7.80 |
| WB2 | 0.45 | 0.10 | 0.90 | 8.38 | 7.00 | 10.50 |
| EB2 | 0.34 | 0.02 | 0.82 | 7.46 | 5.00 | 9.00 |

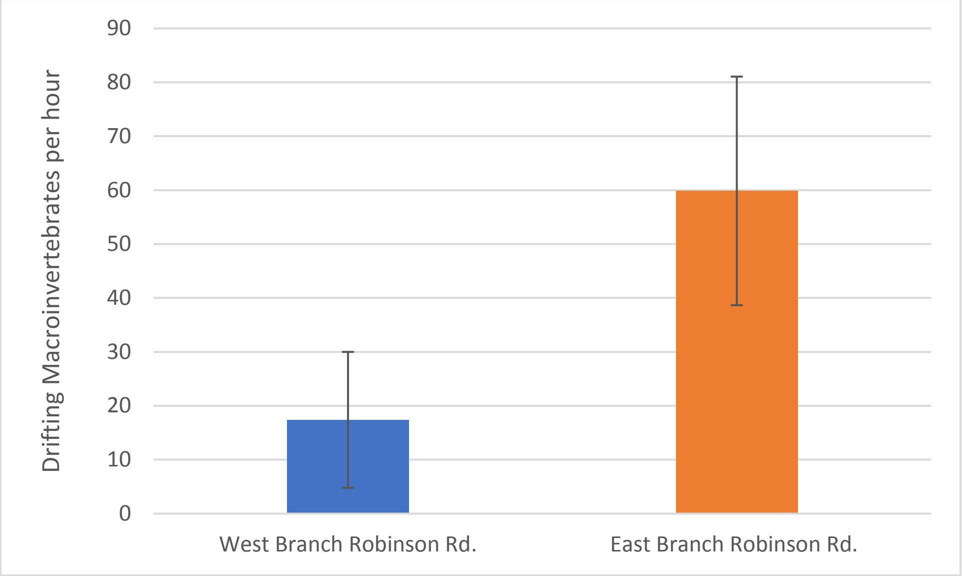
Graph 1: Benthic Macroinvertebrates abundancy distributions between the East and West Branch



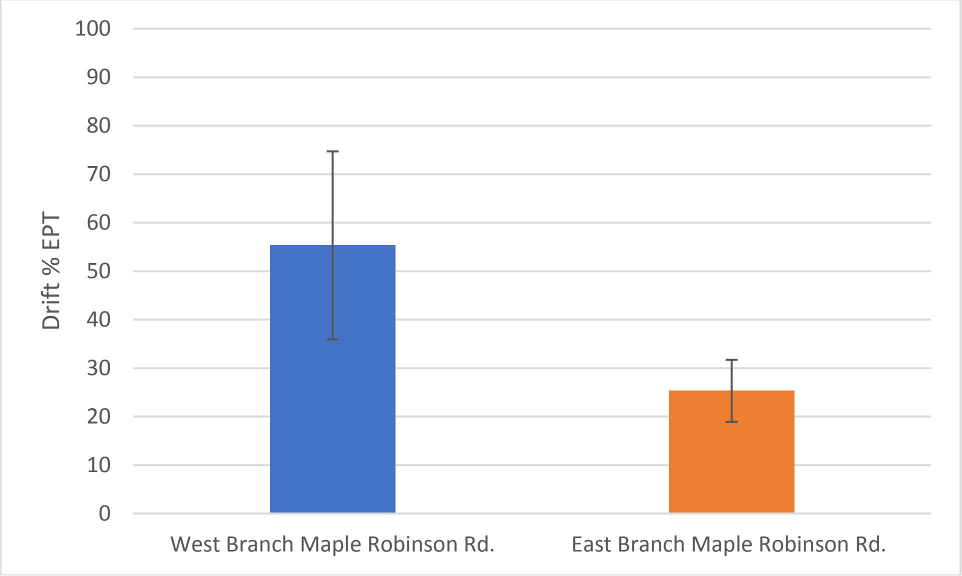
Graph 2: Benthic Macroinvertebrates % EPT distributions between the East and West Branch



Graph 3: Drifting Macroinvertebrates abundancy distributions between the EB1 and WB1



Graph 4: Drift Macroinvertebrates % EPT distributions between the EB1 and WB1



## Sources

Armstrong RH. 1986. A review of Arctic grayling studies in Alaska: 1952-1982. Biological papers of the University of Alaska.

Bogue MB. 2000. Fishing the Great Lakes: an environmental history, 1783-1933. University of Wisconsin Press; Madison, WI.

Byström PCA , Persson L, Wahlstrom E, Westman E. 2003. Size- and Density-dependent Habitat use in Predators: Consequences for Habitat Shifts in Young Fish. Journal of Animal Ecology 72:156–168.

Cutting KA, Cross WF, Anderson ML, Reese EG. 2016. Seasonal Change in Trophic Niche of Adfluvial Arctic Grayling (Thymallus arcticus) and Coexisting Fishes in a High-Elevation Lake System. PloS one 11(5): e0156187.

Danhoff BM. 2014. Big Manistee River Tributaries as Potential Arctic Grayling Habitat. [Master's Thesis]. Michigan Technological University.

Danhoff BM, Huckins CJ , Auer AN, Goble CW, Ogren SA, Holtgren JM. 2017. Abiotic Habitat Assessment for Arctic Grayling in a Portion of the Big Manistee River, Michigan: Transactions of the American Fisheries Society. 146: 645-662.

DNR Fishing. 2017. DNR - Michigan Grayling Only a Memory [Internet]: Michigan DNR; [cited 2017 Aug 17]. Available from http://www.michigan.gov/dnr/0,4570,7-153-10364_18958-53612--,00.html

Crock JG, Seal RR, Gough LP, Weber-Scannell P. 2003. Results of Elemental and Stable Isotopic Measurements, and Dietary Composition of Arctic Grayling (*Thymallus arcticus*) Collected in 2000 and 2001 from the Forty mile River Watershed, Alaska. U.S. Department of the interior (US); [cited 2017 Aug 16]. Available from https://pubs.er.usgs.gov/publication/ofr0357

Everett RA, Ruiz GM. 1993. Coarse woody debris as a refuge from predation in aquatic communities. Oecologia, 93(4): 475-486.

Feldmeth CR, Eriksen CH. 1978. A hypothesis to explain the distribution of native trout in a drainage of Montana’s Big Hole River. Verhandlungen des Internationalen Verein Limnologie 20:2040–2044.

Heim K C, Wipfli MS, Whitman MS, Seitz AC. (2016). Body size and condition influence migration timing of juvenile Arctic grayling. Ecology of freshwater fish. 25(1): 156-166.

Hughes NF, Dill LM. 1990 . Position choice by drift-feeding salmonids: model and test for Arctic grayling (Thymallus arcticus) in subarctic mountain streams, interior Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 47(10): 2039-2048.

Jones NE, Tonn WM, Scrimgeour GJ, Katopodis C. 2003. Productive capacity of an artificial stream in the Canadian Arctic: assessing the effectiveness of fish habitat compensation. Canadian Journal of Fisheries and Aquatic Sciences. 60(7): 849-863.

*Maple River.* Michigan: Tip of the Mitt Watershed Council, Aug 2006

McFarland JJ, Wipfli MS, Whitman MS. 2017. Trophic pathways supporting Arctic Grayling in a small stream on the Arctic Coastal Plain, Alaska. Ecology of Freshwater Fish.

Nuhfer AJ. 1992. Evaluation of the Reintroduction of the Arctic Grayling, into Michigan Lakes and Streams (No. 1985) [Internet]. Lewiston (MI): Michigan Department of Natural Resources, Fisheries Division; [cited Aug 17]. Available from http://quod.lib.umich.edu/f/fishery/AAG2862.1985.001?rgn=main;view=fulltext

O'brien JW, Barfield M, Sigler K. 2001. The functional response of drift-feeding Arctic grayling: the effects of prey density, water velocity, and location efficiency. Canadian Journal of Fisheries and Aquatic Sciences. 58.10: 1957-1963.

Platts WS. 1979. Relationships among stream order, fish populations, and aquatic geomorphology in an Idaho river drainage. Fisheries. 4(2): 5-9.

Stewart DB, Mochnacz NJ, Reist JD, Carmichael TJ, Sawatzky CD. 2007. Fish Diets and Food Webs in the Northwest Territories: Arctic Grayling. Fish Diets and Food Webs in the Northwest Territories: Arctic Grayling. Winnipeg (MB): Fisheries and Oceans Canada; [cited Aug 17]. Available from http://publications.gc.ca/collections/collection_2014/mpo-dfo/Fs97-4-2794-eng.pdf

Tingley RW. 2010. Evaluating Stream Habitats in Northern Michigan: Implications For Conserving Arctic Grayling (*Thymallus arcticus*) [thesis]: Michigan State University. 1548 p.