U.S. Fish and Wildlife Service

Alpena FWCO - Detroit River Substation
Fisheries Evaluation of the Frankenmuth Rock Ramp in Frankenmuth, MI

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Alpena FWCO – Detroit River Substation
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On the cover:

Staff from the Alpena Fish and Wildlife Conservation Office – Detroit River Substation holding the only northern pike that was recaptured upstream of the rock ramp; a tagged walleye; a small flathead catfish; a net full of tagged fish ready to be released downstream; four tagged white suckers recaptured upstream and boat crew conducting an electrofishing transect.

Summary

- Since the construction of the rock ramp, 17 fish species not previously detected upstream have been captured. These species include eight freshwater drum, eleven walleye, two gizzard shad, eight flathead catfish and two round goby. Over the past three years 2,604 fish have been tagged downstream of the rock ramp. Twenty-nine of these fish were recaptured upstream during boat electrofishing assessments or by anglers. Based on the mean monthly discharge of the Cass River during April and May, the data suggests that white and redhorse suckers can move past the rock ramp during normal discharge years.
- All fish species tagged were captured upstream of the rock ramp, this includes, redhorse suckers, white suckers, northern pike, walleye, and smallmouth bass. This proves that all of these species can navigate the rock ramp, however it is unknown under what flow conditions.
- While full dam removal likely would have resulted in greater fish passage, the rock ramp maintained the impounded area, while allowing target fish species (walleye, redhorse suckers, white suckers, northern pike, and smallmouth bass) access to upstream habitat.

Introduction

The Cass River is 80 miles long and flows through Sanilac, Saginaw, and Tuscola counties in Michigan's lower peninsula and is part of the Saginaw Bay watershed. The Cass River begins in Tuscola County and flows westerly to its confluence with the Saginaw River, which flows into Saginaw Bay and Lake Huron (Figure 1).

The City of Frankenmuth, in Saginaw County, was settled along the Cass River in 1845 by German immigrants. Frankenmuth was well-known for their flour and wool mills, as well as the production of food, such as sausage and cheese. In 2010, the population within the city was less than 5,000 people, but is also a popular tourist destination for thousands of visitors annually. Today, Frankenmuth is nicknamed "Little Bavaria" and tourism and agriculture are the main economic drivers.

In 1848, the Frankenmuth Dam was constructed on the Cass River. The dam was located adjacent to the city's downtown and originally supported a grain mill. The original structure was constructed of earth and stone but was later modified to a wooden structure and finally to a concrete structure. The Frankenmuth Dam measured 13 feet in height and 235 feet in width. The impoundment created upstream allowed navigation of commercial boats in the upper Cass River. In 2004, the Michigan Department of Environmental Quality listed the Frankenmuth Dam as in fair condition, though the dam no longer served its original purpose. Frankenmuth officials decided to pursue dam removal and the construction of a rock ramp in order to address long term dam maintenance concerns, to improve the connectivity and ecology of the Cass River watershed, and to restore fish habitat while maintaining historic water levels upstream. Frankenmuth engaged the services of the U.S. Army Corps of Engineers as project manager under their regulatory authority of the Water Resources Development Act of 2000 (PL 106-541) as amended. Ellen River Partners, Inc. was contracted for

design and on-site management. CTI and Associates were contracted to demolish the dam and for rock ramp construction.

Total demolition and construction cost for the Frankenmuth rock ramp was $3.5 million. The federally funded Great Lakes Restoration Initiative provided 65% of project costs and Frankenmuth funded the balance with the help of local businesses, charitable foundations, and the Downtown Development Authority. In addition, Frankenmuth received grant funding from the U.S. Fish and Wildlife Service and the Saginaw Bay Watershed Initiative Network.

While complete dam removal is usually the most effective option when the goal is to reconnect fish habitat and to improve fish populations, economic or social factors may make dam removal unfeasible. Some of the economic sources for Frankenmuth include two upstream river cruises: a paddlewheel riverboat called the "Bavarian Belle" and a small fleet of electric boats called the "Frankenmuth FunShips". In order for these businesses to maintain themselves, water levels upriver needed to remain at historically elevated levels. ***Therefore, the goal of the Frankenmuth rock ramp was to maintain historical water levels upstream of the former dam, while allowing fish access to an additional 25 miles of habitat upstream.***

Frankenmuth Dam was removed in 2014 and the rock ramp was completed in October 2015 (Figure 2). The Frankenmuth rock ramp was placed approximately 351feet downstream of the original impoundment. It is 298 feet long and contains 14 limestone rock weirs. Weirs were designed to provide riffles and resting areas for fish attempting passage upstream. Each weir contains a 5’ foot diameter "header" stone and a 3’ foot diameter "footer" stone, with 2’ foot diameter stones spanning the distance between the header and footer. These rocks were placed with riprap at a 3% grade. The weirs span the width of the river and contain a low flow channel to allow for canoe and kayak passage. In total, over 20,000 tons of limestone was used to build the rock ramp.

The practice of using rock ramps to replace unwanted dams and increase fish passage is fairly new in Michigan. While other rock ramp structures have been constructed (i.e. River Raisin in Monroe, MI and Chippewa River in Mt. Pleasant, MI), there is limited data available evaluating their effectiveness (Jeff Braunschiedel, Michigan DNR, personal communication). In Chesaning, MI a rock ramp was installed on the Shiawassee River. Leonardi (2016) determined successful fish passage using the presence of indicator species and tag data. Indicator species walleye (*Sander vitreus*), quillback (*Carpoides cyprinus*), freshwater drum (*Aplodinotus grunniens*), and gizzard shad (*Dorosoma cepedianum*) were found upstream where they previously were undetected. The capture of tagged fish upstream of the Chesaning rock ramp provided conclusive evidence of passage. However, fish passage (particularly with spawning walleye) varied annually and was believed to be influenced by ramp design and flow conditions aligning with optimal spawning preferences (i.e., photoperiod, water temperature). The Chesaning rock ramp also provided new riffle habitat for other fish species including smallmouth bass (*Micropterus dolomieu*) (Leonardi 2016).

The Cass River supports over 70 species of fish including recreationally important walleye, smallmouth bass (*Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), and northern pike (*Esox lucius*). Annual spawning runs of walleye, white suckers (*Catostomus commersonii*), quillback, and redhorse suckers occur each spring, with many ascending from Saginaw Bay. As a structure, Frankenmuth Dam prohibited upstream fish passage to historical river habitat and provided negative impacts on river function (Burroughs 2001).

Two potential drawbacks to dam removal include the passage of invasive species upstream and the potential for downstream fish to serve as vectors of contaminants upstream. Round gobies (*Neogobius melanostomus*), an invasive species, are known to occupy the section of the Cass River below the dam. The removal of the dam could allow these fish to move further upriver, where they could disrupt the food web. Sea lamprey (*Petromyzon marinus*) were found upstream of the Frankenmuth Dam prior to its removal and the U.S. Fish and Wildlife Service Sea Lamprey Control Program has indicated there is limited sea lamprey habitat upstream of the former dam. On the Muskegon, Manistee, and Au Sable rivers in Michigan, levels of polychlorinated biphenyls (PCBs) and 2,3,7,8-tetrachlorodibenzo-*p*-dioxin equivalents (TEQs) were greater in fish sampled downstream of impoundments than those sampled upstream. Levels were high enough in downstream fish to present a hazard to fish-eating birds and mammals (Giesy et al. 1994, 1995). Therefore, the passage of contaminated fish could impact bird and mammal health upstream. Despite potential drawbacks, the City of Frankenmuth and partners decided that the benefits of restoring fish passage and habitat outweighed the possible movement of invasive species and contaminants. Additionally, the U.S. Army Corps of Engineers conducted an environmental assessment of the proposed rock ramp which indicated that construction would not result in significant adverse environmental effects (USACE 2012).

Since 2010, the U.S. Fish and Wildlife Service and project partners have been assessing fish species diversity and relative abundance upstream and downstream of the former dam. The first objective of this study was to compare species presence and relative abundance upstream and downstream prior to the dam removal and after the construction of the rock ramp. The second objective was to conduct a mark-recapture study to determine whether target fish species were migrating upstream of the rock ramp. Post-assessment monitoring occurred 2016 – 2018.

Methods

To gauge the success of fish passage through the rock ramp, project partners (Army Corps of Engineers, Central Michigan University, City of Frankenmuth, Michigan Department of Natural Resources, and U.S. Fish and Wildlife Service) developed and implemented a monitoring plan similar to that conducted on the Chesaning rock ramp (Leonardi 2016). Investigators realized that quantitative measurement would be difficult due to similar fish communities existing both upstream and downstream prior to dam removal. However, spawning migrations of walleye, quillback, silver redhorse (*Moxostoma anisurum*), black redhorse (*Moxostoma duquesnei*), golden redhorse (*Moxostoma erythurum*), greater redhorse (*Moxostoma valenciennesi*), shorthead redhorse (*Moxostoma macrolepidotum*) and white suckers were known to congregate downstream of Frankenmuth Dam, and investigators believed these species could be used as

indicator species as they were likely candidates to migrate further upstream. In addition, two resident fish species, northern pike and smallmouth bass were also chosen due to their popularity as a game fish and relative abundance upstream and downstream. Investigators believed relative abundance of spawning congregations of indicator species could be used to attest to fish passage. Of the indicator species selected, only freshwater drum and walleye had not been documented upstream of the former Frankenmuth Dam. However, walleye are present in the Caro Impoundment, approximately 25 miles upstream of the City of Frankenmuth. The Caro Dam near the impoundment was breached in 2014 (Joseph Leonardi, Michigan DNR, personal communication), therefore untagged walleye collected during post-assessments in the reach above the rock ramp may have originated from the Caro Impoundment and may not be a result of passing the rock ramp.

Fish passage was also determined by tagging fish species downstream of the rock ramp and searching for recaptures upstream during subsequent sampling events. Fish species targeted for tagging included walleye, smallmouth bass, white suckers, silver redhorse, black redhorse, golden redhorse, greater redhorse, shorthead redhorse, and northern pike. Total length, sex, and maturity data were collected from all fish that received a tag and weight was collected from a subsample of fish from each species. Fish were tagged with a yellow Floy® T-Bar anchor tag (FD-68BC) near the dorsal fin, which included a unique ID and a phone number so recreational anglers could report recaptures. The goal was to tag approximately 1,000 fish total during mark- recapture assessments every year for a three year total of 3,000 fish.

Pre-assessment sampling occurred in the spring (March and April) of 2010, 2011, and 2012, and coincided with indicator species spawning events (Table 1). Pre-assessment sampling consisted of conducting 10-minute boat electrofishing transects at locations downstream of the Frankenmuth Dam (starting at the dam to approximately 0.5 miles downstream) and at several locations upstream of the dam to the Bray Road Bridge (Figure 3). During the 10-minute transects, all fish were netted, identified to species and measured for total length (mm). These surveys provided relative abundance of fish species prior to dam removal and fish species diversity information upstream and downstream of the dam.

Post-assessment sampling took place in the spring and summer (March, April, May, and July) of 2016, 2017, and 2018 (Table 1). Spring assessments were conducted upstream and downstream of the rock ramp to monitor changes in the relative abundance of fish species, fish species diversity, and also to tag fish for the mark-recapture study. Relative abundance was measured by conducting 10-minute boat electrofishing transects in a similar fashion and locations of pre-assessments (Figure 3). Additional electrofishing upstream targeted only those species which were tagged. During recapture assessments upstream, only a subsample of fish were measured for total length, these assessments took place from the impoundment to the Bray Street Bridge, a distance of more than four miles. Summer assessments were primarily conducted to target recaptures upstream and document any tagged fish that may be residing in the river. In 2016, 2017, and 2018 water chemistry data was collected using a Hydrolab (Quanta Multi-Probe Meter) and included measurements for specific conductivity (SpC), pH, water temperature, turbidity, and dissolved oxygen (DO).

Day boat electrofishing was used for all sampling and utilized a Smith Root 5.0 GPP or Smith Root Type VI-A electrofisher with two anodes and two netters using 3/16" inch mesh nets at the bow of the boat. Peak volts used during electrofishing were set to low and ranged from 50 – 500. Pulsed direct current was used for all assessments; however, pulse rates varied between 15 and 120 pulses per second. Percent power ranged from 10 – 45% and amps from 1 – 10. Electrofisher settings were adjusted throughout each survey to maximize taxis and minimize tetany and potential harm to fish. Catch per unit effort (CPUE) was calculated as the number of fish caught per hour of electrofishing.

Statistical tests were performed to determine if indicator species relative abundance (CPUE) was different between pre and post-assessment surveys. Normality was tested using the Shapiro-Wilk test, since our CPUE data contained many zeros and data transformation could not normalize, Mann-Whitney tests were performed by pooling years within pre and post-assessment time periods. Redhorse species were grouped together for analysis. Freshwater drum was not analyzed due to low catches and walleye comparisons were only made downstream because no walleye were captured upstream during pre-assessment surveys. An alpha value of 0.05 was used to determine statistical significance for all tests.

Results and Discussion

Pre-assessment results - Downstream

During 1.85 hours of electrofishing, a total of 37 fish species were captured downstream of the Frankenmuth Dam prior to construction of the rock ramp (Tables 1 & 2). Species that represented a large proportion of the catch included white sucker (25.5%), emerald shiner (*Notropis atherinoides*) (22.5%), yellow perch (*Perca flavescens*) (15.8%), golden redhorse (6.0%), northern hogsucker (*Hypentelium nigricans*) (4.0%), silver redhorse (3.8%), common shiner (*Luxilus cornutus*) (3.2%), shorthead redhorse (2.8%), smallmouth bass (2.8%), rock bass (*Ambloplites rupestris*) (1.5%), walleye (1.5%), logperch (*Percina caprodes*) (1.3%), bluntnose minnow (*Pimephales notatus*) (0.9%), greater redhorse (0.9%), spottail shiner (*Notropis hudsonius*) (0.9%). northern pike (0.8%) and pumpkinseed (*Lepomis gibbosus*) (0.7%). In addition, two freshwater drum were captured during downstream post-assessment surveys, however CPUE was not calculated because effort was not collected. CPUE of species captured during pre-assessments are presented in Tables 4 & 5.

Pre-assessment results - Upstream

During 4.39 hours of electrofishing, a total of 24 species were captured upstream with golden redhorse being the predominant species representing 25.9% of the total catch (Tables 1 & 3). Species that also represented a large proportion of the catch included smallmouth bass (9.7%), greater redhorse (8.9%), silver redhorse (8.4%), rock bass (7.7%), mimic shiner (*Notropis volucellus*) (6.8%), bluegill (3.7%), rainbow darter (*Etheostoma caeruleum*) (3.5%), spottail shiner (3.3%), greenside darter (*Etheostoma blennioides*) (3.0%), northern hogsucker (3.0%), pumpkinseed (2.8%), common carp (*Cyprinus carpio*) (1.1%), brook stickleback (*Culaea inconstans*) (0.8%), northern pike (0.8%), white sucker (0.8%). During pre-assessments upstream,

no shorthead redhorse, walleye or freshwater drum were captured. CPUE of species captured during pre-assessments are presented in Tables 4 & 5.

Post-assessment results - Downstream

During 5.12 hours of electrofishing downstream in 2016, a total of 23 fish species were captured. There were no new species that were not detected during pre-assessment surveys (Tables 1 & 2). Species that represented a large proportion of the catch were white sucker (48.5%), greenside darter (6.6%), black redhorse (6.2%), golden redhorse (5.5%), walleye (5.5%), silver redhorse (5.2%), rock bass (4.8%), emerald shiner (4.1%), black crappie (*Pomoxis nigromaculatus*) (2.6%), rainbow darter (2.2%), northern pike (1.8%), smallmouth bass (1.8%), common carp (1.1%), greater redhorse (1.1%), and yellow perch (1.1%). In addition, six shorthead redhorse, one freshwater drum and three quillback were captured during downstream post-assessment surveys in 2016 but were not used in calculating CPUE because they were not collected during the 10-minute transects when effort was noted and all species were collected. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

During 5.17 hours of electrofishing downstream in 2017, a total of 31 fish species were captured including six species that previously had not been detected, blacknose shiner (*Notropis heterolepis*), goldfish (*Carassius auratus*), golden shiner (*Notemigonus crysoleucas*), rosyface shiner (*Notropis rubellus*), spotfin shiner (*Cyprinella spiloptera*) and yellow bullhead (*Ameiurus natalis*) (Tables 1 & 2). Species that represented a large proportion of the catch were white sucker (23.7%), emerald shiner (15.2%), blacknose shiner (13.6%), golden redhorse (9.5%),yellow perch (8.6%), spotfin shiner (4.1%), walleye (3.3%), black redhorse (2.7%), rock bass (2.5%), shorthead redhorse (2.3%), smallmouth bass (2.1%), rosyface shiner (1.9%), black-side darter (1.4%), bluntnose minnow (1.2%), greater redhorse (1.2%), northern pink (1.2%), northern hogsucker (0.8%), and silver redhorse (0.8%) In addition, one freshwater drum was captured during downstream post-assessment surveys in 2017 but was not used in calculating CPUE because it was not collected during the 10-minute transects when effort was noted and all species were collected. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

During 3.76 hours of electrofishing downstream in 2018, a total of 23 fish species were captured including two species that previously had not been detected, longear sunfish (*Lepomis megalotis*) and white crappie (*Pomoxis annularis*) (Tables 1 & 2). Species that represented a large proportion of the catch were white sucker (23.3%), northern pike (17.8%), rock bass (12.8%), yellow perch (9.4%), smallmouth bass (8.9%), walleye (7.8%), northern hogsucker (3.9%), golden redhorse (2.8%), silver redhorse (2.8%), black redhorse (2.2%), pumpkinseed (1.7%), shorthead redhorse (1.7%), and black crappie (1.1%). In addition, twenty-four greater redhorse and one quillback were captured during downstream post-assessment target surveys in 2018 but they were not used in calculating CPUE because they were not collected during the 10-minute transects when effort was noted and all species were collected. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

While we did not expect species composition or relative abundance downstream to change

drastically, we did believe these metrics could change after construction of the rock ramp. Accessibility of the Cass River downstream of the Frankenmuth Dam for researchers was difficult prior to rock ramp construction. As a result, during certain years boat access was limited when walleye and other species may have been spawning below the dam. During rock ramp construction, a small boat landing was built on the west side of the river allowing access during all times of the year.

A total of eight new species were detected downstream of the rock ramp during post-assessment surveys. It is likely that these were not new species inhabiting the Cass River, but a result of our failure to detect these species during pre-assessment surveys. Results comparing the pre and post-assessment relative abundance of indicator species downstream of the rock ramp varied by species (Table 4). Redhorse suckers, smallmouth bass and white suckers were the dominant species captured upstream during both pre and post-assessments. Mann-Whitney tests revealed statistically different CPUE of redhorse ($P = 0.006$), smallmouth bass ($P = 0.002$), and white sucker ($P = 0.018$), between the two sampling periods, with higher CPUE downstream prior to dam removal. CPUE of walleye, quillback, and northern pike were similar between the two sampling periods and statistical differences were not observed. The decrease in relative abundance of redhorse species and white suckers could be a result of the fish no longer staging and spawning just downstream of the rock ramp and migrating upstream to other spawning areas. Environmental conditions during sampling events may have also had an effect on the CPUE differences between pre and post-assessment time periods. Sampling during the post-construction time period took place at a much wider range of water temperatures and sampling began earlier in the year at cooler temperatures. Since redhorse and white suckers may not have been in the sampling area at these cooler water temperatures, this may have resulted in lower CPUE.

Post-assessment results - Upstream

During 13.18 hours of electrofishing upstream in 2016, a total of 28 species were collected including nine species not detected during pre-assessment surveys. These species were goldfish, freshwater drum, walleye, yellow perch, shorthead redhorse, channel catfish (*Ictalurus punctatus*), chinook salmon (*Oncorhynchus tshawytscha*), common shiner and spotfin shiner (Tables 1 & 3). Species that represented a large proportion of the catch included golden redhorse (30.1%), black redhorse (24.0%), smallmouth bass (10.9%), greater redhorse (9.1%), quillback (7.6%), silver redhorse (5.8%), emerald shiner (3.6%), white sucker (2.4%), shorthead redhorse (1.8%), common carp (1.5%), northern hogsucker (1.2%) and freshwater drum (0.6%). Also, a total of four walleye (413 – 532 mm TL) were captured during 2016 upstream post-assessment sampling but they were not used in calculating CPUE because they were not collected during the 10-minute transects when effort was noted and all species were collected. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

During 13.41 hours of electrofishing upstream in 2017, a total of 33 species were collected including eight species that previously had not been detected. These species were flathead catfish (*Pylodictis olivaris*), gizzard shad, golden shiner, logperch, rainbow trout (*Oncorhynchus mykiss*), rosyface shiner, spotted sucker (*Minytrema melanops*), and warmouth (*Lepomis gulosus*) (Tables 1

& 3). Species that represented a large proportion of the catch included golden redhorse (28.2%), black redhorse (20%), emerald shiner (10.5%), greater redhorse (7.4%), smallmouth bass (6.0%), spotted sucker (5.7%), quillback (4.8%), white sucker (3.1%), spotfin shiner (2.8%), rock bass (2.5%), common carp (1.5%), rosyface shiner (1.2%), northern hogsucker (0.9%), and silver redhorse (0.9%). In addition, one freshwater drum was captured during 2017 upstream post-assessment sampling but they was not used in calculating CPUE because it was not collected during the 10-minute transects when effort was noted and all species were collected. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

During 19.31 hours of electrofishing upstream in 2018, a total of 29 species were collected including two species that previously had not been detected, central stoneroller (*Campostoma anomalum*) and round goby. Species that represented a large proportion of the catch included golden redhorse (41.1%), black redhorse (22.3%), greater redhorse (11.9%), white sucker (7.1%), smallmouth bass (4.0%), northern hogsucker (3.4%), rock bass (1.8%), roseyface shiner (1.6%), quillback (1.4%), emerald shiner (1.0%), silver redhorse (0.8%), and common carp (0.7%). Also a total of one freshwater drum, two northern pike, three shorthead redhorse, and two walleye were captured during our 10 minute transects where effort was noted. CPUE of species captured during post-assessments are presented in Tables 4 & 5.

Unfortunately, since the Caro Dam was breached in 2014, we cannot say for certain whether the walleye captured during electrofishing surveys migrated past the rock ramp or came downstream from the Caro Impoundment where they were stocked by the Michigan Department of Natural Resources. Genetic samples were taken from a subsample of the walleye collected upstream; however, since a source population for the walleye stocked in the Caro Impoundment came from the Tittabawassee River, within the Saginaw River watershed, it would be difficult to distinguish genetic differences between walleye from the impoundment and those migrating into the Cass River from Saginaw Bay. It was also not practical to age the walleye collected to correlate to a stocking event in the Caro Impoundment since it is believed that walleye natural reproduction may be taking place (Joseph Leonardi, Michigan DNR, personal communication).

A total of 17 new species were detected upstream of the rock ramp during post-assessment surveys. It is likely that these were all not new species inhabiting the Cass River, but a result of our failure to detect certain species during pre-assessment surveys. However, since the amount of new species detected upstream of the ramp was two times the amount of new species detected downstream during this same time period, it is likely that some of the new species detected were a result of increased access upstream. Redhorse suckers, smallmouth bass and white suckers were the dominant species captured upstream during both pre and post-assessments. Mann-Whitney tests revealed statistically different CPUE of northern pike ($P = 0.002$) and smallmouth bass ($P = 0.04$) between the two sampling periods, with higher CPUE upstream prior to dam removal. Redhorse (pre = 118.8/hr; post = 148.0/hr; $P = 0.32$), quillback (pre = 1.02/hr; post = 8.5/hr; $P = 0.07$, and white sucker (pre = 1.9/hr; post = 10.5/hr; $P = 0.14$) all had higher mean CPUE upstream post dam removal, however statistical differences were not observed.

Mark-recapture results

In 2016, tagging began on March 18 and ended April 15. Water temperature during this time period ranged from 38.6 – 46.0°F. A total of 652 fish were tagged downstream of the rock ramp. The number and species of fish tagged is presented in Table 6. Fourteen tagged fish were recaptured downstream of the rock ramp, and three fish were recaptured upstream of the rock ramp (Table 6 & 8). A male white sucker was tagged downstream on April 15 and recaptured upstream of the rock ramp on April 25. On April 14, a male silver redhorse was tagged downstream and recaptured upstream on May 13. A female silver redhorse was tagged downstream on March 24 and recaptured on July 13 upstream. An additional five fish were recaptured downstream and reported by anglers in 2016 (Table 7).

In 2017, tagging began on March 16 and ended April 18. Water temperature during this time period ranged from 32.4 – 54.9°F. A total of 771 fish were tagged downstream of the rock ramp, an increase of 119 fish from 2016 tagging events. The number and species of fish tagged can be seen in Table 6. Forty-five tagged fish were recaptured downstream of the rock ramp and seven fish were recaptured upstream of the rock ramp, an increase of four fish from 2016 (Table 6 & 8). In 2017, eleven fish were recaptured downstream and reported by anglers, while two fish were recaptured upstream and reported by anglers (Table 7).

In 2018, tagging began on March 22 and ended April 9. Water temperature during this time period ranged from 37.6 – 41.8°F. A total of 1,181 fish were tagged downstream of the rock ramp, an increase of 410 fish from 2017 tagging events, and an increase of 529 fish from 2016 tagging events. During the three years of post-assessment tagging events a total of 2,604 fish were tagged. The number and species of fish tagged can be seen in Table 6. Eighty-nine tagged fish were recaptured downstream of the rock ramp and sixteen fish were recaptured upstream of the rock ramp, an increase of nine fish from 2017 and an increase of thirteen fish from 2016 (Table 6 & 8). During the three years of post-assessment work, a total of twenty-nine fish have been recaptured upstream of the rock ramp through boat electrofishing and angler recaptures. In 2018, nine fish were recaptured downstream and reported by anglers, while one fish was recaptured upstream and reported by anglers (Table 7). All fish species tagged were captured upstream of the rock ramp, including a walleye that was recaptured by an angler. This proves that all of these species can navigate the rock ramp, however it is unknown under what flow conditions.

The successful passage of fish upstream of the rock ramp depends largely on water velocity and discharge volumes. A U.S. Geological Survey gauging station (USGS 04151500) is located approximately 656 yards downstream of the rock ramp. By noting the initial tagging and recapture dates of the twenty-nine fish recaptured upstream (could not determine discharge range on the three fish recaptured upstream with no tag ID's reported), we can determine at what discharge rates these fish were able to move upstream of the rock ramp. While the range of discharges observed between initial tagging and recapture dates was quite large for many of the fish captured upstream, several of the recaptures moved upstream of the rock ramp during a narrow time frame (Table 8). Based on the range of discharges observed for white and redhorse suckers captured upstream, these species can move upstream of the rock ramp during a discharge range between 693 – 1,150 m^3/s. Since the

mean monthly discharge for the months of April is 1,204 m^3/s and May is 704 m^3/s, we suggest that these species should be able to move past the rock ramp during normal discharge years. While one smallmouth bass was recaptured upstream in 2017, the tag number was not reported, so we cannot make any inferences regarding fish movement and flow conditions. The range of discharges between initial tagging and recapture dates for northern pike and walleye was too large to make inferences about flow conditions during passage.

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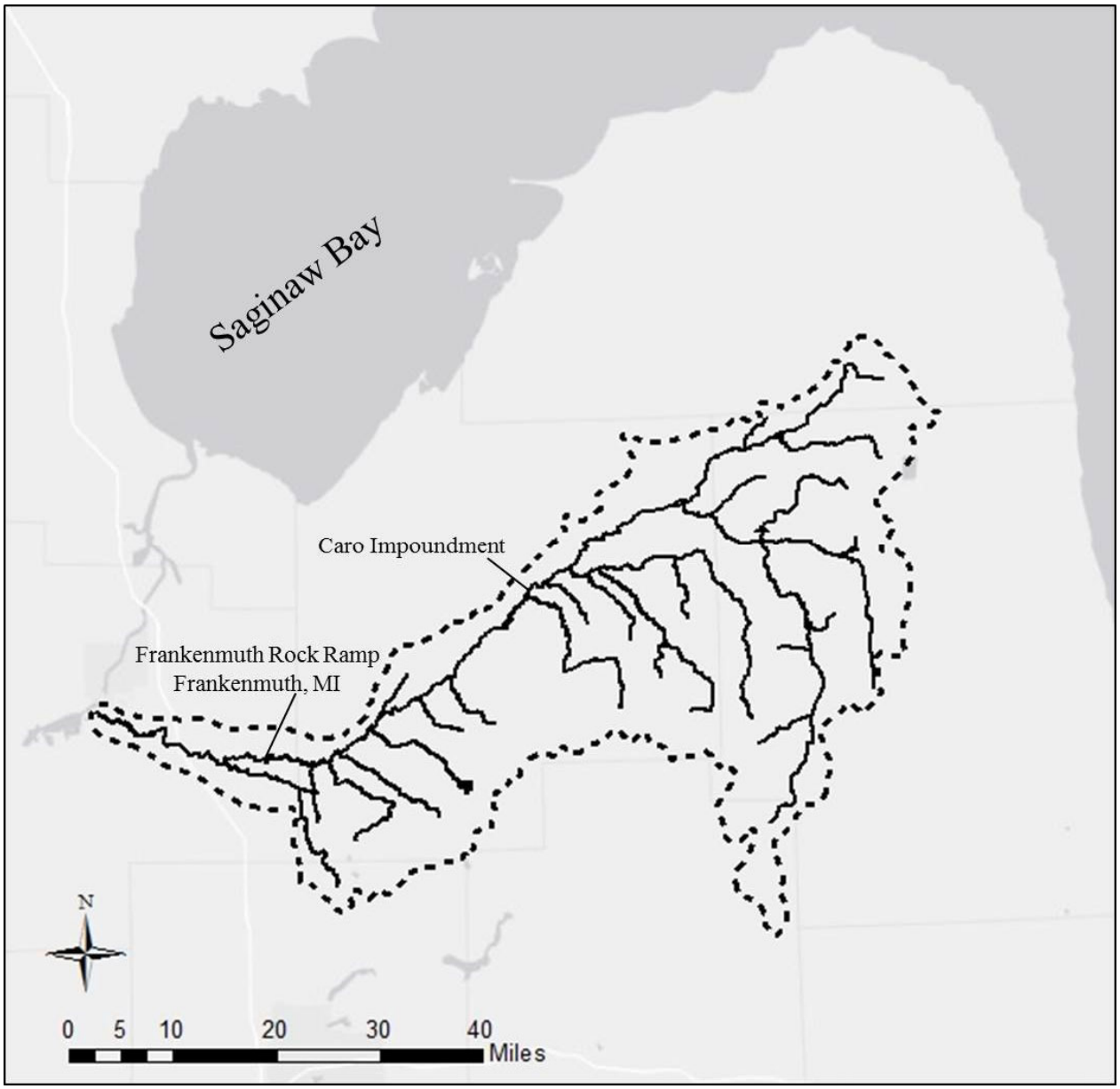

Figure 1. Map of the Cass River watershed and location of Frankenmuth rock ramp and Caro Impoundment.

Figure 2. Aerial view of the Frankenmuth rock ramp completed in October 2015 in Frankenmuth, MI.

Figure 3. Location of Frankenmuth rock ramp, Bray Street Bridge, and general description of electrofishing locations downstream of the rock ramp, in the impounded area, and upstream sites near the Bray Street Bridge. Yellow rectangles indicate general transect locations.

Table 1. Dates sampled, water temperature, and electrofishing effort during downstream and upstream electrofishing assessments on the Cass River.

Downstream

	Dates Sampled	*Water Temperature Range* (°F)	*Total Effort (hrs.)*
Pre-Assessment			
2010	March 26 – April 2	44.8 – 53.8	0.67
2011	April 15	50.0 – 50.9	0.33
2012	March 19 – April 2	46.8 – 57.9	0.85
Post-Assessment			
2016	March 18 – April 14	38.7 – 44.1	5.12
2017	March 16 – April 18	32.4 – 54.9	5.17
2018	March 22 – April 9	37.6 – 41.8	3.76

Upstream

	Dates Sampled	*Water Temperature Range* (°F)	*Total Effort (hrs.)*
Pre-Assessment			
2010	March 26 – April 2	43.5 – 57.6	1.00
2011	April 8 – April 15	41.0 – 52.0	1.60
2012	March 19 – April 2	43.0 – 57.2	1.79
Post-Assessment			
2016	April 22 – May 6; July 13	48.9 – 57.4; 75.7 – 75.9	13.18
2017	March 20 – April 28; July 28	46.04 – 59.14; 73 – 73.5	13.41
2018	March 21 – April 30; July 25, 27	36.9 – 52.27; 73.58 – 75.74	19.31

Table 2. A comprehensive list of all fish species caught during electrofishing surveys downstream of the Frankenmuth rock ramp during pre and post-assessment surveys. Bold species were either indicator species or targeted for tagging.

Downstream

Pre-Assessment	*New Species Detected Post-Assessment*		
	2016	2017	2018
Black bullhead	-	Blacknose shiner	Longear sunfish
Black crappie		Goldfish	White crappie
Black redhorse		Golden shiner	
Bluegill		Rosyface shiner	
Bluntnose minnow		Spotfin shiner	
Brook stickleback		Yellow bullhead	
Blackside darter			
Brook silverside			
Channel catfish			
Common carp			
Common shiner			
Emerald shiner			
Fathead minnow			
Freshwater drum			
Golden redhorse			
Greater redhorse			
Green sunfish			
Greenside darter			
Largemouth bass			
Logperch			
Mimic shiner			
Northern hogsucker			
Northern pike			
Northern redbelly dace			
Pumpkinseed			
Quillback			
Rainbow darter			
Rainbow trout			
Rock bass			
Round goby			
Shorthead redhorse			
Silver redhorse			
Smallmouth bass			
Spottail shiner			
Walleye			
White sucker			
Yellow perch			

Table 3. A comprehensive list of all fish species caught during electrofishing surveys upstream of the Frankenmuth rock ramp during pre and post-assessment surveys. Bold species were either indicator species or targeted for tagging.

Upstream			
Pre-Assessment	*New Species Detected Post-Assessment*		
	2016	2017	2018
Bluegill	Channel catfish	Flathead catfish	Central stoneroller
Black redhorse	Chinook salmon	Gizzard shad	Round goby
Blackside darter	Common shiner	Golden shiner	
Brook stickleback	**Freshwater drum**	Logperch	
Brook silverside	Goldfish	Rainbow trout	
Common carp	**Shorthead redhorse**	Rosyface shiner	
Emerald shiner	Spotfin shiner	Spotted sucker	
Golden redhorse	**Walleye**	Warmouth	
Greater redhorse	Yellow perch		
Greenside darter			
Green sunfish			
Largemouth bass			
Mimic shiner			
Northern hogsucker			
Northern pike			
Pumpkinseed			
Quillback			
Rainbow darter			
Rock bass			
Silver redhorse			
Smallmouth bass			
Spottail shiner			
White sucker			
Yellow bullhead			

Table 4. Catch per unit effort (CPUE; fish caught/hour) of indicator fish species captured downstream of the Frankenmuth rock ramp. Standard deviations are in parenthesis.

	Downstream CPUE					
Species	*Pre-Assessment*			*Post-Assessment*		
	2010	*2011*	*2012*	*2016*	*2017*	*2018*
Black redhorse	3 (±6.0)	0	0	11 (±23.1)	8 (±13.0)	4 (±3.1)
Golden redhorse	9 (±18.0)	300 (±424.3)	71.5 (±42.9)	10 (±12.0)	28 (±41.0)	5 (±5.9)
Greater redhorse	4.5 (±5.7)	48 (±67.9)	9.5 (±8.1)	2 (±6.0)	4 (±5.8)	0*
Northern pike	7.5 (±11.4)	0	8.2 (±5.2)	3 (±4.3)	4 (±5.1)	32 (±17.3)
Shorthead redhorse	0	0	45.3 (±49.5)	0*	7 (±14.8)	3 (±7.2)
Silver redhorse	70.5 (±106.5)	6 (±8.5)	12.7 (±12.0)	9 (±10.0)	2 (±3.1)	5 (±4.5)
Smallmouth bass	15 (±6.0)	45 (±63.6)	37.3 (±37.7)	3 (±7.9)	6 (±9.8)	16 (±20.7)
Walleye	30 (±39.8)	0	4.8 (±7.7)	10 (±9.9)	10 (±11.7)	14 (±13.5)
White sucker	174 (±217.4)	12 (±17.0)	200.4 (±168.1)	88 (±122.0)	69 (±86.0)	42 (±52.0)
Freshwater drum	0	0	0	0*	0*	0*
Quillback	0	0	0	0*	2 (±5.7)	0*

* Even though greater redhorse, shorthead redhorse, freshwater drum and quillback were captured during upstream post-assessments, CPUE was noted as zero because these fish were not collected during the 10-minute transects when effort was noted and all species were netted.

Table 5. Catch per unit effort (CPUE; fish caught/hour) of indicator fish species captured upstream of the Frankenmuth rock ramp. Standard deviations are in parenthesis.

	Upstream CPUE					
Species	*Pre-Assessment*			*Post-Assessment*		
	2010	*2011*	*2012*	*2016*	*2017*	*2018*
Black redhorse	9.0 (±19.3)	0	0	38.9 (±47.2)	56 .3(±68.5)	46.8 (±48.5)
Golden redhorse	11.0 (±26.9)	59.3 (±75.9)	97.8 (±80.4)	48.7 (±28.1)	79.5 (±50.2)	83.5 (±73.4)
Greater redhorse	13.0 (±11.0)	7.1 (±10.5)	41.9 (±24.7)	14.9 (±12.6)	21.0 (±24.1)	23.0 (±25.9)
Northern pike	4.0 (±4.9)	2.4 (±5.4)	3.0 (±3.2)	0.5 (±1.7)	1.0 (±2.3)	0.5 (±1.7)
Shorthead redhorse	0	0	0	2.9 (±8.3)	0	0.7 (±2.6)
Silver redhorse	89.0 (±151.0)	0.6 (±1.3)	6.3 (±15.6)	9.2 (±19.6)	2.7 (±5.1)	1.7 (±3.7)
Smallmouth bass	19.0 (±12.8)	6.8 (±9.9)	54.3 (±55.9)	17.8 (±19.3)	17.0 (±15.4)	8.3 (±10.3)
Walleye	0	0	0	0*	0.3 (±1.4)	0.5 (±1.7)
White sucker	4.0 (±7.3)	2.4 (±3.3)	0	3.9 (±6.6)	8.7 (±16.9)	14.9 (±29.4)
Freshwater drum	0	0	0	1 (±3.5)	0*	0.2 (±1.2)
Quillback	2.0 (±4.9)	0	0.9 (±1.8)	12.4 (±24.0)	13.7 (±15.1)	2.9 (±8.5)

* Even though freshwater drum and walleye were captured during upstream post-assessments, CPUE was noted as zero because these fish were not collected during the 10-minute transects when effort was noted and all species were netted.

Table 6. Number of fish tagged and recaptured upstream and downstream of the Frankenmuth rock ramp in 2016, 2017 and 2018 during boat electrofishing assessments. The total number of target fish examined for recaptures upstream was included for reference.

Species	*Number Tagged Downstream*			*Number Recaptured Downstream*			*Number Recaptured Upstream*			*Total Number of Target Fish Captured Upstream*		
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018
Black redhorse	73	74	37	3	7	10	0	2	0	293	356	600
Golden redhorse	50	140	81	2	8	14	0	3	0	615	800	1310
Greater redhorse	42	29	19	1	8	5	0	0	2	223	293	448
Northern pike	11	16	31	0	1	7	0	0	1	14	7	5
Shorthead redhorse	6	97	8	0	4	0	0	0	0	9	0	17
Silver redhorse	35	23	15	0	1	5	2	0	0	87	32	73
Smallmouth bass	16	14	27	1	0	5	0	0	0	160	116	168
Walleye	32	40	43	0	3	3	0	0	0	4	4	2
White sucker	387	338	920	7	13	40	1	2	13	50	74	275
Total	652	771	1181	14	45	89	3	7	16	1455	1682	2898

Table 7. Fish species recaptured, date tagged, date recaptured/reported, and recapture location reported by anglers in 2016, 2017 and 2018. Bold entries are angler recaptures upstream of the rock ramp (blank spaces in "Date Tagged" column indicate fish tag number not reported by angler).

***** Indicates fish has been recaptured more than once by different anglers.

Species Recaptured	*Date Tagged*	*Date Recaptured/Reported*	*Recapture Location*
Walleye	March 18, 2016	May 3, 2016	Saginaw Bay (1 mi. from Saginaw River)
White sucker	March 24, 2016	May 12, 2016	Saginaw River (near St. Charles)
Walleye	March 18, 2016	May 14, 2016	Saginaw River (Veteran Memorial Bridge)
Smallmouth bass	-	May 19, 2016	Cass River (below rock ramp)
White sucker	April 15, 2016	March 7, 2017	Cass River (near Bridgeport)
White sucker	March 24, 2017	April 1, 2017	Cass River (below rock ramp)
White sucker	April 15, 2016	April 1, 2017	Cass River (below rock ramp)
Shorthead redhorse	April 18, 2017	April 20, 2017	Cass River (below rock ramp)
Shorthead redhorse	April 13, 2017	April 24, 2017	Cass River (below rock ramp)
Golden redhorse	April 14, 2017	May 10, 2017	Cass River (below rock ramp)
White sucker	**April 18, 2017**	**May 12, 2017**	**Cass River (Indian Field Park)**
Walleye	March 24, 2017	May 15, 2017	Saginaw River (below Zilwaukee Bridge)
Smallmouth bass	**-**	**May 25, 2017**	**Cass River (above rock ramp)**
Smallmouth bass	March 24, 2017	May 28, 2017	Cass River (below rock ramp)
Smallmouth bass	-	June 9, 2017	Cass River (below rock ramp-at rapids)
Walleye	-	June 16, 2017	Saginaw River (St. Charles, MI)
Walleye	March 24, 2017	July 3, 2017	Cass River (below rock ramp)
Walleye	-	April 28, 2018	Cass River (below rock ramp)
* Smallmouth bass	March 22, 2018	April 29, 2018	Cass River (below rock ramp)
* Smallmouth bass	March 22, 2018	May 3, 2018	Cass River (middle of rock ramp)
* Smallmouth bass	March 23, 2018	June 16, 2018	Cass River (below rock ramp)
* Smallmouth bass	March 23, 2018	June 19, 2018	Cass River (below rock ramp)
* Walleye	March 22, 2018	July 5, 2018	Saginaw Bay (1/2 mi. from KawKawlin)
* Walleye	March 22, 2018	July 6, 2018	Saginaw Bay (Bay City State Park)
Walleye	**March 22, 2018**	**July 6, 2018**	**Cass River (above rock ramp)**
Walleye	-	November 14, 2018	Lake Huron (near Harbor Beach)
Smallmouth bass	April 2, 2018	May 10, 2018	Cass River (below rock ramp)

Table 8. Dates of fish species tagged downstream and recaptured upstream including the range of discharge between the date tagged and date of recapture upstream of the rock ramp. Bold text indicates angler recapture.

Species	*Date Tagged Downstream*	*Date Recaptured Upstream*	*Discharge Range (Cubic Feet/Second)*
Silver redhorse	March 24, 2016	July 13, 2016	74 – 8,540
Silver redhorse	April 14, 2016	May 13, 2016	343 – 1,330
White sucker	April 15, 2016	April 25, 2016	489 – 1,150
White sucker	March 24, 2017	April 3, 2017	416 – 2,190
White sucker	March 24, 2017	April 28, 2017	416 – 8,080
Black redhorse	April 14, 2017	April 21, 2017	693 – 2,010
Golden redhorse	April 18, 2017	April 25, 2017	693 – 3,260
Black redhorse	April 18, 2017	April 28, 2017	709 – 3,260
White sucker	**April 18, 2017**	**May 12, 2017**	**542 – 3,260**
Golden redhorse	April 18, 2017	July 28, 2017	118 – 5,590
White sucker	March 22, 2018	April 27, 2018	456 – 7,860
Walleye	**March 22, 2018**	**July 6, 2018**	**73.3 – 7,860**
White sucker	April 2, 2018	April 27, 2018	535 – 7,860
White sucker	April 2, 2018	April 23, 2018	535 – 7,860
White sucker	April 2, 2018	April 30, 2018	531 – 7,860
Northern pike	April 2, 2018	July 27, 2018	35.7 – 7,860
White sucker	April 2, 2018	April 30, 2018	531 – 7,860
White sucker	April 3, 2018	April 30, 2018	531 – 7,860
White sucker	April 3, 2018	April 30, 2018	531 – 7,860
White sucker	April 9, 2018	April 30, 2018	531 – 7,860
White sucker	April 9, 2018	April 30, 2018	531 – 7,860
White sucker	April 9, 2018	April 30, 2018	531 – 7,860
White sucker	April 9, 2018	April 27, 2018	677 – 7,860
*White sucker	March 24, 2017	April 27, 2018	-
* White sucker	March 29, 2017	April 23, 2018	-
*Greater redhorse	April 14, 2016	April 30, 2018	-

* Discharge data was not calculated for these fish due to the length of time between tagging and recapture.