Ecological Monitoring – Final Report
January 15, 2018
Additional information on the changes in benthos and larval fish are expected to be complete in early 2019 and will be submitted to GLC/NOAA.

Background
The St. Marys River supports a diverse cool- and cold-water fish community, which includes Lake Sturgeon (*Acipenser fulvescens),* Walleye *(Sander vitreus),* Lake Whitefish (*Coregonus clupeaformis)*, and Atlantic and Pacific Salmon (*Salmo salar and Oncorhynchus* spp.) (Schaeffer et al. 2011). Many of these species (e.g. salmon) are considered lithophilic spawners, meaning that they require faster flowing water and coarse substrate for successful reproduction. Historically, diverse rapids habitat was present throughout the St. Marys River, including the Main Rapids and the Little Rapids areas. However, human alterations to river flow and morphology, along with intensive industrial and commercial use of the river over the past century, has resulted in degradation of critical fisheries habitat (Duffy et al. 1987). Consequently, the St. Marys River was listed as an AOC by both the United States and Canada in 1985, and has since had a Remedial Action Plan (RAP) developed to provide a framework for environmental improvements and ultimately delisting.

As part of the RAP, the St. Marys Little Rapids area was identified as a target for restoration to address Beneficial Use Impairments (BUI) identified by the Michigan Department of Environmental Quality. Three of the BUIs – loss of fish and wildlife habitat, degradation of fish populations, and degradation of benthos – were proposed to be addressed through a project that would restore hydrological connectivity and current velocities in the Little Rapids area. Historically this area possessed complex habitat with diverse water velocities, depths, and substrate; however, a causeway with two undersized culverts restricted water flow for the last several decades. The causeway resulted in reduced flows, increased temperatures and poor habitat for native and recreationally important fishes.

To address the historical loss of rapids habitat in the St. Marys River, restoration of flow and habitat in the Little Rapids area was determined a priority by local stakeholders. In 2016, the two culverts that were restricting flow were removed and replaced with a larger bridge spanning approximately 190 m (625 feet). The goal of the bridge replacement was to reconnect hydrology and restore rapids fisheries habitat in this area.

A monitoring program was initiated in 2013 to collect pre- and post-restoration monitoring of physical and biological parameters in response to the Little Rapids restoration.

Methods
Monitoring of the Little Rapids restoration was a collaborative effort led by Lake Superior State University's Center for Freshwater Research and Education (formerly Aquatic Research

Laboratory) but involved data collection by the Michigan Department of Environmental Quality, Michigan Department of Natural Resources, and U.S. Geological Survey.

Study Design

Figure 1. Location of the Little Rapids (project site) and Main Rapids (proposed reference), in the St. Marys River, MI. Pre-restoration monitoring was conducted in 2013 and 2014 and post-restoration monitoring in 2017 and 2018.

Monitoring was conducted in the Little Rapids prior to restoration during the summers of 2013 and 2014 to document baseline conditions in biological communities, water quality, and habitat (bathymetry and velocity), and in 2017 and 2018 after restoration was complete (Figure 1). According to modeling efforts prior to construction, the restoration at the Little Rapids site was expected to result in the majority of habitat changes occurring approximately 200 m upriver and 400 m downriver of the causeway. Therefore, standardized transects were established perpendicular to flow and spanning the entire channel width, upriver and downriver of the causeway (Figure 2). The majority of monitoring was conducted across these transects (e.g., benthos sampling stations, velocity).

Transects were established every 100 m beginning 10 m from the existing roadway and extending to the water's edge (Figure 2). Drift nets were limited to locations possessing flow prior to restoration and therefore were placed closer to the Sugar Island Ferry but were then relocated towards the bridge after restoration.

Originally the Main Rapids was proposed as a reference site; however, high water levels, as a result of increased gate openings by mid-summer, created safety concerns in all sampling years and prohibited effective sampling. Only larval drift was conducted in spring/early summer of the Main Rapids in 2013, which was prior to increased gate openings. Sampling was attempted in 2014 but nets were irretrievable because of safety issues. Sampling in the Main Rapids was not conducted by LSSU in 2017 or 2018, but LSSU did partner with USGS to conduct additional sampling with multiple gear types.

Figure 2. Map of Little Rapids area including location of 100-m transects used for macroinvertebrate and habitat sampling, along with drift net and fyke net locations. Drift nets were limited to areas where flow was sufficient in 2013 and 2014, but they were moved adjacent to the single net on transect 6 after restoration (2017 and 2018) because suitable flow existed. Fyke nets were located in nearshore areas representative of site habitat. The thickened lines on transects 3-7 illustrate locations of current velocity measurements.

Biological Data Collection – Larval Fish

Larval drift nets (76.2 cm wide x 53.3 cm high) were used to capture larval and juvenile fish, as evidence of natural reproduction, in the Little Rapids and the Main Rapids (when possible). Larval drift nets were set by boat in areas behind gravel beds where there was sufficient flow for the nets to fish properly. Nets were anchored to the bottom substrate with large steel anchors having approximately 4-6 foot leads to the frame of the net (Kempinger 1988). Nets were set overnight twice per week usually starting in May through July or August each year in an attempt to target larval fish emerging after winter or spring spawning. Water temperature at the onset of sampling ranged between 3.7°C (in 2018) and 10°C (in 2013).

A total of five to six nets were set prior to restoration—two to three nets were set on the upstream side of the causeway directly in front of the large culverts or near the ferry dock, and three nets were set downstream of the causeway directly below the culverts. Sampling locations in the Little Rapids area were limited because few areas possessed sufficient flow. Six to eight nets were set post-restoration, three upstream of the causeway, three downstream of the causeway, and two attached to the bridge. All nets fished overnight for approximately 12 hours. Samples were sorted in the field when able or returned to the lab for sorting from debris (largely mats of *Didymosphenia geminata*). Fish captured were identified, recorded, and measured (generally only salmonids). All specimens unidentified in the field were preserved and identified in the laboratory using larval fish keys by Auer (1982) and Fuiman et al. (1983), and photos were sent to the USGS GLERL lab for verification.

Biological Data Collection – Juvenile & Adult Fish

Fyke nets, a common passive sampling gear (Hubert et al. 2012), were set twice per week in the Little Rapids from July to September/October in 2013, 2014, and 2017 to capture juvenile and adult fish. Seven fyke nets were set in slower velocity, nearshore locations. Two nets (1 large, 1 mini-fyke) were set upstream of the causeway/bridge, and five nets (3 large, 2 mini-fykes) were set downstream of the causeway. The nets were set by tying the lead line to a tree near the water's edge and running the net perpendicular to the shoreline. The nets were held in place by a fyke net anchor with a float attached to the net to mark the location. The nets were set for 24 hours and then fish captured were identified and counted, and the first 25 individuals of each species were measured for total length (mm). All fish identified in the field were released. Unidentified fishes were preserved in ethanol and identified using dichotomous keys in the laboratory.

Small seines (9.75 m x 2.3 m; mesh = 0.32 cm) were used to sample shallow, nearshore areas in the Little Rapids once per week. Seining was conducted in 2013 from July to October at two representative sites upstream of the causeway and four sites downstream. Total length for the first 25 individuals of each species collected was measured before releasing all captured fish.

Unidentified fishes were preserved in ethanol and identified using dichotomous keys in the laboratory. Seining was attempted post-restoration but did not continue due to high water levels and flows in 2017 and 2018.

Biological Data Collection – Macroinvertebrates

Benthic invertebrates were collected using a modified version of the Large River Bioassessment Protocol for Benthic Macroinvertebrate Sampling (LR-BP; Flotemersch et al. 2006). The LR-BP method is semi-quantitative and samples multiple habitats in proportion to their availability. This method suggests sampling a reach length of 500 m, however due to the smaller site, only 200 m upstream and 400 m downstream of the causeway was sampled using this approach (Figure 2). Along each transect, the sampling zone extends 5 m on each side of the transect (10-m sampling zone). The zone extends from each bank to the mid-point of the river (or until depth >1m). A sample included three kicks or sweeps of the substrate using D-frame nets (500-μm mesh). Each kick/sweep was conducted along a 0.5 m path and covered approximately 0.15 m^2. The sample locations were distributed based on available habitat within the zone to ensure coverage of sub-habitats (rocks, logs, soft sediment, etc.). If water was >1 m deep at the water's edge, sweeps were collected from a boat when possible. Each transect had two zones (one on each bank) and samples from the entire zone were composited into a single sample; therefore each transect has two samples. When a transect encountered an island or shallow bar it was considered to be a separate transect and two additional zones were sampled, resulting in a total of 28 zones (n=10 upstream, n=18 downstream). Samples were washed into a 500-μm sieve to remove fine sediments and then transferred to sample bottles with 70% ethanol and both internal and external labels.

Macroinvertebrate samples were processed in the laboratory at LSSU. All samples were sorted under a Leica dissecting microscope (35x) and identified to genus when possible. Aquatic insect taxa were generally identified to genus (except *Chironomidae* was left at family level) when specimens were intact, but most non-insect taxa were only identified to Class (e.g., *Oligochaeta*) or Order (e.g. *Amphipoda*). A minimum of 15% of all samples were randomly selected and checked by a second person to verify identifications.

Water Quality & Algal Data Collection

Samples of Total Suspended Solids (TSS) were collected once in July 2014 to determine background levels of TSS, and then biweekly in summer 2016 during construction, followed by monthly sampling in 2017 post-restoration. Samples were collected along the established transects at the same sites sampled for benthos (n=28; see above). Downstream sites were sampled first followed by upstream transects. Additionally, all samples were collected off the bow of the boat to avoid possible disturbance of the sediment due to the sampling activity.

Water samples were collected for TSS analysis using an integrated water column PVC sampler. Each sample was emptied into an acid-washed carboy, mixed, and then a 2.5 L cubitainer was filled, labeled, and placed in a cooler on ice until returned to the lab for further processing. TSS samples were processed immediately upon return to the laboratory following EPA Method 160.2 (Gravimetric method). GF/F filters were pre-weighed in an aluminum pan on an analytical balance. Samples were mixed and then filtered using GF/F filters (Gelman A/E) on a vacuum filtration manifold. Total volume of water filtered was recorded. Filters were placed in a drying oven and dried to a constant weight (>24 hours) at 100^{o}C.

In 2017, benthic algal data was collected above and below the berm to provide a baseline on *Didymosphenia geminata* (Didymo) in the Little Rapids area. Clean clay tiles attached to cement blocks were placed in the Little Rapids area and allowed to colonize for at least 4 weeks. Individual tiles were removed monthly to quantify Didymo stalks and cells.

Habitat Data Collection – Cross-sections and Current Velocity

Four channel cross-sections were surveyed using a laser range finder by MDEQ staff in September 2013 and then in 2017 a bathymetric survey was completed using a BSS +3 System. One transect was located upstream of the causeway and the other three were located downstream (~80 m, 150 m, and 200 m downriver of causeway). Depth, sediment depth, and substrate type were recorded at approximately 20 intervals along each cross-section in 2013. Further details are outlined in the DEQ report submitted to John Riley, Office of the Great Lakes.

Current velocity was measured using an acoustic doppler current profiler (ADCP) following USGS Techniques and Methods 3-A22 (Mueller et al. 2013; Appendix D). Measurements were completed in July 2014 and 2017 to map variation in current velocities in the Little Rapids area. Six transects were surveyed, with three above and three below the causeway (Figure 2). Two to four passes were made across each transect. Operation of the ADCP system was conducted by USGS-trained ADCP staff that had conducted surveys previously. ADCP configurations were selected based on water depths and modeled velocities in the area. Data was processed using RD Instruments WinRiver2 software and then imported into USGS program Velocity Mapping Toolbox (VMT). Data for each transect were exported from WinRiver2 software using the ASCII Output Wizard and analyzed using R software. Any bins (or pixels) where velocity or depth data were missing were removed from the analysis. Bins that had velocity readings above 0.24 m/s were summed for each transect and divided by the total number of bins to determine the percentage of the water column meeting or exceeding the desired velocity. To estimate total area with velocities above 0.24 m/s in the study site, the percentages from the previous analyses were extrapolated to the entire study area by averaging values from the two nearest transects. For example, transect width transect 8 and transect 7 were averaged and then multiplied by the distance between the transects (usually 100 m) to calculate total surface area between the two transects. Then, % Vcrit for transect 8 and transect 7 was averaged and multiplied by the total area to determine the total area that met or exceeded the critical velocity. Thus, the results reflect an estimate within the boundaries surveyed and are likely an underestimate of habitat created that meets the target velocity.

Results

Water Quality & Habitat

Total Suspended Solids levels remained low throughout construction and a year following construction (Figure 3), except for a single event when TSS approached 30 mg/L during a breach of the sediment curtain surrounding the construction site. Channel cross-section surveys indicated that upstream and downstream transects were generally dominated by fine sediments prior to restoration. Less than 25% of the substrate was course substrate suitable for lithophils in most pre-restoration transects. Changes in lake bottom depth were documented by MDEQ in their report submitted separately.

Pre-restoration channel cross-section surveys indicated that upstream (cross-section 7) and downstream (cross-sections 5, 4, 3) were generally dominated by fine sediments. Less than 25% of the substrate was coarse substrate suitable for lithophils in cross-sections 7 and 4. In contrast, the substrate in cross-section 5, the first transect downstream of the causeway and culverts, contained over 60% of gravel and cobble. This information was only determined pre-restoration by DEQ staff, comparable post-restoration data were not collected due to a change in personnel and methodology used by the MDEQ before and after restoration. The information collected used transects and grab samples so determining the area of substrate type was not possible.

The USGS completed velocity mapping in summer 2014 and 2017. Pre-restoration data indicated that all measured velocities were below desired levels (desired >0.24 m/s) (Figure 4). Post-restoration mapping illustrates substantial increases in velocity (to or beyond target velocities) throughout the restored area (Figure 5). Over 90% of the water column in downstream transects 3-5 and upstream transect 6 met or exceeded the desired velocities (Figure 6). The furthest upstream transects (8 & 7) had 18% and 50% of the water column, respectively, meeting the desired velocity. An approximate area of 58,717 m^2 (14.5 acres) was surveyed in the Little Rapids site, and of this area, approximately 40,000 m^2 (9.89 acres) met or exceeded the desired velocity (Table 1). Thus, nearly 70% of the surveyed habitat met the desired goal and exceeded the target area.

Biological Responses

Macroinvertebrate communities shifted from pre- to post-restoration and taxa richness declined 2-3-fold in upstream and downstream transects. In 2017 after restoration, richness averaged around 3 taxa in both reaches. In contrast, the % EPT (Ephemeroptera, Plecoptera, Trichoptera) increased by 4-6-fold in both upstream and downstream reaches immediately after restoration (Figure 7). The 2018 data are still being analyzed but indicate continued low numbers in the restored area. Although fish appear to be using the Little Rapids area for spawning and foraging areas, macroinvertebrate abundance remains low throughout the area. *Didymosphenia geminata* blooms continue to occur throughout the rapids habitat and it is unknown how this may impact biological recovery in the long-term.

In 2017, larval fish catches were dominated by *Catostomidae* (suckers) and *Osmeridae* (Rainbow Smelt), along with some sculpin and salmonids. Most of the larval fish were collected downstream of the bridge, which suggests that they were drifting out of the newly created Little Rapids area. It was not surprising that we did not see larval fish of many fall/winter spawners (e.g., salmon and whitefish) because the habitat was not open until late fall 2017 and therefore it is unlikely that large numbers of fish spawned in this area. Fyke net sampling was conducted from late July through mid-September in 2017 in nearshore areas and large numbers of Rainbow Smelt were found in the Little Rapids, along with smaller numbers of *Percidae* (mainly Yellow Perch), *Centrarchidae* (Rock Bass), and *Cyprinidae* (minnows). Site surveys identified large numbers of Pink Salmon and Atlantic Salmon using and spawning in the Little Rapids in late summer/early fall, but these species are generally not effectively sampled using fyke nets. The larval data for 2018 is continuing to be processed, but preliminary analyses indicate that larval fishes were abundant in the Little Rapids area and included *Cottidae* (sculpin), *Salmonidae* (salmon and trout), and *Osmeridae*.

Earlier in the summer 2018, electrofishing surveys collected thousands of Rainbow Smelt, hundreds of adult White Suckers and Trout Perch, and fall surveys collected Atlantic Salmon, Chinook Salmon, and Pink Salmon spawners (Figures 8 and 9). Additionally, numerous adult Walleye and Yellow Perch were collected on multiple dates and a single adult Cisco (*Coregonus artedii)* was collected.

Deviation from Proposed Methods

As mentioned in the Methods section described above, this project did deviate from proposed methods several times due to field constraints. The first deviation was removal of the Main Rapids as a reference site due to increased flow through the compensating gates and conditions that did not allow effective or safe sampling using drift nets. We also changed drift net locations from pre to post-restoration due to location of flow necessary for the gear to fish effectively. Finally, electrofishing was originally conducted once by the MDNR in early summer most years due to their scheduling, but in 2018 the MDNR was able to complete sampling three times during the summer to increase their likelihood of collecting fall spawners.

Achievements of Performance Metrics

Fish abundance & composition, fish diversity, and water quality performance measures were all met within 1-year post-restoration. Benthos abundance and benthos diversity did not meet performance measures. Reduced benthos post-restoration may reflect changes to the habitat as a result of *Didymosphenia geminata* blooms, which began in 2016 and continue today.

Didymo blooms produce large stalks that form dense mats along the bottom substrate and have been shown in studies elsewhere to result in a shift to a community dominated by chironomids. Although we still observed other taxa, numbers and diversity have declined. Since Didymo immediately colonized substrate in the new area it is difficult to separate out the mechanism driving the decline. It is also possible that the modified Large River Bioassessment Protocol method used to sample benthos was less effective after the restoration due to higher water levels and velocities.

As mentioned above, we were unable to evaluate the substrate performance measure due to a change in personnel and methodology used by the MDEQ before and after restoration. Prior to restoration, the frequency of occurrence of sand and silt was high (>50% at all transects), and although it is not quantified, aerial photos illustrate high occurrence of exposed cobble downstream of the bridge.

Velocity data collected by the USGS and analyzed by LSSU indicated that the target to create >7 acres of habitat with velocities exceeding 0.24 m/s was achieved. Research findings have been presented by Moerke and her students at the Michigan Aquatic Restoration Conference (Boyne Mountain, MI), Midwest Fish and Wildlife Conference (Milwaukee, WI), and the Michigan American Fisheries Society Conference (Port Huron, MI).

Lessons Learned

Our main lessons learned during the monitoring portion of this project were related to logistical constraints associated with sampling in a large water level-controlled river system. The high-water levels in recent years resulted in increased gate openings at the compensating gates producing flows that exceeded our ability to access the rapids safely and retrieve our gear. We did not anticipate these large changes in flow and therefore were unable to accommodate them with the proposed sampling methods. A second lesson learned was that more research needs to be done on how to accurately compare data collected in environments where flow has changed significantly. For example, gear used to effectively sample stagnant habitats do not work well in flowing habitats, and vice versa. Thus, standardized approaches to analyze these types of data are needed to be able to compare pre and post-restoration data. A final lesson learned is that communication with monitoring partners is crucial to ensure that methodologies stay consistent and that outcomes reported are consistent with expectations. We often found that agencies were willing to contribute to collecting data, but data analysis and interpretation were generally not part of the outcome and therefore future monitoring programs should make sure to build these expectations into the monitoring plan with existing or additional partners to ensure that data are not just collected, but analyzed to inform understanding of the changes that can be attributed to the restoration.

Future Plans

Data analyses related to changes in benthos and larval fish (2018) are ongoing and will be complete by the end of January 2019. A manuscript summarizing the findings is in preparation for submission to the Journal of Great Lakes Research. Additionally, summarized raw data will be provided to GLC in MSExcel spreadsheets so it can be made publicly available on the GLC's website within a year of the project completion as is specified in the data sharing plan.

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Table 1. Area surveyed and area exceeding desired velocity (Vcritical = 0.24 m/s) for the Little Rapids study area post-restoration, 2017.

Transect No.	Transect width (m)	Avg Transect width (m)	Surveyed Area (m^2)	% > Vcrit	Avg >Vcrit	Total Area >Vcrit (m^2)
8	279			18		
7	139	209	20890	50	0.34	7041
6	179	159	15873	98	0.74	11715
5	146	162	4872	96	0.97	4713
4	69	108	10751	99	0.97	10445
3	57	63	6332	94	0.96	6095
Total (m^2)			58,717			40,010
Total (acres)			14.5			9.9

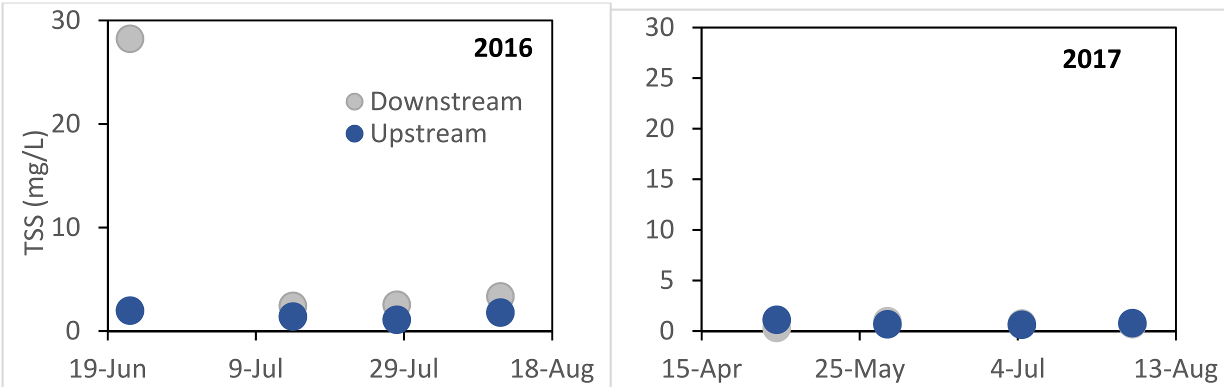

Figure 3. Total Suspended Solids downstream and upstream of the constructed bridge in 2016 (left) during construction and 2017 (right) after construction.

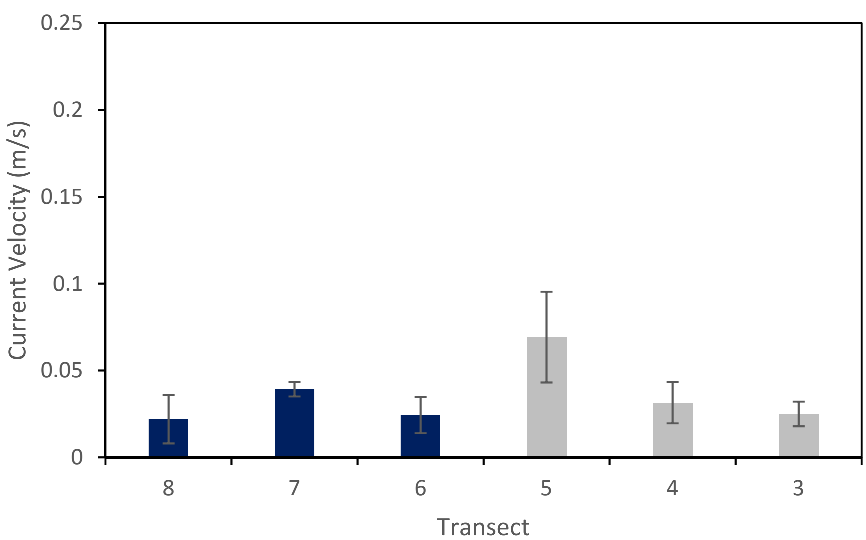

Figure 4. Mean current velocities in transects 6-8 (upstream) and 3-5 (downstream) of the causeway prior to restoration. All were below the desired velocity of 0.24 m/s.

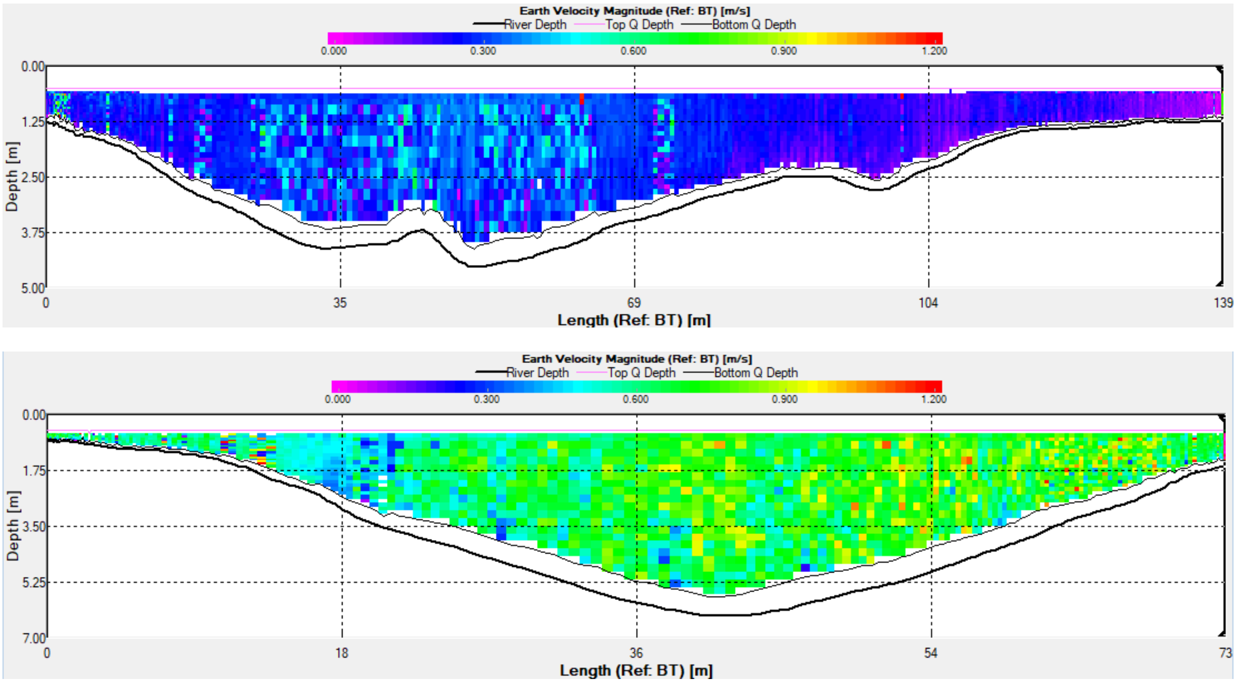

Figure 5. ADCP profiles illustrating current velocity (m/s) at an upstream transect (transect 7, top) and a downstream transect (transect 4, bottom) in 2017 post-restoration. Both demonstrate that velocities above the 0.24 m/s desired range were achieved.

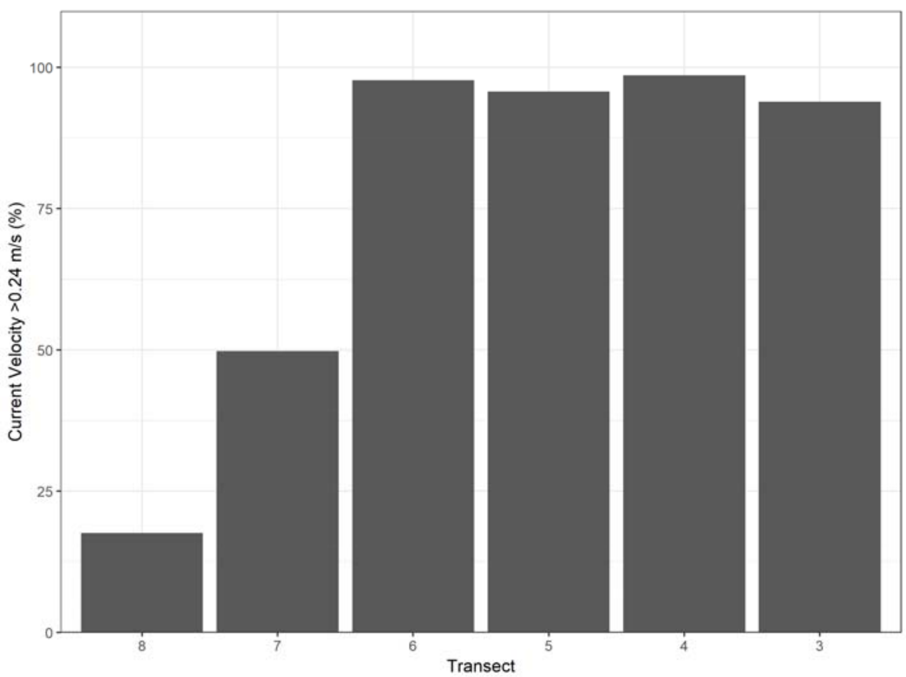

Figure 6. The percentage of the water column that had current velocities above 0.24 m/s during the USGS ADCP survey post-restoration. Transects 3-5 are downstream of the bridge and transects 6-8 are located upstream.

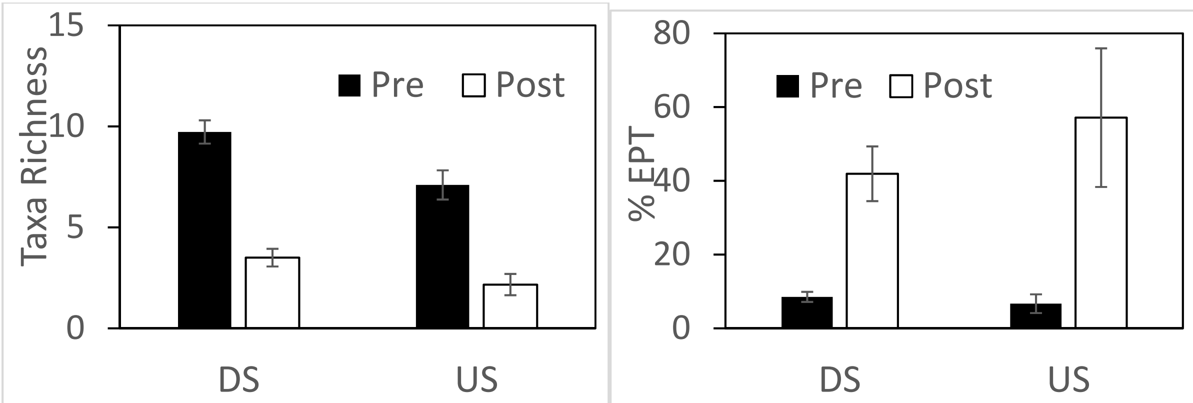

Figure 7. Mean macroinvertebrate taxa richness (left) and %EPT (right) upstream (US) and downstream (DS) of the causeway pre-and post-restoration. Although taxa richness declined, %EPT increased in both reaches after restoration.

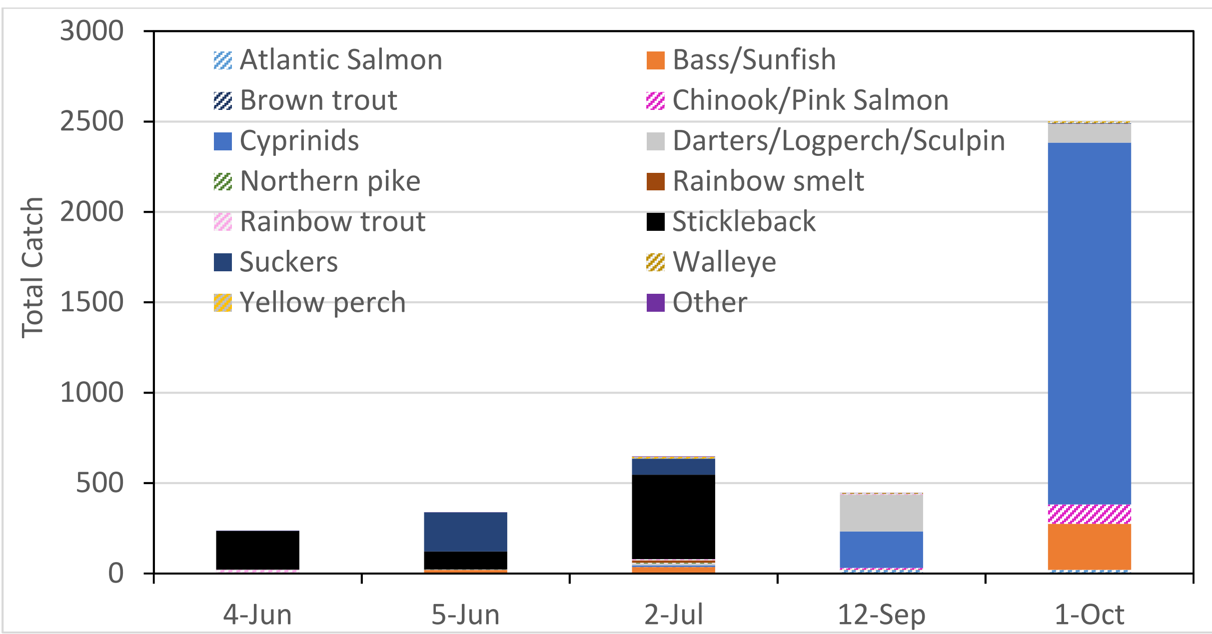

Figure 8. Total catch of all fishes collected using boat electrofishing methods in June, July, September and October 2018 after restoration. Catch was dominated by minnows (cyprinids) and stickleback.

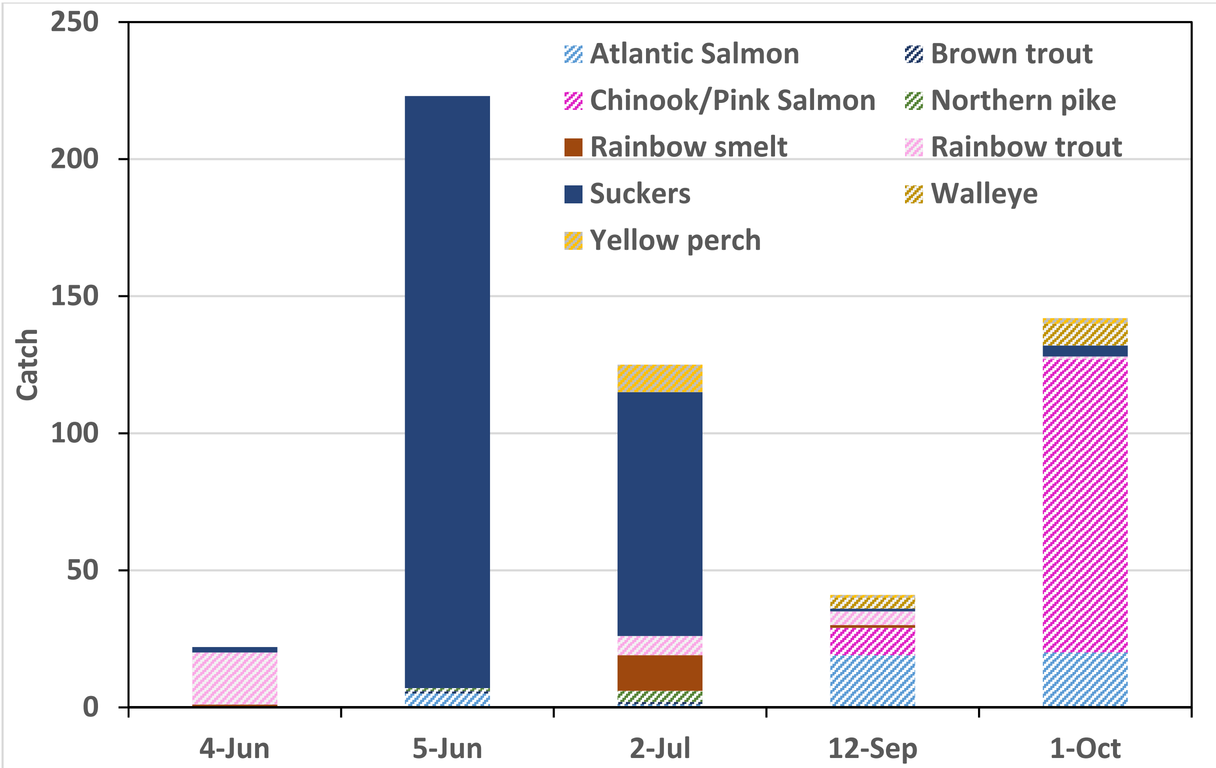

Figure 9. Catch of game fishes and other lithophillic spawners collected using boat electrofishing methods in June, July, September and October 2018 after restoration. Catch was dominated by suckers in the early summer and salmonids in the fall.