BASELINE ASSESSMENT OF THE LITTLE RAPIDS AREA, ST. MARYS RIVER (MI)

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Introduction

The St. Marys River supports a diverse cool- and coldwater fish community, which includes Lake Sturgeon (*Acipenser fulvscens),* 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, meant 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. Currently a causeway with two undersized culverts restricts water flow and has resulted in reduced flows, increased temperatures and poor habitat for native and recreationally important fishes.

Restoration of flow and habitat in the Little Rapids area is scheduled to take place in 2016. The two culverts that are restricting flow will be removed and replaced with a larger bridge spanning approximately 180 m (600 feet). The goal of this restoration is to reconnect hydrology and restore rapids fisheries habitat in this area.

A monitoring program was initiated in 2013 to evaluate changes in physical and biological parameters in response to the Little Rapids restoration. This document provides a summary of baseline, or pre-restoration, data on fish and macroinvertebrate communities, water quality and habitat.

Methods

Study Design

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) (Figure 1). According to modeling efforts, restoration at the Little

Rapids site is 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), including parameters being

Figure 1. Location of the two monitoring sites, Little Rapids and Main Rapids, in the St. Marys River, MI. Baseline monitoring was conducted in 2013 and 2014.

monitored under other funding sources (e.g., channel morphology). 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.

When possible, data were collected from the Main Rapids, which was used as a reference site, and the area sampled was on the U.S. side of the rapids approximately 200 meters upstream from the end of the rapids (Figure 1). High water levels, as a result of increased gate openings by mid-summer, created safety concerns in 2013 and 2014 and therefore limited sampling of the Main Rapids. 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.

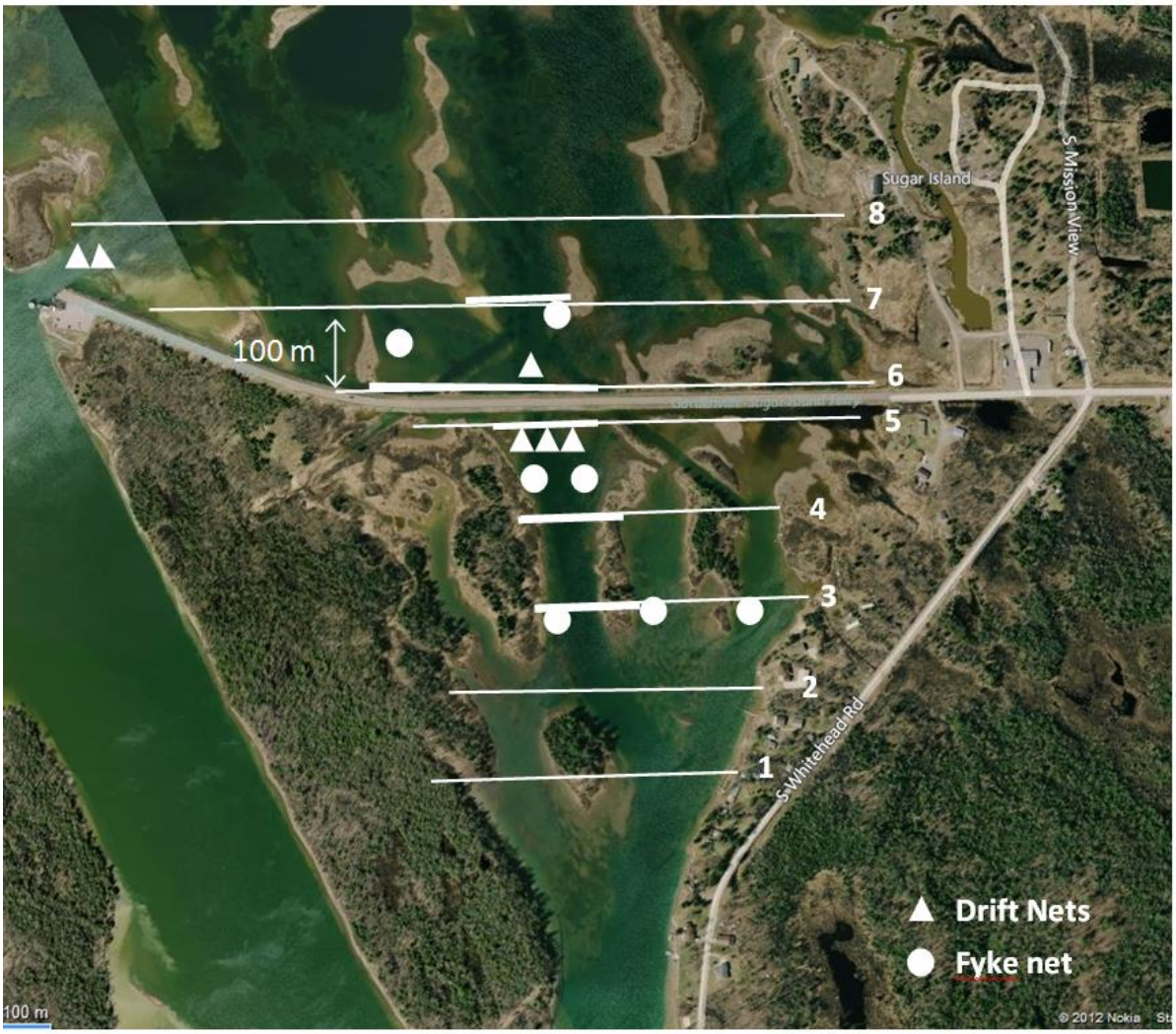

Figure 2. Map of Little Rapids area including location of 100-m transects used for macroinvertebrate and habitat sampling, along with drift net and fyke net locations. Drift nets were limited to areas where flow was sufficient. Fyke nets were located in nearshore areas representative of site habitat. 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 in late May through the middle of July in 2013, and early May to the middle of July in 2014 in an attempt to target larval fish emerging after winter or

spring spawning. In 2013, water temperature was nearly 10^{o}C at the onset of sampling, whereas in 2014 water temperature was <5^{o}C.

In the Main Rapids three nets were set on the American side of the rapids approximately 200 meters from the tail of the rapids. In the Little Rapids, a total of five to six nets were set: two to three nets were set on the upstream side of the causeway directly in front of the large culverts and/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. The nets fished overnight for approximately 12 hours. Upon collection, fish were identified, recorded, and measured (generally only salmonids) and released. 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).

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 October 2013 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, 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.

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. These methods 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 be 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 Data Collection

Samples of Total Suspended Solids (TSS) were collected once in July 2014. 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.

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. 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.

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 once in July 2014 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). Velocity models and analysis remain under development.

Data Summary

Fish Community

Effort varied across the three gear types employed to survey the Little Rapids (Table 1). Effort was lowest for drift nets in 2014, with 1983 hours, and highest in 2013 with 2772 hours. Catch-per-unit-effort (CPUE) also differed depending on gear type. Fyke nets had the highest CPUE at 5.29 for all sampling dates compared to drift nets which had the lowest CPUE at less than 0.5 in both 2013 and 2014. Fyke nets also captured the largest number of species at 37, whereas the seine captured the fewest species at only 15. Over all sampling periods, over 40 fish species were collected in the Little Rapids using larval drift nets, fyke nets, and seines (Table 2).

Table 1. Effort and CPUE for gear types employed to survey fishes (larval, juvenile, and adult) in the Little Rapids during the summers of 2013 and 2014. Catch Per Unit Effort (CPUE) was calculated by taking the total number of fish captured divided by the effort for each type of gear. *Effort was in hours for all nets, except for seines which was recorded as number of hauls.

Method	Effort*	CPUE
2013		
Larval drift nets	2772	0.284
Fyke nets	2280	5.2895
Beach seine	42	42.574
2014		
Larval drift nets	1983	0.3804

Table 2. Total (TA) and relative (%; RA) abundance of fish species collected for each gear type and year. *Species identified as lithophilic spawners (fishtrait categories A_1_3, A_2_3, B_1_3_A, B_2_3A, and B_2_3B); ^Species categorized as cold-water thermal preference (www.fishtraits.info, www.fishbase.org, Coker et al. 2001).

		Drift – 2013		Drift – 2014		Fyke		Seine	
Common Name	Scientific Name	TA	RA	TA	RA	TA	RA	TA	RA
Atlantic Salmon*^	*Salmo salar*					2	0.02		
Banded Killifish	*Fundulus diaphanus*			1	0.13	6	0.05	33	1.85
Blackchin Shiner	*Notropis heterodon*					2558	21.21	23	1.29
Blacknose Shiner	*Notropis heterolepis*					3	0.02	1	0.06
Bluegill	*Lepomis macrochirus*			1	0.13	254	2.11	1	0.06
Bluegill Hybrid	*Lepomis spp.*			2	0.27	841	6.97		
Bluntnose Minnow	*Pimephales notatus*			350	46.42	2514	20.85	1007	56.32
Brook lamprey*^	*Ichthyomyzon fossor*	1	0.20	7	0.93				
Brook Silverside	*Labidesthes sicculus*					1	0.01		
Brook Stickleback	*Culaea inconstans*	1	0.20	1	0.13	1	0.01		
Brown Bullhead	*Ameiurus nebulosus*					29	0.24		
Chinook Salmon*^	*O. tshawytscha*	16	3.25	18	2.39	1	0.01		
Common Shiner*	*Luxilus cornutus*			13	1.72	14	0.12	1	0.06
Creek Chub*^	*Semotilus atromaculatus*			13	1.72				
Emerald Shiner	*Notropis atherinoides*					332	2.75	1	0.06
Fathead Minnow	*Pimephales promelas*			1	0.13	1	0.01		
Golden Shiner	*N.crysoleucas*					7	0.06		
Iowa Darter	*Etheostoma exile*	3	0.61	4	0.53				
Johnny Darter	*Etheostoma nigrum*	24	4.88	12	1.59	4	0.03	171	9.56
Lake Whitefish*^	*Coregonus clupeaformis*					2	0.02		
Largemouth Bass	*Micropterus salmoides*					14	0.12		
Logperch*	*Percina caprodes*	3	0.61	23	3.05	26	0.22	1	0.06
Longnose Dace*^	*Rhinichthys cataractae*			9	1.19				
Mimic Shiner	*Notropis volucellus*					185	1.53	68	3.80
Mottled Sculpin^	*Cottus bairdii*	13	2.64	10	1.33	12	0.10	11	0.62
Muskellunge	*Esox masquinongy*			1	0.13				
Ninespine Stickleback	*Pungitius pungitius*			3	0.40	3	0.02		
Northern Pike	*Esox lucius*			2	0.27	10	0.08		
Pinook Salmon*^	*O. gorbusch x O. tshawytscha*	36	7.32	39	5.17	1	0.01		
Pumpkinseed	*Lepomis gibbosus*	3	0.61			12	0.10		
Rainbow Smelt	*Osmerus mordax*	28	5.69	4	0.53	2	0.02		
Rock Bass	*Ambloplites rupestris*	21	4.27	10	1.33	3498	29.00	4	0.22
Sand Shiner	*Notropis stramineus*			118	15.65	584	4.84	362	20.25
Sculpin spp.^	*Cottus spp.*	40	8.13	1	0.13				
Sea Lamprey*^	*Petromyzon marinus*	3	0.61						
Shiner spp.	*Notropis spp.*	294	59.76	76	10.08				

Shorthead Redhorse*	*M.macrolepidotum*					18	0.15		
Silver Redhorse Sucker*	*Moxostoma anisurum*					1	0.01		
Smallmouth Bass	*Micropterus dolomieu*					437	3.62	9	0.50
Spottail Shiner*^	*Notropis hudsonius*					1	0.01		
Threespine Stickleback	*Gasterosteus aculeatus*	2	0.41	5	0.66	3	0.02		
Trout-perch*^	*Percopsis omiscomaycus*			5	0.66	7	0.06		
Unknown	--	4	0.81	10	1.33				
Walleye	*Sander vitreus*					9	0.07		
White Sucker*	*C. commersonii*			11	1.46	253	2.10	95	5.31
Yellow Perch	*Perca flavescens*					412	3.42		
TOTAL		**492**		**754**		**12,060**		**1,788**	

Larval fish—In the Little Rapids, 492 larval fish representing over 15 species and 754 larval fish representing over 25 species were collected in 2013 and 2014, respectively (Table 2; Figure 3). CPUE was also higher in 2014 when 0.38 fish/hour were captured compared to 0.28 fish/hour in 2013. In the Main Rapids, 292 larval fish of 14 different species were collected in 2013, and CPUE was similar to the Little Rapids in 2013 with 0.39 fish/hour.

Larval fish composition in the Little Rapids was dominated by minnow species (Cyprinidae; >60% of total catch; Figure 3B) whereas the Main Rapids was dominated by salmon (Salmonidae; >90% of total catch; Figure 3A). Recreationally important species were captured in the Little Rapids including Chinook Salmon (*Oncorhynchus tshawytscha)*, Pinook Salmon *(Oncorhynchus spp.)*, Pink Salmon (*Oncorhynchus gorbuscha)*, and one Muskellunge *(Esox masquinongy).* However, less than 25% of larvae captured in the Little Rapids were classified as coldwater and less than 20% were classified as lithophilic spawners for both years (Figures 4 and 5).

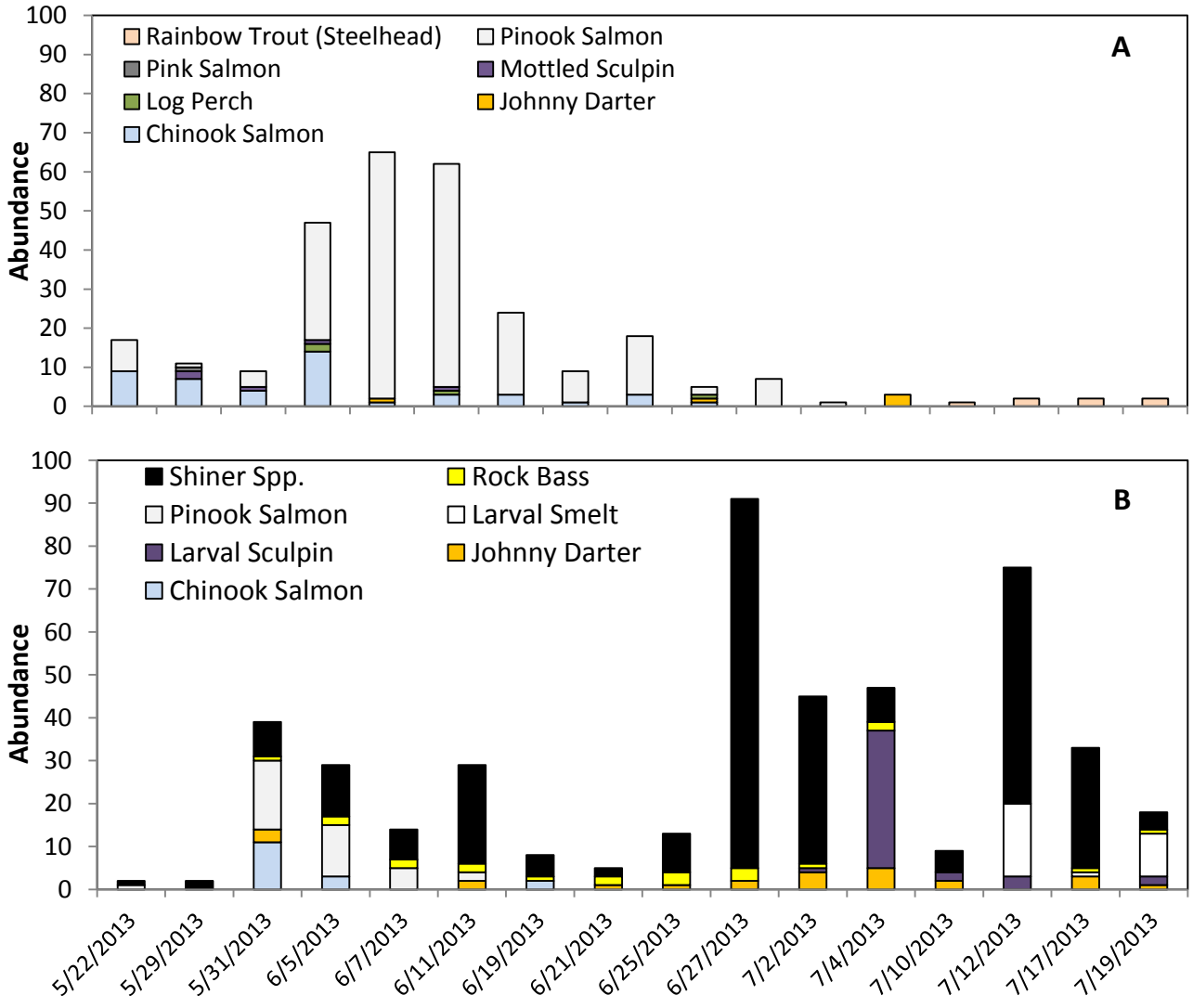

Figure 3. Species composition of larval fishes captured in the A) Main Rapids and B) Little Rapids, 2013. Only the dominant 7 species are shown because they comprised > 95% of the total catch. Shiners (*Notropis* spp.) made up 60% of the total catch in the Little Rapids whereas Pinook Salmon comprised over 70% of the catch in the Main Rapids.

Adult & Juvenile Fishes – Over 35 species of juvenile and adult fishes were collected in the Little Rapids area using fyke nets (Table 2). Rock Bass dominated catches throughout the summer and comprised nearly 30% of the total catch. Recreational species (e.g., Chinook Salmon, Lake Whitefish, Northern Pike*)* were present, but were less than 20% of the total catch and were generally dominated by warm-water species such as sunfish and bass (Centrarchidae spp.). Less than 1% of the juvenile and adult species captured by fyke nets were classified as coldwater fishes (Figure 4), and <3% were classified as lithophilic spawners (i.e., require current and gravel/cobble substrate for reproduction) (Figure 5).

Nearly 1800 individuals representing 15 fish species were collected in the Little Rapids area by seines (Table 2). The most prominent species captured were Bluntnose minnows (*Pimephales notatus*), which comprised over 50% of the total catch. Forage species were primarily captured using this method and <1% of total catch included game species. Additionally, less than 1% of the juvenile and adult species captured by seines were classified as coldwater fishes (Figure 4), and <6% were classified as lithophilic spawners (Figure 5).

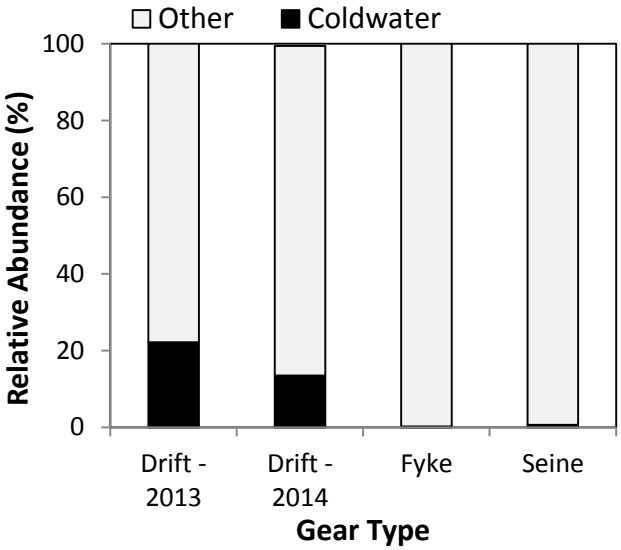

Figure 4. Relative abundance (%) of fish species classified as coldwater by gear type. See Table 2 for classifications.

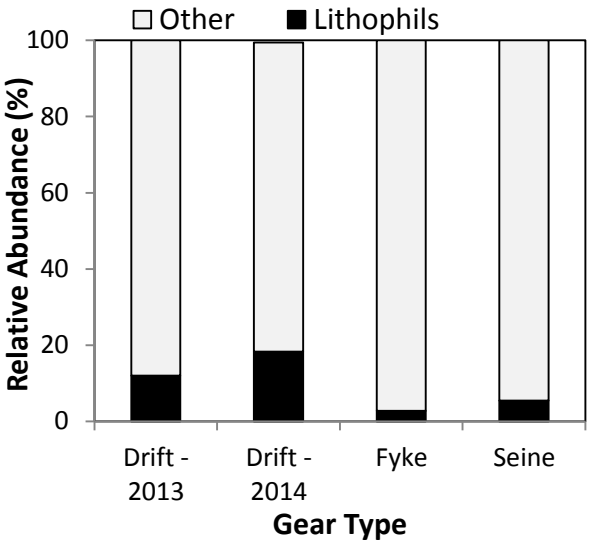

Figure 5. Relative abundance (%) of fish species classified as lithophilic spawners by gear type. See Table 2 for classifications.

Macroinvertebrate Community

Macroinvertebrate abundance at each site ranged from approximately 30 to 150 individuals per site (Table 3). Similarly, taxonomic richness was variable, with only 9 different taxa collected at transect 6 (upstream) compared to 24 taxa collected at transect 4 (downstream). Upstream transects had an average taxa richness of 14 compared to 18 downstream, but richness was not statistically different (Figure 6; t-test, $p>0.05$).

Across all transects, Chironomids (Diptera), snails (Gastropoda), and amphipods (Amphipoda) were the most dominant invertebrate taxa present in the Little Rapids area (Table 3). Although 6 Trichoptera and 7 Ephemeroptera families were collected in the Little Rapids, their abundances were low. The EPT (Ephemeroptera-Plecoptera-Trichoptera) index was low across all sites and averaged less than 8% of the entire community both upstream and downstream of the causeway (Figure 7).

Table 3. Mean macroinvertebrate abundance for each transect surveyed in the Little Rapids, 2013. Transects 1-5 are downstream of the causeway and 6-8 are located upstream.

	Mean Abundance per Transect							
TAXA	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Acari	1.0	2.0	0.2	0.3	0.0	0.0	0.0	0.0
Amphipoda	3.0	22.5	5.2	21.0	2.5	8.5	5.0	4.5
Coleoptera	0.0	1.5	0.0	1.0	0.0	0.0	0.0	1.8
Dytiscidae	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.8
Haliplidae	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Decapoda	1.0	0.5	0.5	1.2	0.5	0.0	0.0	0.3
Diptera	61.5	77.0	59.8	85.0	29.5	16.0	74.0	50.8
Ceratopogonidae	1.0	0.5	0.8	0.2	0.5	0.0	0.0	0.8
Chaoboridae	0.0	0.0	0.0	1.0	0.5	2.5	3.3	0.0
Chironomidae	60.5	76.5	59.0	83.8	28.5	13.5	70.8	48.8
Simuliidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Ephemeroptera	4.0	7.5	4.2	10.0	3.0	1.0	3.8	1.5
Baetiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Caenidae	0.5	1.0	0.5	0.2	1.0	0.0	2.8	0.3
Ephemerellidae	0.0	0.0	0.0	0.2	1.0	1.0	0.3	0.0
Heptageniidae	3.0	4.5	2.0	7.2	0.0	0.0	0.3	1.0
Leptohyphidae	0.5	1.5	0.5	1.5	0.0	0.0	0.0	0.0
Polymitarcyidae	0.0	0.5	0.3	0.7	1.0	0.0	0.5	0.0
Ephemeridae	0.0	0.0	0.8	0.3	0.0	0.0	0.0	0.0
Gastropoda	0.0	9.0	6.7	20.0	38.5	1.0	8.5	3.8

Lymnaeidae				0.0	8.5	5.7	17.8	32.5	0.0	7.5	2.8
Planorbidae				0.0	0.5	1.0	2.2	6.0	1.0	1.0	1.0
Hemiptera				0.0	2.5	0.2	0.8	1.0	0.0	0.5	0.0
Notonectidae				0.0	0.0	0.0	0.2	1.0	0.0	0.3	0.0
Corixidae				0.0	2.5	0.2	0.7	0.0	0.0	0.3	0.0
Hirudinea				0.0	0.0	0.2	0.0	0.5	0.5	0.0	0.0
Isopoda, Asellidae				0.0	0.0	0.0	1.3	11.0	0.0	0.5	0.0
Megaloptera, Sialidae				0.5	0.0	0.0	0.5	0.0	0.0	0.3	0.0
Nematomorpha				0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Nematoda				0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Oligochaeta				0.0	5.5	1.8	3.3	0.5	1.5	0.0	0.3
Trichoptera				1.0	2.0	0.8	2.5	1.5	0.5	1.0	2.8
Brachycentridae				0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Helicopsychidae				0.5	0.5	0.3	0.8	1.0	0.0	0.0	0.0
Hydropsychidae				0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
Limnephilidae				0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Molannidae				0.5	1.0	0.3	0.7	0.0	0.0	0.0	0.0
Polycentropodidae				0.0	0.0	0.2	1.0	0.5	0.0	1.0	0.3
Unionoida				0.0	5.5	1.3	1.5	1.5	0.5	1.3	0.3
ABUND (No./site)				72	135	81	149	90	30	95	67
% EPT				6.9	7.0	6.2	8.4	5.0	5.1	5.0	6.4
TAXA RICHNESS	11	19	19	24	17	9	16		16		

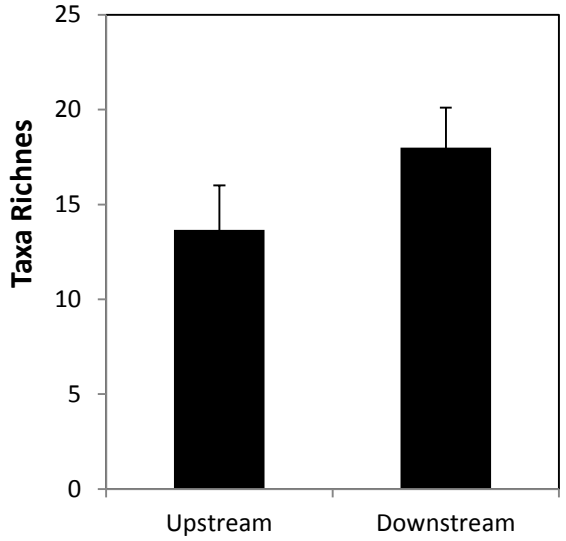

Figure 6. Mean (+SE) taxa richness of macroinvertebrates surveyed in upstream and downstream reaches of the Little Rapids, 2013.

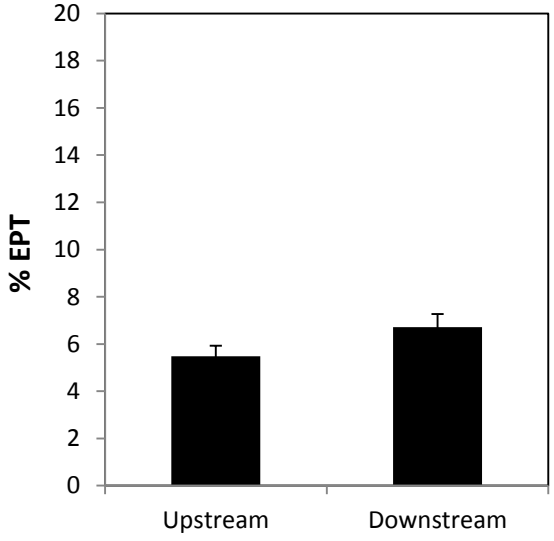

Figure 7. Mean (+SE) EPT Index of upstream and downstream reaches of the Little Rapids, 2013.

Water Quality & Habitat

TSS concentrations ranged from 0.12 mg/L to 2.07 mg/L, but all values were low (Table 4). TSS was significantly higher in the downstream reach averaging 1.60 mg/L compared to 0.17 mg/L upstream (t-test; $t=3.993$, $p<0.005$).

Channel cross-section surveys indicated that upstream (cross-section 1) and downstream (cross-sections 2-4) were generally dominated by fine sediments (Figure 8). Less than 25% of the substrate was course substrate suitable for lithophils in cross-sections 1 and 3. In contrast, the substrate in cross-section 2, the first transect downstream of the causeway and culverts, contained over 60% of gravel and cobble.

Table 4. Total Suspended Solids (mg/L) measurements taken at transects downstream (1-5) and upstream (6-8) of the causeway.

Transect	Mean TSS (mg/L)	SE
1	1.51	0.61
2	1.10	0.30
3	2.07	0.72
4	1.13	0.31
5	1.39	0.51
Downstream	**1.60**	**0.28**
6	0.12	0.03
7	0.16	0.06
8	0.21	0.06
Upstream	**0.17**	**0.03**

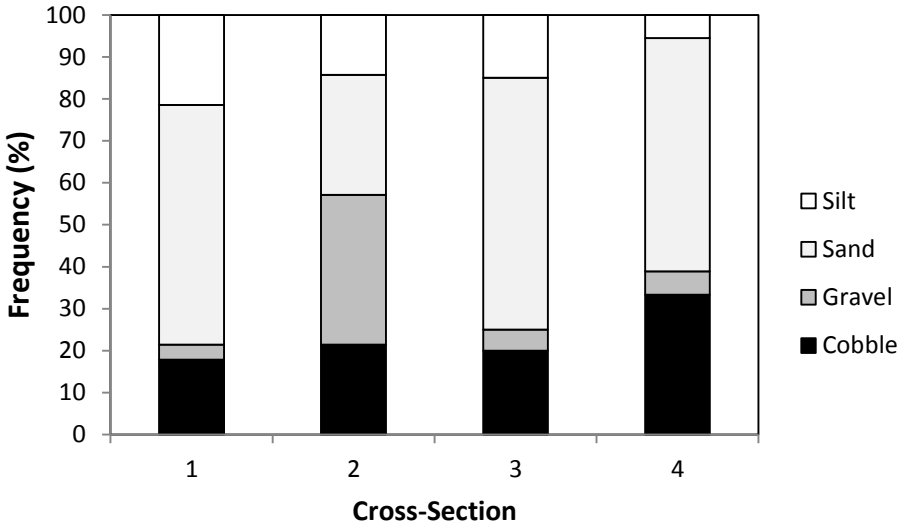

Figure 7. Frequency of occurrence of substrate types (silt, sand, gravel, and cobble) across four cross-sections surveyed in the Little Rapids, 2013. Cross-section 1 was located upstream of the causeway and 2-4 were located downstream.

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