Final Report

To

VHB Incorporated
101 Walnut Street, Watertown, MA 03472

for

Eversource Energy
Box 270
Hartford, CT 01641

Title: Evaluation of fish use and passage at the Owens Pond Fishway, Wentworth Farm Conservation Area, Amherst, MA

By

Boyd Kynard, Brian Kynard, and Campbell Morgan
BK-Riverfish, LLC, 28 Echo Hill Rd., Amherst, MA 01002

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Summary

From late-May to mid-November 2015, we evaluated the Owens Pond Fishway for providing fish habitat and fish passage. The fishway is a step-pool design with a 4% slope and rubble-boulder substrate throughout. It is an artificial stream connecting the pond to the Fort River drainage. We used an electroshocker to sample for fishes using the fishway and we monitored up- and downstream fish passage at the top of the fishway with underwater video. We found the fishway successfully provided habitat during spring-fall for diverse fish species (485 fish representing 10 species and six Families). Snakes were common in the fishway in Spring and Summer (when small forage fish were most abundant), and frogs were abundant in the Fall. The fishway successfully provides a downstream emigration route for year-0 juveniles of two fish species that spawn in the pond. Many year-0 Pumpkinseed Sunfish (P) left the pond and moved downstream in the fishway during May and June, and similarly, many year-0 Largemouth Bass (LMB) moved downstream in July. The tens to hundreds of these species we observed on a sample day during May-July (peak of fish descent from the pond) likely represents thousands of fish during their total movement period. These large numbers suggests the pond is a major source of year-0 P and LMB to the Fort River drainage, and perhaps, to the Connecticut River. Only 20 fish (four species) ascended the fishway (75% or 15 fish were year-0 P (nine fish) and year-0 LMB (six fish), which could be fish returning to their natal site. The few fish ascending the fishway may be related to a lack of behavioral drive by fish to ascend or to elements of fishway design. When the fishway was designed, there was no information on species or size of fish that would use the fishway. The present study found only small fish in the fishway. Swimming ability is limited for small fish and several design features of the fishway may provide suitable habitat and channel stability, but create hydraulic conditions that are difficult for fish to ascend. The present semi-natural step-pool fishway provides fast water and pool habitats; thus, it provides aquatic habitat diversity and freshwater fish used all available habitats. The present fishway is a great improvement for fish and wildlife compared to the previous situation.

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Introduction

In many small 3-4 order tributary streams in the northeast USA, particularly in New England states, there are thousands of barriers to migration of riverine fishes. Many dams will be removed, restoring an un-segmented stream course (Heinz Center 2002; Magilligan et al. 2016). However, some barriers will remain due to historical or economic factors. Providing a fishway at these barriers for migrating fish is the recommended practice by state and federal agencies. A fishway will not restore a dammed stream to the natural ecological conditions below the dam, but a fishway can remove the barrier to fish migration, allowing up- and downstream natural migrations by fish, and a restoration of semi-natural connectivity for fish (and mussel) communities.

Using semi-natural bypass channels and fishways to allow fish to pass dams or other stream barriers is widespread in Europe (Jungwirth et al. 1998). However, this technology only recently came to the USA and the best prescribed methods are still being studied (Franklin 2009).

Using a fishway to connect a pond to the downstream drainage area is common for diadromous Alewife in eastern Massachusetts that migrate upstream from the sea and spawn in coastal freshwater ponds (Hartel et al. 2002). However, we could find no example of this technique being used at an inland pond with native and introduced freshwater fish. Thus, a study of the Owens Pond fishway would provide useful information on freshwater fish movements, habitat use, and fish passage to pond and stream management agencies.

The semi-natural channel-fishway designed by VHB (Fig. 1) is a mitigation project for Eversource Energy. It was installed in 2013 at the Owens Pond outflow to the Fort River drainage on the Wentworth Farm Conservation Area, Amherst, MA. The design is a geomorphic channel using the widely accepted design of Rosgen (2007). The channel has not been evaluated for providing fish passage nor for providing habitat to fish, amphibians, and reptiles.

This Final Report provides results of our evaluation conducted during 2015. Goals of the evaluation follow: 1) record water temperature and water depth near the passage area and examine relationships between passage timing and these environmental factors, 2) identify the fish species and lower vertebrates (amphibians and reptiles) using the aquatic habitat in the fishway, and 3) provide seasonal information on fish passage (upstream movement of fish through the fishway into the pond) and emigration of pond fish (downstream movement from pond through the fishway).

Objectives

I. Monitor water temperature and water depth at the top of the fishway during Spring-Fall 2015.

2. Determine fish species, size, abundance and life stages in the fishway (top of the fishway at the pond) in Spring-Summer-Fall during low and high water discharge. Record presence of amphibians and reptiles as incidental observations.

3. Determine the number and species of fish passing the cutoff wall (top) of the fishway and examine the correlation between temperature, water depth, and number of ascents. If no fish ascend past the cutoff wall into Owens Pond during any flow conditions monitored, instead determine the ascent attempts of fish in the top and in a mid-length pool and characterize water velocity in the ascent flow in the heads of pools and across the cutoff wall.

Study Area

The fishway is a semi-natural channel (Jungwirth et al. 1998; Rosgen 2007) with seven step pools or cross rock vanes (VHB design drawings, April 2013). Fig. 1 shows an overhead view of the constructed fishway (174 ft 4 inches long (53.2 m) from the top of the fishway at the overflow cut-off wall at Owens Pond to the downstream end of Reach 1, the downstream limit of our fish sampling.

The large boulder steps forming the upstream edge of each pool naturally divide the fishway into 7 reaches (labeled 1-7 on Fig. 1). Each step has a head of 6-9 inches. Also on Fig. 1 are the following important locations: underwater camera location (X) used to monitor fish passage up- and downstream at the v-notch in the cut-off wall (CW), and the location of the temperature-water depth logger (L).

Fig. 2 (a, b, c on three separate pages) shows two pictures of Reaches 1, 5, and 7. These pictures show the habitat and reach variability in the fishway, from Reach 1 (with a downstream, not an upstream pool at the boulder step, Reach 5 (typical of Reaches 2, 3, 4, and 6 with a riffle-run downstream reach ending at an upstream pool and boulder step), and Reach 7 (atypical reach with no pool, but instead is a riffle-run reach to the boulder at the cutoff wall). (A pool was designed and constructed just downstream of the boulder (one of several boulders making a reverse horseshoe), but the pool was filled by rubble by 2015 (2 years). The picture in the lower one-half of each page shows the fast water riffle-run reach and the picture in the upper one-half of the page shows a pool and boulder step that forms the upstream limit of the reach. Pictures were taken when the water depth in the middle of the v-notch of the cutoff wall was 2 inches deep. Water depths were similar during video and fish captures.

Methods

Water depth and water temperate

Prior to sampling the fishway, we installed an Onset data logger (Hobo U2OL; 0.1% accuracy) in Owens Pond (location – L indicated on Fig. 1). This site was the closest location to the top of the fishway that provided security from vandals. The location was close enough to the cut-off v-notch that passes water from the pond into the top of the fishway to monitor general changes in water depth and water temperature during the entire study. Installation date was 18 May 2015 (2 days before the first video sample); removal date was 18 November 2015 (day of last electroshocking sample). The data logger recorded temperature and depth each 2 h, providing a daily mean for each factor. We used a measured water depth over the logger and a measured water depth in the center of the v-notch to convert logger water depths to water depths in the v-notch of the cutoff wall, where fish passed moving up- or downstream in the fishway (thus, the location where we monitored fish passage). Additionally, we monitored water depth in the center of the v-notch of the cutoff wall on each day we monitored fish passage at the cutoff wall.

Fish in the fishway and habitat use

On the day following a video sample, we electroshocked the entire fishway with a SAMUS 725G electroshocker to capture the fish species that were in the fishway (and available to pass upstream or that had passed downstream). Characteristics of the shocker follow: Frequency = 50Hz, pulse duration = 0.05 ms, voltage = 1.32V (UI), power = 100-200 wtts. A block net was installed across the downstream limit of each reach prior to electrofishing to insure discrete sampling of the targeted reach from block net to step pool. During surveys, we also recorded the occurrence of amphibians (frogs) and reptiles (snakes) visually observed in the fishway and identified them using (Conant, 1958).

In those sample reaches with a long riffle-run downstream of the pool, we sampled the riffle-run separately from the pool by using a block net to separate the two habitat types (riffle-run vs. pool). This allowed us to characterize fish species captured in each habitat type. Differences within a fish species for observed use vs. an expected 50:50 frequency in each habitat type was analyzed by Chi-square tests.

During sampling when we observed a fish movements were indicated a disorientation in the electrical field, we immediately dip-netted it to remove it from the fishway water. Fishes from a reach of interest were held in a 5-gal bucket containing fishway water, which was changed periodically. Typically, we sampled 1-2 reaches, and then, stopped to process fish. During processing, the water in buckets was replaced by Owens Pond water and Start Rite (an electrolyte restorative for fish) was added to the water. After processing, we returned fish to the fishway reach where they were captured.

For captured fish, we identified each to species using Hartel et al (2002), and measured each for TL (mm) and body weight (g). We also noted fish mortality and for some species, noted adults in breeding colors. For some species, we could easily characterize fish to life stage (juvenile vs. adult). However, for species that were small as adults (like shiners), we did not identify whether fish were juveniles or adults as we would have to kill them to examine their gonads for maturity.

Fish captures are usually shown by date of capture. However, fish may also be grouped by capture date into three seasons: Spring (22 May to 21 June), Summer (22 June to 21 September), and Fall (22 September to 18 November).

Fish passage

We monitored fish up- and downstream movements at the top of the fishway into Owens Pond from May to November by placing a GOPRO 3 camera to view at an angle underwater across the approach to the cut-off wall v-notch, the only passage route (Fig. 3). The white plastic wall directly across from the camera provided a uniform background to see fish in low light. The wall was a 1 x 4 ft piece of ¼ inch white foam-board pvc held upright by a metal pole at each end. Some fish moved downstream into the v-notch and then returned upstream into the pond (a down-up movement), so we oriented the camera to view slightly downstream across the v-notch to see if fish moved past the v-notch and into the fishway. Distance of camera to viewing wall was adjusted to be able to produce and image of the fish large enough to allow a reviewer to identify the fish to species or Family. After each video monitoring session, we removed the white wall, leaving no trace of our activities.

On sampling days, we monitored fish from dawn to sunset using the sunset-sunrise calendar of Onset, Inc.. Preliminary visual observations in the fishway found no fish in the day, when illumination level was high. Thus, we thought monitoring from dawn to sunset should capture movements of fish moving early and late in the day during low light intensity, the time many fish species migrate (Lucas and Baras 2001). We would like to have monitored fish movements at night, but funding limitations prevented this because it meant having a person at the site overnight. After the monitoring system was installed, we stayed away from the site until camera batteries had to be changed (5-6 h intervals).

Because the water at the monitoring site was clear most days and shallow (<12 inches deep), we visually observed schools of fish in the pond margin approaching the cut-off wall. Sometimes we observed schools of fish moving in relation to the monitoring site. We recorded these observations as notes.

In a video lab in the ECO Department, UMass, Amherst, we visually viewed the video recording fish as 1) moving upstream, 2) moving downstream, or 3) moving downstream-upstream. The total number of fish in these three movement categories was calculated for each sampling period. The number of sampling periods for each season follow: Spring (3 samples), Summer (3 samples), and Fall (4 samples). We analyzed number of each species or Family observed by sample date. Although most fish could be identified to species using the video image, electroshock fish samples in the fishway were helpful for identifying the species present on the video. For example, the video sample may record just Sunfish, but the electroshock sampling the following day may only capture Pumpkinseed Sunfish (P), so the Sunfish observed by video was most likely a P. Lastly, we identified the time of day fish moved up- or downstream and for the dominant species, determined the mean and range of movement times.

We analyzed the frequency of occurrence of three lotic species between two downstream reaches and the two most upstream reaches to indicate if the small fish have difficulty ascending the fishway. Thus, we tested the null hypothesis of no difference in frequency of occurrence of the three fish species between the bottom two reaches (1-2) vs. the top two reaches 6-7.

Results & Discussion

Water temperature and water depth

The logger was not vandalized and recorded water temperature and water depth during the entire study. Fig. 4 shows water depth variation in the v-notch of the cutoff wall and water temperature at the top of the fishway during the study.

Temperatures when sampling began were already typically > 18 °C, so we did not sample the fishway (or monitor fish passage) during cooler water temperatures (or higher discharge levels) typical of Spring. Temperatures during late-May and June during the peak downstream migration of P from the pond were 20-24 °C and temperatures in mid-July, when the peak downstream movement of Largemouth Bass (LMB) occurred was warmer, typically 24-28 °C.

Measurement of water depth in the v-notch on 10 days of video recording found all of our video passage samples were taken during low flows (mean, 2.8 inches ; range, 1.3-5 inches). Thus, the lack of high water flow from the pond eliminated the possibility of comparing fish passage during low vs. high flows. Fish passage observations in the fish passage section all reflect passage during low flows into the fishway, which appear typical for most of the time (Fig. 4).

Fish in the fishway and habitat use

We captured 484 fish in the fishway from May to November (Table 1). Species from six families were captured (most abundant to least): Centrachidae, Umbridae, Cyprinidae, Ictaluridae, Catostomidae, and Esocidae. P was the most abundant species, and they were present on all sample days, except in November. P abundance peaked in May and early-June and was greatly reduced during the remainder of sampling. As found by video monitoring, P were leaving the pond during May and June (see Video Section) and entering the fishway, where we sampled them. Juvenile LMB was only captured in July and August (one in September; Table 1), and video monitoring also found many LMB emigrating from the pond during July (See Video Section). More juvenile P remained in the fishway after the peak emigration than LMB, which must have quickly passed downstream and out of the fishway. Spottail Shiners (SS) and Common Shiner (CS) were common in the fishway during June-August. Abundance of all species was greatly reduced from September to November, indicating no major use of the fishway (or likely descents or ascents by any species) in Fall. No species seemed likely to overwinter in the fishway. The fishway likely is colonized each Spring-Summer by upstream migrants from the Fort River drainage and downstream migrants from the pond.

Size and life stage of the species captured in the fishway are shown in Table 2. Only juveniles were present for those species that are large in size as adults (like P, LMB, White Sucker (WS), Brown Bullhead Catfish (BB), and Chain Pickerel (CP). Shiners and dace were the size of adults, but some may have been large juveniles. Some species only had YOY present: P, BB, and LMB. We did not determine Condition Factor of fish, but observations indicate body condition of all species was normal, indicating fish were obtaining sufficient forage and growing normally in the fishway or pond, before entering the fishway. Almost all P were parasitized on their fins by leeches. Year-0 P originated from the pond and were likely parasitized there. However, year-0 LMB also originated in the pond and zero were parasitized by leeches. Wonder why?

Our captures in late-May and June of many year-0 P supports the video monitoring, which found a major downstream movement by P from the pond in late-May and June (See Video Section). We also observed many year-0 LMB leaving the pond. The juvenile CP and few year-0 BB and some of the shiners we captured in the fishway may also be fish that emigrated downstream from the pond as all these species are in the pond (B. Kynard unpubl. data).

Stream or lotic species were represented by juvenile white sucker, adult or large juvenile shiners, and adult Central Mudminnow (CM). This species was the most abundant stream fish in the fishway. Thus, the fishway provided stream habitat for adults or juveniles of several families of diverse lotic fishes.

Interestingly, the use of fast water without aquatic vegetation is unusual for the non-native CM, which according to Hartel et al. (2002) uses slow or ponded water with abundant vegetation. The present study indicates CM has a broader ecological niche than previously thought. Also, in June collections, many adult CM males were in breeding colors, and females with eggs were also identified, so the fishway likely provides spawning habitat for CM. This is new information on spawning habitat for this fish. The fishway habitat is entirely constructed of rubble-boulder substrate, which may be excellent habitat for CM to avoid predation by foraging snakes. With their cigar-shaped bodies, CM can more easily seek shelter from snakes under large rocks than can stream fish, like shiners or P, with flattened wide bodies.

Riffle-run vs. pool use for the six most abundant fish species is shown in Table 3. P, CM, SS, and LMB occurred with similar frequency in both habitats. CS and BB had significantly greater frequencies in pool than in riffle-run habitat. Thus, the most abundant species in the fishway (CM) used both fast water and pool habitats.

Frequency of amphibians and reptiles in the fishway is shown in Table 4. Snakes (water snakes were most common, but corn and milk snakes were also identified). Snakes were most abundant in May and June, when year-0 P (and fish in general) were abundant in the fishway (Table 1). Later in summer, P, other fishes, and snakes were rare, suggesting snakes left the fishway when forage fish decreased. Although many year-0 LMB entered the fishway in June (see Fish Passage Section), we captured only a few, so they did not remain in the fishway like P, and thus, did not likely provide forage for snakes. It would be interesting to examine snake stomachs to determine if in May and June they are foraging on P or on CM.

Fish Passage

***Descent from Owens Pond into the fishway*. –** Schools of year-0 P were observed swimming around the shallow margin of the pond, and sometimes, individuals at the outside margin entered the fast water near the v-notch and were swept downstream into the fishway. Thus, all of the large number of P moving downstream into the fishway (Table 5) are not the result of a directed downstream emigration, but instead seem to be an unscheduled movement into the fishway and an inability (or behavioral drive) to ascend the fishway and return to the pond (although some P did ascend the fishway and return to the pond – see Table 6). Table 5 also shows the large number of downstream-upstream moves by LMB in July, which indicates at least some of the year-0 LMB may be involuntary migrants. The fishway serves as exit route for these fish spawned in the pond, reduces the number of year-0 P and LMB in the pond, and reduces competition among year-0 fish that remain. P and LMB represent the dominant downstream movement of fish from the pond. The few year-0 BB, juvenile CP, and likely adult CS that were captured in the fishway also may be downstream migrants from the pond.

***Ascent from the fishway into Owens Pond*. –** Table 6 shows the fish species ascending the fishway by date. In 131.5 hours of video observations, only 20 fish were observed ascending the fishway. Nine juvenile P ascended the fishway and most were in August and September (possibly after they had increased total length and swimming ability). Six juvenile LMB ascended the fishway, two in July and four in September. Thus, most ascents were done in late-summer. Only one unidentified species of shiner and one CS (probably, both were CS) ascended the fishway. It is interesting that a juvenile CP ascended the fishway. CP are a major predator in the pond and the species prefers lentic or pond waters (Hartel et al. 2002). This study provided no data to indicate if the P, LMB, CS, or CP ascending the fishway were actually returning to their natal pond, but this could be the case.

Only 20 fish (all species) ascended the fishway during our observations and the daily mean temperature on the day of ascent ranged from 18 °C to 27 °C (Table 7; Fig 1). So, there was no obvious relationship between temperature and migration peak of fish. However, 15 of the 20 fish (75%) ascended on 5 August or 10 September (late-summer), when temperatures were 26 °C and 27 °C, respectively. In summary, while the sample size of ascending fish is small, our observations show that from 20 May to 17 November, most fish ascended the fishway in late-Summer at warm temperatures, 26-27 °C. We missed recording possible ascents during most of the Spring when water temperatures were cooler than 18°C.

The connection between a semi-natural stream (fishway) and a cutoff wall is poorly researched for providing fish passage and this is the site where ascent fails for fish at many fishways (B. Kynard pers. obs. at semi-natural bypass fishways in Germany and Austria). Observations during the present study indicate the horseshoe boulder design at the cutoff wall of Owens Pond Fishway is likely a problem for fish ascent and alternatives should be considered in the future. .

***Timing of descent from the pond and ascent into the pond*. –** Decent time from the pond of 22 P on 20 May occurred at a mean time of 1517.2 h (range, 1400-1800) and on 3 June, decent time for 81 P was a mean of 1412.5 h (range, 0700-1700 h). On 15 July, decent time of 79 LMB was a mean time of 1402.5 h (range, 0900-2000 h). Thus, neither species departed the pond in the earliest morning hours, and most downstream movement peaked in the early afternoon hours.

There was no obvious pattern for timing of ascents to occur in the morning, mid-day, or afternoon--fish ascended at all times of the day. Ascent times for P follow: (0600-0700 h – n = 4; 0900 h – n = 1; 1700 h –n = 2). For LMB, ascent times were 0600-1000 h – n = 2; 1200 h - n = 1; 1500-1700 h – n = 3. The one CS ascended at 1400 h; the one CP ascended at 1000 h.

***Ascent within the fishway*. –**Table 7 shows the number of three stream (lotic) fish species, CM, CS, and SS captured in Reaches 1-2 and Reaches 6-7. Due to the small number of observed fish, only the CM observations could be statistically compared. In Spring, there was a significantly greater number of CM in the two lower reaches than in the two upstream reaches ($P < 0.01$) and the same pattern existed in the Fall, but numbers were small. CS also had more fish in the bottom than at the top in Spring. Because habitat is similar between the bottom and upper reaches, the difference may indicate difficulty by CM and CS ascending the fishway steps. Zero CM ascended into the pond. While SS were more numerous in the bottom reaches in Spring, the observed and expected 50:50 frequency distributions were not significantly different. There was no difference in Spring for the number of SS or CS in the bottom reaches vs. the top reaches (P

>0.05), although many more SS were in the bottom reaches than in the top reaches (Table 7). During Summer and Fall, few SS were in the fishway, whereas the number of CS in the fishway was low but similar Spring and Summer. CS likely descended out of the fishway in Fall as only one CS was captured in Fall. The capture data indicate a strong seasonal component to using the fishway by shiners and a poor ascent success into the pond.

Velocity of flow over the v-notch or at steps in the fishway may be a barrier to small fish ascent. Velocity at 2 inch water depth in the center of the v-notch of the cut-off wall was 53 cm/s. The 2 inch depth is similar to the 2.8 inch mean water depth in the v-notch during May-November and during the Spring-Summer fish migration period (see water temperature and depth section; Fig. 4). Further, velocities in water spill over the rock steps was similar or greater than the velocity in the v-notch -- velocity (cm/s) in the six steps measured in the center of the spill, 2 inches upstream from where spill entered the pool follow: step 1 = 55; step 2 = 40; step 3 = 77; step 4 = 55; step 5 = 60; and step 6 = 67. Table 2 (mean body lengths of fish species) plus v-notch velocity, indicates most fish species must have a swim speed > 1-1.5 body lengths/s to ascend the v-notch and step spill velocities. Selection of one or two water spills at steps is also important to fish passage. In the present fishway, the spill water is split in one-half of the steps (steps 1, 2, 4) producing two small shallow spills (example, Fig. 2a, b). This makes it difficult for small fish to ascend in the low flows typically present (Fig. 4). In fishways with low flow, there should be only one spill at all steps. Lastly, there are no studies on swimming ability of any of the small fish using the Owens Pond Fishway (or any other fishway type in Massachusetts), although this information is obtainable in a fish behavior-passage lab with a hydraulic flume like the BK-Riverfish lab in Erving, MA. Information on swimming ability of small fish would contribute greatly to the success of designing future fishways, particularly ones that connect a pond to an artificial stream and creates upstream fish passage of small fish.

Recommendations

We recommend the Amherst Conservation and Development Department institute a regular survey of the fishway. The objective of surveys would be to reduce the debris problem and to identify maintenance issues in the fishway, like removal of rubble deposited in pools. BK-Riverfish,llc offers to work with Amherst to develop a survey.

Beavers in the pond brought mud and debris to stop the pond draining into the fishway during the Spring. Debris continued to drift onto the v-notch during all months. We cleared debris from the v-notch during surveys and talked with many hikers that removed debris when they hiked almost daily past the fishway. However, none realized the value of what they did nor that the small stream at the pond drainage was a fishway. Removal of debris is necessary for upstream and downstream fish passage to succeed. We recommend the Amherst Conservation and Development work with the appropriate Town Department to remove debris.

Agencies associated with the fishway should be recognized to the public for their conservation work. We recommend the creation of a Fishway Poster be placed on the existing kiosk of the Wentworth Conservation Area. This poster would describe the fishway, the agencies involved, give brief results of the evaluation, and emphasize the need for hikers to remove debris when they find it at the v-notch.

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Tables

Table 1. List of 10 fish species and the number captured in the fishway by sample date. Order of species across page is their abundance rank, greatest (left) to least abundance (right). Key to species in order of abundance: Pumpkinseed Sunfish = P; Central Mudminnow = CM; Spottail Shiner = SS; Common Shiner = CS; Brown Bullhead Catfish = BB; Largemouth Bass = LMB; White Sucker = WS; Blacknose Dace = BND; Golden Shiner = GS; and Chain Pickerel = CP.

Date			**Species List**								
	P	**CM**	**SS**	**CS**	**BB**	**LMB**	**WS**	**BND**	**GS**	**CP**	**Totals**
22-May	70	16	0	1	0	1	4	3	4	0	99
4-Jun	59	39	11	11	1	0	0	3	0	0	124
17-Jun	35	16	61	0	0	0	0	0	0	2	114
16-Jul	3	9	0	18	0	8	0	0	0	0	38
6-Aug	3	8	2	2	13	10	0	0	0	0	38
11-Sep	5	8	0	1	7	0	0	0	0	0	21
24-Sep	4	8	0	0	5	1	1	0	0	0	19
8-Oct	6	4	0	0	3	0	1	0	0	0	14
22-Oct	7	1	0	0	2	0	1	0	0	0	11
18-Nov	0	5	0	1	1	0	0	0	0	0	7
Totals	192	114	74	34	32	20	7	6	4	2	485

Table 2. Abundance and size of the 10 species captured during electro-sampling in 2015, all seasons combined. Species name abbreviations follow: chain pickerel (CP), spottail shiner (SS), brown bullhead catfish (BB), largemouth bass (LMB), blacknose dace (BND), white sucker (WS), common shiner (CS), golden shiner (GS), central mudminnow (CM), pumpkinseed sunfish (P). Species are ranked from top (most abundant) to bottom.

Species	N	Mean TL - SD(mm)	Mean wt-SD (g)	Life Stage
P	192	63.5-1.0	4.4-0.3	Juvenile
CM	114	57.7-0.8	2.9-0.1	Adult
SS	74	67.9-1.1	2.9-0.1	Adult
CS	34	72.1-2.1	3.5-0.3	Adult
BB	32	50.6-3.5	2.2-0.5	Juvenile
LMB	20	49.6-3.1	1.9-0.4	Juvenile
WS	7	115.2-10.1	16.7-4.0	Juvenile
BND	6	59.8-4.6	2.5-0.3	Adult
GS	4	84.3-9.9	7.5-2.4	Adult
CP	2	148.0-81.5	37.5-35.5	Juvenile
	N = 485			

Table. 3. Riffle vs. pool use comparison by species. Not all species or individuals of a species were observed. Chi-square significance between the observed frequency vs. an expected 50:50 frequency is indicated in Significant column.

Species	# in Riffle	# in Pool	Significant.
Pumpkinseed Sunfish	78	115	No
Central Mudminnow	55	58	No
Spottail Shiner	39	25	No
Common Shiner	5	29	Yes
Brown Bullhead Catfish	2	30	Yes

Table 4. Number of amphibians and reptiles observed in the fishway by date.

Date	Snakes	Turtles	Frogs
22-May	4	0	2
4-Jun	3	1	0
17-Jun	2	0	2
16-Jul	3	0	11
6-Aug	2	0	2
11-Sep	0	1	1
24-Sep	0	0	5
8-Oct	0	0	10+
22-Oct	0	0	10+
18-Nov	0	0	10+

Table 5. Downstream and down-upstream movements by fish species at the Owens Pond fishway by date. Downstream moves = swim into fishway; down-up moves = move down from pond into or near v-notch of fishway, then return into pond. Species = Sunfish (Pumpkinseed Sunfish or unknown sunfish); LMB = Largemouth Bass; Common Bass; CS = Common Shiner.

	Downstream Move			Downstream-up Move		
Date	Sunfish	LMB	CS	Sunfish	LMB	CS
30-May	22	0	0	7	0	0
3-Jun	81	1	0	7	0	0
16-Jun	1	2	0	3	0	0
15-Jul	24	79	0	0	54	0
5-Aug	5	0	0	9	3	0
10-Sep	4	0	1	0	2	0
7-Oct	1	0	0	0	0	0
22-Oct	0	0	0	0	0	0
17-Nov	0	0	0	0	0	0

Table 6. Date and fish (N =20) ascending the fishway to the top. Species ID follow: Sunfish (Pumpkinseed Sunfish or Unknown sunfish); LMB = Largemouth Bass; Chain Pickerel = CP; Common Shiner = CS; Shiner = species unknown; Unknown = Family/Species unknown.

		Fish Species ID				
Date	Sunfish	LMB	CS	CP	Shiner	Unknown
20-May	0	0	0	0	0	0
3-Jun	0	0	0	**1**	**1**	0
16-Jun	**1**	0	0	0	0	0
15-Jul	0	**2**	0	0	0	0
5-Aug	**4**	0	**1**	0	0	0
10-Sep	**4**	**4**	0	0	0	**2**
7-Oct	0	0	0	0	0	0
21-Oct	0	0	0	0	0	0
17-Nov	0	0	0	0	0	0

Table 7. Number of three stream (lotic) fishes in Reaches 1-2 (bottom of fishway) vs. Reaches 6-7 (top of fishway) during Spring, Summer, and Fall. Central Mudminnow = Cm; Spottail Shiner = SS; and Common Shiner = CS.

Species	**Spring** 1 & 2	**Spring** 6 & 7	**Summer** 1 & 2	**Summer** 6 & 7	**Fall** 1 & 2	**Fall** 6 & 7
CM	43	4	12	9	14	1
SS	31	17	2	0	0	0
CS	6	1	5	7	1	0

Figures

Fig. 1. Plan view of fishway showing reaches 1-7; CW= cutoff wall, L = temperature/depth logger location, and X is location of video camera.

Fig. 2a. Reach 1 (deep slow run bottom picture) and rocky riffle-run (top picture).

Fig. 2b. Reach 5 showing Riffle-run (bottom picture) and pool (top picture).

Fig. 2c. Reach 7 showing rocky riffle-run (bottom picture) and top of fishway at cutoff wall with the apex boulder of the horseshoe shaped boulder loop placed close to the cutoff wall (top picture).

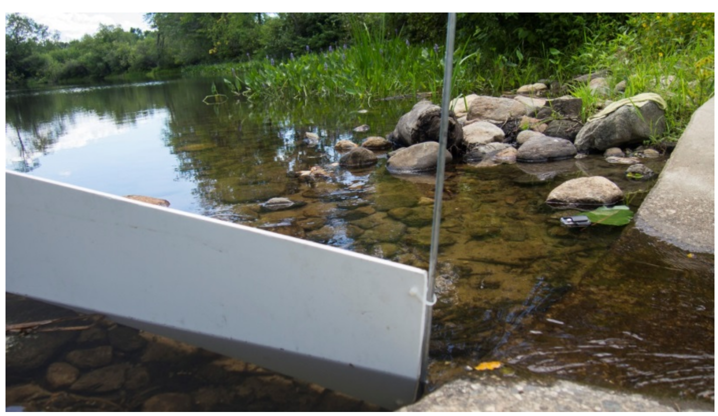

Fig. 3. White wall and camera setup for video monitoring fish moving past the v-notch in the cutoff wall (bottom right corner of picture).

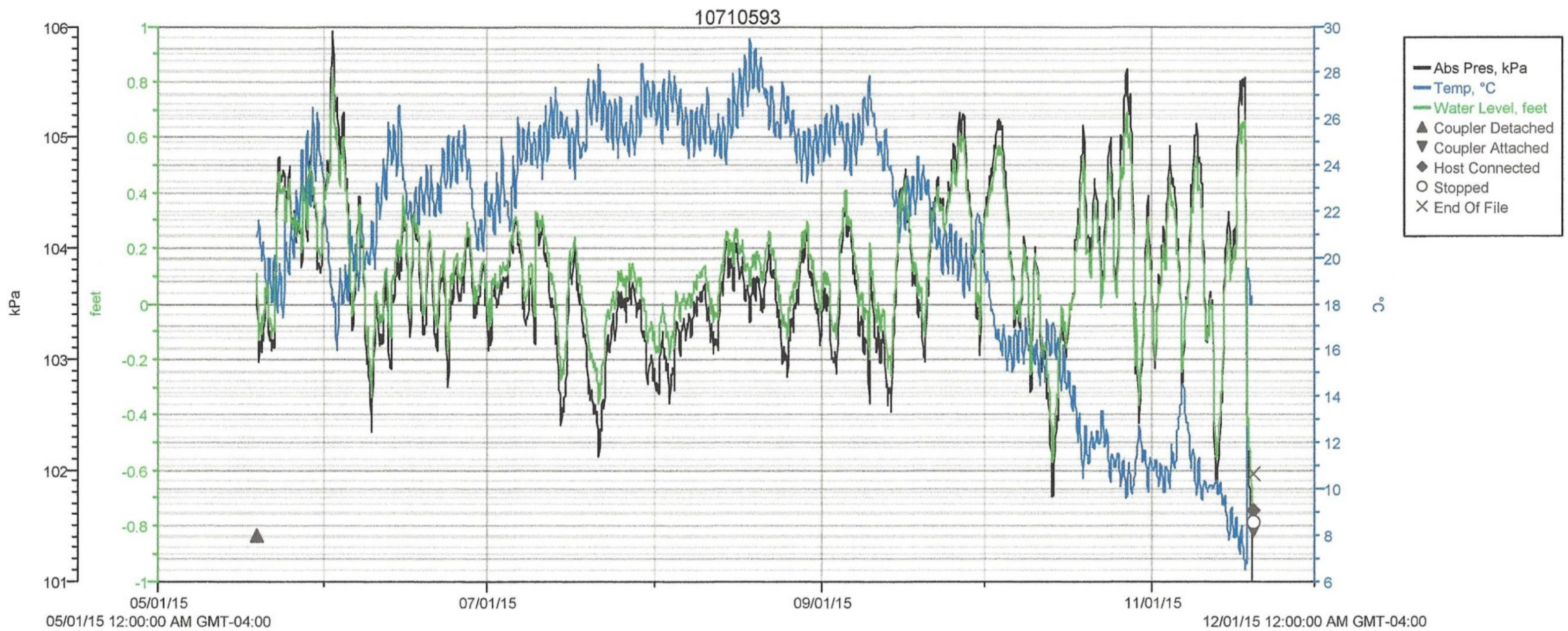

Fig. 4. Daily mean water temperature and depth in the cutoff wall v-notch during the study, 18 May-18 November 2015. Location of the depth logger is shown in Fig. 1.