Project Title:
An Annual Report Examining the Recovery of Diadromous Fishes in the Brandywine Creek, DE, 2020

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Abstract:

Recent coastwide assessments of multiple alosine species including Alewife, Blueback Herring and American Shad have suggested low levels of abundance persist coastwide for these fishes. However, the relative abundance of these species remains unknown in many small tributaries along the Atlantic coast that contribute to the coastwide stock. Further, impediments to fish passage along many of these tributaries, particularly in the northeastern United States including both historic, nonfunctional and currently used dams prevent fish passage of diadromous fishes that rely on freshwater reaches to successfully reproduce. In order to assess relative juvenile abundance as it relates to dam removal of American Shad in Brandywine Creek, a subtributary of the Christina River and the Delaware River, I lead a volunteer-based haul seine survey at multiple locations in Brandywine Creek above the site of a recently removed dam. Our findings demonstrate juvenile and adult American Shad have utilized habitat above the site of a former impediment only one year after dam removal. Further, these results suggest that as impediments to fish passage are removed, successful recolonization of historic habitat is occurring demonstrating the need for more barriers to be removed in order to enhance currently depressed levels of abundance along the coast by providing additional spawning habitat.

Introduction:

Since 2008, the state of Delaware river herring (Alewife and Blueback Herring) fishery has remained closed. However, a small American Shad fishery has persisted since then. Unfortunately, very little data are available to assess the current status of multiple alosine populations, including Alewife (*Alosa pseudoharengus*), American Shad (*Alosa sapidissima*), Blueback Herring (*Alosa aestivalis*), and Hickory Shad (*Alosa mediocris*) in the greater Delaware River watershed. Furthermore, Brandywine Creek had eleven dams (ten presently) impeding diadromous fish passage in this tributary to the Christina River. Brandywine Creek begins in Chester County, Pennsylvania, but traverses through the center of Wilmington, Delaware functioning as an urbanized watershed which has suffered environmental impairment in the past. To address this data deficiency and critically evaluate fish passage as dams are removed, we designed and implemented a juvenile American Shad sampling survey that mirrors the sampling frequency and design of another state survey in order to align our sampling methodology with that of the State of Delaware, Department of Natural Resources &

Environmental Control, Division of Fish & Wildlife, Fisheries Section (hereafter DFW; Park & Stangl 2020).

In building a complimentary survey, we have collected valuable data that can be used in other applications such as coast wide assessments of spawning stock biomass, thus enhancing our overall utility to state (DFW), regional (e.g. Atlantic States Marine Fisheries Commission, Delaware River Basin Commission) and national (NOAA, USFWS) fisheries managers and stakeholders. However, we have designed our seine survey to integrate community involvement of local underrepresented communities by soliciting local volunteers thus serving as a broader effort to aid in environmental justice. Further, these relative abundance data will help support ongoing American Shad and river herring restoration efforts and inform planners and managers about the relative production in stretches of Brandywine Creek, supporting the overall mission of multiple organizations including Brandywine Shad 2020, DFW, NOAA and the USFWS. The objectives of our study were to (1) Quantify relative juvenile abundance of alosine fishes including Alewife, American Shad, Blueback Herring, and Hickory Shad, (2) Characterize size frequency for observed alosine fishes, and (3). Estimate relative abundance of other resident and migratory fishes.

Methods:

We sampled with two tows at one location above and below Dam #2 in Brandywine Creek to quantify relative abundance of juvenile alosine fishes in Brandywine Creek using a similar modified Swingle Method (Park & Stangl 2020; Swingle 1956; Figure 1), where we anchored one end of the net and conducted a single arc through the water column. We sampled during the daytime, at a twice monthly frequency (every other week) from mid-July through mid-October with a 22.9-m long x 3.0-m deep haul seine consisting of 6.35-mm nylon netting. All fish were identified and enumerated to the lowest taxonomic level possible and released alive as soon as possible. For all alosine species observed, length data of a random subsample (n = 20) of each species was collected so that we could analyze trends in size frequencies by location and year. In order to validate our sampling methodology, we have compared the trends of our survey to those of the DFW surveys in the Christina River, and Brandywine Creek, as well as with the New Jersey Department of Environmental Protection juvenile Striped Bass seine survey at two locations directly across from the mouth of the Christina River, which collects information on alosine abundance.

Results:

We found juvenile and adult American Shad utilized habitat above the location of former Dam #1 near the Washington Street Bridge on Brandywine Creek in Wilmington, DE, USA. We collected 160 juvenile American Shad over a two-week period, with 159 fish documented in a single tow (Table 1). The average size of juvenile American Shad encountered was 77.3 mm TL (+/- 4.6 mm SD) on July 28, 2020 and 81.0 mm TL on August 11, 2020. The geometric mean of the juvenile catch at the station below Dam #2 was 0.510 (Table 2). We collected 8 adults at the

same location below Dam #2 location over two separate sampling dates. Average sizes of the adults encountered ranged from 436.0 mm TL (+/- 29.2 mm SD) to 447 mm TL (+/- 12 mm SD). Interestingly, all American Shad collected, were caught on the second tow of the day (Table 1). No juvenile or adult Alewife or Blueback Herring were collected in 2020. However, one juvenile American Eel (*Anguilla rostrata*) which was 205 mm TL, was collected above Dam #2 at the upriver sampling location. Additionally, 13 other species were collected among the two locations including Banded Killifish (Fundulus diaphanous), Bluegill (*Lepomis macrochirus*), Eastern Silvery Minnow (Hybognathus regius), Fallfish (*Semotilus corporalis*), Largemouth Bass (*Micropterus salmoides*), Mosquitofish (*Gambusia holbrooki*), Pumpkinseed (*Lepomis gibbosus*), Redbreast Sunfish (*Lepomis auritus*), Satinfin Shiner (*Cyprinella analostana)*, Spottail Shiner (*Notropis hudsonius*), Tesselated Darter (*Etheostoma olmstedi*), White Sucker (*Catostomus commersonii*), Yellow Perch (*Perca flavescens*; Table 3).

Discussion:

Restoring habitat for diadromous fishes is imperative to help rebuild and recover these species, especially under the context of ongoing climate change. Although fishing remains an important, and in many cases, dominant driver of population abundance, there is now substantial evidence that climate change and decadal variability affect fish and invertebrate populations (Perry et al. 2005). Those impacts can be positive as well as negative and successful fisheries management requires careful consideration of impacts that individual variables have on each species as well as potential multiplicative or synergistic effects on fisheries. As a functional group, diadromous fishes have been identified as one of the most sensitive groups to climate change and have been predicted to experience a negative directional impact from climate change projections (Hare et al. 2016). Rewilding or reopening available habitat will likely offset some of the negative consequences to these species by providing more available habitat to potentially colonize.

With the removal of Dam #1 on Brandywine Creek in 2019, roughly a half mile (Eichman 2019) of habitat was made available to diadromous species including American Shad to use for spawning and juvenile riverine residency. Our results represent the first known scientific documentation of juvenile American Shad moving above a 115-year-old dam in Brandywine Creek. Further, we observed adult American Shad using this habitat in addition to juveniles, demonstrating that multiple life history stages simultaneously benefit from impediment removal. American Shad historically migrated into freshwater stretches of rivers from Florida to Newfoundland (Bigelow and Schroeder 1953) and contributed millions of pounds of landings to commercial fisheries in the tributaries and coastal waters of the northwestern Atlantic Ocean (Scott and Crossman 1973; Haro & Castro-Santos 2012). Overfishing, pollution and impediments to fish passage have all been suggested to have contributed to the relative decline of diadromous fishes, however, the degree of significance for each of these parameters relative to the others remains unknown (Stevenson 1897; MacKenzie et al.; Haro & Castro-Santos 2012). Despite the relatively unknown scale impediments to

diadromous fish passage have on the population abundance of many species including Alewife, American Shad, and Blueback Herring, restoring fragmented habitat corridors via the removal of these obstructions coupled with the complete rewilding of river systems will enhance ecosystem performance (Brown et al. 2013).

Our survey was similar to other surveys in documenting the presence of juvenile American Shad in Brandywine Creek. However, we did not collect any other alosine species in our sampling efforts. In 2020, the DFW survey encountered 65 American Shad total at their lower Brandywine Creek sampling station below the site of former Dam #1, over seven sampling events. The DFW survey had a lower variability with more consistent smaller catches (e.g. $n \leq 7$), than what was observed in our study. The DFW Brandywine Creek geometric mean was 3.32, while the geometric mean of American Shad in the Christina River was 20.46 in 2020. However, in 2019 the DFW did not collect any American Shad at the Brandywine Creek sampling location and found higher catches in 2018 and 2017 relative to 2020. Further, no juvenile Alewife or Blueback Herring were collected at the lower Brandywine Creek sampling station by DFW in 2019 (Park & Stangl 2020). Similar data were requested from the New Jersey Marine Fisheries Administration (NJMFA), which conducts a seine survey in the Delaware River across from the mouth of the Christina River. However, that information was not available in 2020 because NJMFA did not sample due to restrictions resulting from COVID-19 safety protocols. Given the confirmation of juvenile and adult American Shad above the site of former Dam #1 and relative performance of our survey (e.g. total number) relative to another similar survey in Brandywine Creek, our survey methodology adequately reflects the relative habitat use of American Shad in the stretch of Brandywine Creek between the location of former Dam #1 and Dam #2 in 2020. Interestingly, we found our largest catch of juvenile American Shad coincided with the lowest average discharge ($ft^3 \cdot s^{-1}$) and turbidity (Form Neph) observed at Wilmington, DE (USGS 01481500) throughout the time series suggesting that water flow may affect habitat usage. Future work should focus on targeting similar collections of alosine species in Brandywine Creek, as well as standardizing an index of abundance with significant environmental covariates affecting occupancy, such as water discharge rates, as well as broader spatial comparisons with similar surveys. Further, additional sites along Brandywine Creek and methodologies including electroshocking should be examined to determine if other suitable locations or capture methods may be used to augment our growing body of information on diadromous fishes in the area. Finally, determining the degree of connectivity of American Shad between the Delaware River stock and Brandywine Creek is needed to critically address the question of stock status in tributaries of the Delaware River, i.e. does the depleted status of American Shad in the Delaware River match stock status in Brandywine Creek.

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Tables and Figures:

Table 1. Average fork length (FL.AVG) in mm with the standard deviation of fork length (FL.SD) in mm, as well as total length (TL.AVG) in mm with the standard deviation of total length (TL.SD) in mm.

Date	Time	Station	Tow	*Genus species*	Common Name	Stage	Count	FL.AVG	FL.SD	TL.AVG	TL.SD
7/14/2020	10:40	Dam 2-DR	2	*Alosa sapidissima*	American Shad	Adult	5	-	-	436.0	29.2
7/28/2020	11:15	Dam 2-DR	2	*Alosa sapidissima*	American Shad	Adult	3	401.7	16.5	447.0	12.0
7/28/2020	11:25	Dam 2-DR	2	*Alosa sapidissima*	American Shad	Juvenile	159	70.9	4.0	77.3	4.6
8/11/2020	11:15	Dam 2-DR	2	*Alosa sapidissima*	American Shad	Juvenile	1	74.0	0.0	81.0	0.0

Table 2. The geometric mean number of juvenile American Shad per haul in Brandywine Creek in 2020 at the downriver location only.

Juvenile American Shad Index		
Geometric Mean	0.510	
Standard Error	0.672	
95 % Confidence Interval	0.000	2.276

Table 3. Species and number observed during the Brandywine Creek survey in 2020.

Date	**Time**	**Station**	**Tow**	***Genus***	***species***	**Common Name**	**Stage**	**Count**
7/14/2020	10:00	Dam 2-UR	1	*Lepomis*	*macrochirus*	Bluegill		2
7/14/2020	10:00	Dam 2-UR	1	*Lepomis*	*auritus*	Redbreast Sunfish		5
7/14/2020	10:15	Dam 2-DR	1	*Notropis*	*hudsonius*	Spottail Shiner		12
7/14/2020	10:15	Dam 2-UR	2	*Anguilla*	*rostrata*	American Eel		1
7/14/2020	10:15	Dam 2-UR	2	*Etheostoma*	*olmstedi*	Tesselated Darter		2
7/14/2020	10:15	Dam 2-UR	2	*Lepomis*	*auritus*	Redbreast Sunfish		3
7/14/2020	10:40	Dam 2-DR	2	*Alosa*	*sapidissima*	American Shad	Adult	5
7/14/2020	10:40	Dam 2-DR	2	*Notropis*	*hudsonius*	Spottail Shiner		1
7/28/2020	10:10	Dam 2-UR	1	*Lepomis*	*macrochirus*	Bluegill		5
7/28/2020	10:10	Dam 2-UR	1	*Lepomis*	*auritus*	Redbreast Sunfish		4
7/28/2020	10:10	Dam 2-UR	1	*Micropterus*	*salmoides*	Largemouth Bass		1
7/28/2020	10:30	Dam 2-UR	2	*Lepomis*	*macrochirus*	Bluegill		3
7/28/2020	10:30	Dam 2-UR	2	*Lepomis*	*auritus*	Redbreast Sunfish		2
7/28/2020	10:30	Dam 2-UR	2	*Micropterus*	*salmoides*	Largemouth Bass		1
7/28/2020	11:00	Dam 2-DR	1					
7/28/2020	11:15	Dam 2-DR	2	*Alosa*	*sapidissima*	American Shad	Adult	3
7/28/2020	11:25	Dam 2-DR	2	*Alosa*	*sapidissima*	American Shad	Juvenile	159
8/11/2020	10:00	Dam 2-UR	1	*Lepomis*	*macrochirus*	Bluegill		2
8/11/2020	10:00	Dam 2-UR	1	*Lepomis*	*auritus*	Redbreast Sunfish		5
8/11/2020	10:00	Dam 2-UR	1	*Micropterus*	*salmoides*	Largemouth Bass		3
8/11/2020	10:15	Dam 2-UR	2	*Etheostoma*	*olmstedi*	Tesselated Darter		1
8/11/2020	10:15	Dam 2-UR	2	*Lepomis*	*auritus*	Redbreast Sunfish		1
8/11/2020	11:00	Dam 2-DR	1	*Cyprinella*	*analostana*	Satinfin Shiner		6

8/11/2020	11:00	Dam 2-DR	1	*Gambusia*	*holbrooki*	Mosquitofish		1
8/11/2020	11:00	Dam 2-DR	1	*Hybognathus*	*regius*	Eastern Silvery Minnow		1
8/11/2020	11:00	Dam 2-DR	1	*Micropterus*	*salmoides*	Largemouth Bass		1
8/11/2020	11:15	Dam 2-DR	2	*Alosa*	*sapidissima*	American Shad	Juvenile	1
8/11/2020	11:15	Dam 2-DR	2	*Catostomus*	*commersonii*	White Sucker		3
8/11/2020	11:15	Dam 2-DR	2	*Cyprinella*	*analostana*	Satinfin Shiner		4
8/11/2020	11:15	Dam 2-DR	2	*Fundulus*	*diaphanus*	Banded Killifish		1
8/11/2020	11:15	Dam 2-DR	2	*Lepomis*	*macrochirus*	Bluegill		4
8/11/2020	11:15	Dam 2-DR	2	*Lepomis*	*auritus*	Redbreast Sunfish		1
8/11/2020	11:15	Dam 2-DR	2	*Lepomis*	*gibbosus*	Pumpkinseed		2
8/11/2020	11:15	Dam 2-DR	2	*Micropterus*	*salmoides*	Largemouth Bass		2
8/11/2020	11:15	Dam 2-DR	2	*Notropis*	*hudsonius*	Spottail Shiner		5
8/11/2020	11:15	Dam 2-DR	2	*Perca*	*flavescens*	Yellow Perch		3
8/24/2020	13:00	Dam 2-UR	1					
8/24/2020	13:00	Dam 2-UR	2					
8/24/2020	13:50	Dam 2-DR	1	*Etheostoma*	*olmstedi*	Tesselated Darter		3
8/24/2020	13:50	Dam 2-DR	1	*Fundulus*	*diaphanus*	Banded Killifish		1
8/24/2020	13:50	Dam 2-DR	1	*Gambusia*	*holbrooki*	Mosquitofish		1
8/24/2020	13:50	Dam 2-DR	1	*Hybognathus*	*regius*	Eastern Silvery Minnow		4
8/24/2020	13:50	Dam 2-DR	1	*Micropterus*	*salmoides*	Largemouth Bass		1
8/24/2020	13:50	Dam 2-DR	1	*Notropis*	*hudsonius*	Spottail Shiner		186
8/24/2020	13:50	Dam 2-DR	2	*Etheostoma*	*olmstedi*	Tesselated Darter		4
8/24/2020	13:50	Dam 2-DR	2	*Hybognathus*	*regius*	Eastern Silvery Minnow		2
8/24/2020	13:50	Dam 2-DR	2	*Micropterus*	*salmoides*	Largemouth Bass		1
8/24/2020	13:50	Dam 2-DR	2	*Notropis*	*hudsonius*	Spottail Shiner		6
9/8/2020	12:00	Dam 2-UR	1	*Lepomis*	*macrochirus*	Bluegill		2
9/8/2020	12:00	Dam 2-UR	1	*Perca*	*flavescens*	Yellow Perch		12
9/8/2020	12:20	Dam 2-UR	2	*Perca*	*flavescens*	Yellow Perch		9
9/8/2020	12:40	Dam 2-DR	1					
9/8/2020	12:50	Dam 2-DR	2	*Semotilus*	*corporalis*	Fallfish		6
9/22/2020	10:00	Dam 2-UR	1					
9/22/2020	10:15	Dam 2-UR	2					
9/22/2020	10:45	Dam 2-DR	1	*Dorosoma*	*cepedianum*	American Gizzard Shad		5
9/22/2020	11:15	Dam 2-DR	2	*Dorosoma*	*cepedianum*	American Gizzard Shad		3
9/22/2020	11:15	Dam 2-DR	2	*Notropis*	*hudsonius*	Spottail Shiner		3
10/6/2020	10:00	Dam 2-UR	1					
10/6/2020	10:10	Dam 2-UR	2					
10/6/2020	10:30	Dam 2-DR	1					
10/6/2020	10:45	Dam 2-DR	2					

Figure 1. Sampling locations above and below Dam #2, as well as the DFW sampling location in Brandywine Creek, DE.

Appendix:
Picture 1. An adult American Shad collected at the Brandywine Creek downriver sampling location. Photo credit: Mrs. Kim Hachadoorian of The Nature Conservancy.

Picture 2. A juvenile American Shad collected at the Brandywine Creek downriver sampling location. Photo credit: Mrs. Kim Hachadoorian of The Nature Conservancy.

Picture 3. Sampling at the Brandywine Creek downriver sampling location on July 28, 2020. Photo credit: Mrs. Kim Hachadoorian of The Nature Conservancy.