



Final Performance Report

Project Number: F16AF00037 (F-47-R-26)

Project Title: Anadromous Species Investigations, Study 2: Shad and Herring Research, Activity 4: Adult alosine abundance, juvenile alosine abundance and American Shad nursery habitat evaluation in the Christina system

Grant Period: 02/01/16 – 1/31/17

Reporting Period: 02/01/16 – 1/31/17

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This project was funded under the Federal Aid in Fisheries Restoration Act of the U.S. Fish and Wildlife Service. This project was completed by the Delaware Division of Fish and Wildlife
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ABSTRACT

Similar to many east coast states, Delaware closed its river herring fishery in 2008 due to ASMFC Fishery Management Plan mandates. The current status of the Delaware River watershed alosine populations, including those on the White Clay Creek, Christina River, and Brandywine Creek is relatively unknown. Five sampling locations on the Christina River, a tributary of the Delaware River, were sampled biweekly from July through October with a 45.7-m long x 3.0-m deep haul seine consisting of 6.35-mm nylon netting. The four species targeted during this effort included: American Shad (*Alosa sapidissima*), Hickory Shad (*Alosa mediocris*), Alewife (*Alosa pseudoharengus*), and Blueback Herring (*Alosa aestivalis*), and all four species were collected during the project. Determining a juvenile index for shad and river herring in the Christina River will support American Shad and river herring restoration efforts, as will increasing access to historically used habitat from the removal of any of the 18 dams in the watershed.

INTRODUCTION

The Delaware River Basin Fish and Wildlife Cooperative (DRBFWC) identified the Delaware shad stock as stable, but at low levels in their sustainable fishing plan for American Shad (DRBFWC 2017). The only drainage in Delaware, where adult and juvenile alosine populations have historically been monitored, occurred as part of an ongoing restoration project within the Nanticoke River watershed (Moore 2016). The current status of the Delaware River watershed alosine populations, including those on the White Clay Creek, Christina River, and Brandywine Creek is relatively unknown. The objective of this activity is to support alosine restoration efforts by determining a juvenile abundance index (JAI) to assess annual and long term trend in reproductions and recruitment for these species in the Christina River. The four species targeted during this effort included: American Shad (*Alosa sapidissima*), Hickory Shad (*Alosa mediocris*), Alewife (*Alosa pseudoharengus*), and Blueback Herring (*Alosa aestivalis*).

The American Shad population in the Christina system (Brandywine Creek, White Clay Creek, and Christina River) has received considerable attention from the 1950's into the early 1970's. Bi-state efforts were made to restore the population on Brandywine Creek with the Delaware Department of Natural Resources and Environmental Control (DNREC) providing

fish passage at dams 1, 2 and 4 (3 is breached) and the Pennsylvania Fish and Boat Commission stocking fry well upriver in the Pennsylvania portion of Brandywine Creek. However, diminishing numbers of returning adult shad resulted in the discontinuation of active restoration efforts. Eventually the fishways were removed or closed due to being an unmaintained safety hazard in an urban area and vandalism of the fishways. Despite the low numbers of American Shad returning, a limited recreational fishery on the Brandywine Creek below Dam 1 has remained.

In 2005 the Brandywine Conservancy (BC) completed an American Shad restoration feasibility study (BC 2005) for the Delaware portion of Brandywine Creek and developed partnerships to remove Dams 1 (owned by the City of Wilmington) and 4 (owned in part by DNREC). The project was delayed after funding delays and key staff from the Brandywine Conservancy and DNREC resigned or retired. As part of a Natural Resources Damage Assessment consent order (effective November 2015) with DNREC, the removal of Dam 1 is to be funded by the City of Wilmington and is scheduled to begin in 2017. Pre-removal fish sampling began in 2016 directly above and below Dam #1. Post-removal sampling will be conducted once the dam is removed to evaluate the effectiveness of removal on fish movement and migration. Passage upstream of Dam 1 is currently being addressed by the Delaware Nature Conservancy in cooperation with the University of Delaware Water Resource Agency (UDWRA). In addition, the Delaware Division of Parks and Recreation has been actively seeking solutions to corresponding dam ownership along state-owned lands.

The UDWRA successfully removed Dam 1 on White Clay Creek in 2014 (www.wra.udel.edu/Shad/). The UDWRA assembled a White Clay Creek Shad restoration committee comprised of various private and public stakeholders that included the Division of Fish and Wildlife, and completed a shad and anadromous fish restoration feasibility study on the White Clay Creek in 2010 (UDWRA 2010). The feasibility study helped justify removal and included a creel survey conducted by DNREC with UDWRA near the historic Hale-Byrnes house on the White Clay Creek to document the recreational alosine fishery. Interviews with anglers determined that Hickory Shad was the most commonly caught fish, with one American Shad and a Striped Bass reported.

The UDWRA and BC initiated a Shad in Schools program from 2010-2014 as an

education tool about American Shad life history and the focuses on the importance of water quality and fish habitat. In 2014 the BC and UDWRA coordinated 11 schools; 8 in the Brandywine, 1 in the Red Clay, and 2 in the White Clay Creek watersheds that participated in this program in Pennsylvania and Delaware. The stocking sites were located along the White Clay Creek and Brandywine Creek in non-tidal Delaware waters based on the location of the school, river access, and the logistics of getting the students to the site. The American Shad eggs were sourced from the Interstate Commission of the Potomac River Basin and the Easton Hatchery in Easton, Pennsylvania. A lack of American Shad eggs resulted in the discontinuation of this program since 2015 (Martha Narvaez, UDWRA, personal communication).

METHODS

Juvenile abundance

Potential seining locations were identified in 2013 and selected based on the availability of shoreline work up area, proximity to snags, and bathymetry. Sampling was fully implemented in 2014. In 2015, adjustments were made to the sampling locations based on the previous years sampling results and the lack of target species captured at the lower sampling locations. One downstream site was removed from the sampling scheme, and two upriver sample locations were added. In 2016 these same five sampling locations on the Christina River (Table 1; Figure 1), a tributary of the Delaware River, were sampled biweekly from July through first week of November with a 45.7-m long x 3.0-m deep haul seine consisting of 6.35-mm nylon netting. One end of the net was anchored to the shoreline while the remainder of the net was set in a semicircle pattern off the bow of a Carolina Skiff, and then hauled to shore. Haul seines efforts were conducted during ebb or slack tides. All captured fish were identified to species and enumerated.

The JAI was determined by calculating the geometric mean number taken per haul of age-0 fish for each target species. The method for calculating the JAI involved logarithmic transformation of the arithmetic mean as described in Sokal and Rohlf (1995), ASMFC (1992), and Crecco (1992). Typically, a few large catches of alosine species can occur and bias CPUE estimates within the sampling period, thus a geometric mean is used to smooth out the bias associated with single large catches of schooling species. Confidence limits (95%) of the log-

transformed values were calculated for the geometric mean. Catch per unit effort (CPUE), recorded as fish caught per haul, and the associated standard error was calculated for each of the four species.

Dam surveys

Boat electrofishing for adult alosine species was conducted five times between April 6, 2016 and May 23, 2016 to evaluate presence or absence upstream and downstream of Dam 1 (West St. dam) in Brandywine Creek

(<https://www.google.com/maps/place/Brandywine+Creek/>); scheduled for removal in 2017).

The Smith-Root electrofishing boat used on the Delaware River (Study 1) was used to sample the tidal portion below Dam 1. The boat was operated in a serpentine pattern along the shorelines in depths ranging from 0.6 m to 4.3 m, while the output amperage was kept within a range of 7.0 to 8.5 amps and was cycled on for ten seconds and then off for four seconds. The section of the Brandywine Creek sampled was approximately 915 m downstream of Dam 1 (the same distance that occurs between Dam 1 and Dam 2), and the average sample time was 37.7 minutes of active electrofishing. The electrofishing raft used on the Nanticoke River Shad Restoration Project (Activity 3) was used to sample for adult alosine species between Dam 1 and Dam 2 in the non-tidal Brandywine Creek on June 1, 2016 and was also a segment of the creek approximately 915 m in length. The raft was also operated in a serpentine pattern along the shorelines, and output amperage was kept between 4.0 to 7.0 amps and was cycled on for 10 seconds and off for five seconds. There was about 25 minutes of active electrofishing time conducted between Dam 1 and Dam 2.

Back pack electrofishing for adult American Shad, Hickory Shad and River Herring on White Clay Creek was conducted to evaluate species presence or absence between Dam 2 and the location where Dam 1 was previously located. Sampling below Dam 2 took place on three occasions between April 19, 2016 and May 13, 2016. Two crew members operated the back pack and sampled the shoreline habitat; deeper areas below Dam 2 were sampled using a tote barge as three personnel assisted in netting stunned fish. The same back pack electrofishing unit was used to sample the location above where Dam 1 was located, in a similar manor on April 26, 2016.

RESULTS AND DISCUSSION

Juvenile abundance

The Christina drainage is comprised of four dammed tributaries in descending order of mean annual discharge: Brandywine Creek, Christina River, White Clay Creek and Red Clay Creek. Of these, only the Christina River is currently sampled downstream of the dam that occurs at Smalleys Pond (<https://www.google.com/maps/place/Smalleys+Pond>). In 2016 the Division attempted to sample in Brandywine Creek and only one suitable haul seine location was found, but the area had some sort of object below the surface and was not able to be sampled.

Haul seine sampling produced 23 American Shad, 66 Blueback Herring, and 30 Alewife from July 8, 2016 through November 4, 2016 (Table 2). Three of the four target alosine species were captured, and an additional 24 other species were sampled. The JAI decreased substantially from 2015 for all three species (Table 3). The increase in the geometric mean number taken per haul in 2015 when compared to 2014 was thought to be the result of the new sampling locations, but those same locations were sampled again in 2016 and the geometric mean number taken per haul dropped to levels closer to what was seen in 2014. The highest CPUE (5.2 fish/haul) was on August 8, 2016 with 26 Blueback Herring being captured (Table 4). Blueback Herring exhibited the highest total CPUE (1.5 fish/haul), followed by Alewife (0.7 fish/haul), and American Shad (0.5 fish/haul). This is a decrease from 2015 when Alewife had the highest total CPUE (7.8 fish/haul), American Shad had a CPUE of 7.5 fish/haul, and Blueback Herring had the lowest CPUE of 5.6 fish/haul. Hickory Shad were not collected during the 2016 sampling season. Catch amongst sampling sites varied greatly (Table 5), with Site 2 producing the greatest number of alosines (n=52), and Site 4 producing the least (n=6). This was similar to 2015 when Site 2 produced the most alosines and Site 4 produced the least. Site 4 is closer to the mouth of the Christina River and typically exhibits a higher salinity value than the other 3 locations (Figure 1). This change in water quality may be a factor for the higher abundance. In 2016 United States Geological Survey (USGS) water quality monitoring gauge located between sites 2 and 3, recorded salinity values that were greater than average for most of the season (Figure 2). This higher salinity value may have impacted the available habitat, pushing juvenile alosines further upstream than our sampling locations, or may have impacted early-stage survival rates.

The absence of Hickory Shad in any collection may be a function of gear avoidance and habitat preference since juvenile Hickory Shad are seldom taken consistently even in those systems which have significant adult spawning runs (Richardson et al. 2009). Similar observations were made by Mansueti (1962) who reported a scarcity of Hickory Shad fingerlings in fish samples from the Chesapeake Bay tributaries.

Dam Surveys

Sampling below Dam 1 in the tidal portion of Brandywine Creek resulted in the capture of all four target alosine species during a combined 3.15 hours of electrofishing, and staff captured one Alewife, three American Shad, five Blueback Herring, and two Hickory Shad (Table 6). The number of fish caught is lower than what was anticipated but it does provide an insight into the presence of alosine species below Dam 1 and allows for a catch per unit effort (CPUE; fish/minute of electrofishing) to be generated that can be compared with future sampling events. Division staff documented 15 other fish species below Dam 1.

Surveying the non-tidal portion above Dam 1 occurred after the alosine species were documented below Dam 1. The area was only sampled once and resulted in the capture of six adult American Shad. This was somewhat unexpected since only three were caught below the dam over the course of five sampling events, although the Division documented the capture of nine American shad in the same non-tidal area while conducting an assessment of smallmouth bass in 1998 (Michael Stangl, DNREC, personal communication). Their presence documents that at least adult American Shad were able to pass over the low-head of Dam 1 and the catch per unit effort was greater above Dam 1 than below it (Table 7).

Sampling in White Clay Creek was limited in scope with three days of effort downstream of Dam 2 and one day where Dam 1 was located. The access point to sample the Dam 1 site is through a golf course owned by a private country club so access was difficult. Sampling below Dam 2 did not produce any of the targeted alosine species which led to sampling the Dam 1 location to see if alosine species could be captured there. The section of White Clay Creek just below where Dam 1 originally was appeared to be very shallow and sediment may act as a barrier to fish passage, especially during low tide. This situation warrants further evaluation in the future.

Survey Validation

The 2014 and 2015 American Shad geometric mean evaluated from the Christina Sampling was comparable to the geometric mean number taken per haul of age-0 fish for American Shad in the New Jersey Department of Environmental Protection (NJDEP) juvenile Striped Bass seine survey. While the haul seine used in the NJDEP survey is only 30.5-m long x 1.8-m deep, the survey is also completed from July through November and is performed twice a month. Data from two of the NJDEP seine sites which are within two miles of the mouth of the Christina River were calculated for comparison. The comparison between the two surveys demonstrates a similar trend in abundance with an increase in catch from 2014 to 2015 (Table 8).

Recommendations

1. Continue to conduct a survey of juvenile alosines in the Christina River and calculate a JAI to assess trends in population abundance.
2. Continue to monitor presence and absence of alosines in relation to dam removals.
3. Continue to validate survey using the NJDEP Striped Bass haul seine survey.

Literature Cited

- ASMFC (Atlantic States Marine Fisheries Commission). 1992. Supplement to the striped bass FMP - Amendment #4. Addendum III - calculation of juvenile indices. Atlantic States Marine Fisheries Commission, Washington, D.C
- Brandywine Conservancy. 2005. The Restoration of American Shad to the Brandywine River. A feasibility study. Brandywine Conservancy, Chads Ford PA. Available: <http://www.brandywineconservancy.org>
- Crecco, V. 1992. Revised striped bass juvenile indices from the Maryland survey based on the geometric mean. Report to the Atlantic States Marine Fisheries Commission, Washington, D.C.
- Delaware River Basin Fish and Wildlife Cooperative. 2017. Delaware River sustainable fishing plan for American Shad. Available: <http://www.asmfc.org>
- Mansueti, R. 1962. Eggs, larvae, and young of the hickory shad, *Alosa mediocris*, with comments on its ecology in the estuary. Chesapeake Science 3(3): 173-205.
- Moore, J.E. 2016. Nanticoke River Shad and river herring restoration. Study No.2, Activity 2 and 3 in Anadromous Species Investigations. Federal Aid in Fisheries Restoration Project F-47-R-25, Annual Performance Report. Delaware Division of Fish and Wildlife, Dover, DE.
- Richardson, B.M. C.P. Stence, M.W. Baldwin, and C.P. Mason. 2009. Restoration of Hickory Shad in three Maryland Rivers. Maryland Department of Natural Resources. Annapolis, MD
- Sokal, R.R. and F.J. Rohlf. 1995. Biometry- the principles and practice of statistics in biological research. W.H. Freeman and Company, New York.
- UDWRA 2010. Restoration of Shad and anadromous fish to the White Clay Creek National Wild and Scenic River: a feasibility report. University of Delaware Water Resources Agency, Newark, DE.

Table 1. Juvenile index of abundance sites in tidal waters of the Christina River that were sampled using haul seine gear in 2016.

Site #	Site Name	Latitude	Longitude	Description	Rkm
1	Churchmans Rd	39.6876	-75.6257	Two bends east of Churchmans Rd ramp	15.3
2	White Clay	39.6971	-75.6217	Across from White Clay Creek	13.9
3	Newport Utility	39.7109	-75.6037	South bank at underground utility crossing	11.6
4	Rt. 95	39.7191	-75.5811	West of Rt. 95 overpass on the North bank	9.3
5	Nature Center	39.7269	-75.5616	DuPont Environmental Education Center	6.5

Table 2. Species and the number observed during Christina River haul seine in 2016.

Family	Scientific Name	Common Name	Number Captured
Achiridae	<i>Trinectes maculatus</i>	Hogchocker	63
Anguillidae	<i>Anguilla rostrata</i>	American Eel	4
Atherinopsidae	<i>Menidia beryllina</i>	Inland Silverside	1
Centrarchidae	<i>Lepomis cyanellus</i>	Green Sunfish	1
	<i>Lepomis gibbosus</i>	Pumpkinseed	4
	<i>Lepomis machrochirus</i>	Bluegill	12
	<i>Micropterus salmoides</i>	Largemouth Bass	7
	<i>Pomoxis nigromaculatus</i>	Black Crappie	1
Clupeidae	<i>Alosa aestivalis</i>	Blueback Herring	66
	<i>Alosa pseudoharengus</i>	Alewife	30
	<i>Alosa sapidissima</i>	American Shad	23
	<i>Brevoortia tyrannus</i>	Atlantic Menhaden	19
	<i>Dorosoma cepedianum</i>	Gizzard Shad	264
Cyprinidae	<i>Cyprinella analostana</i>	Satinfin Shiner	273
	<i>Cyprinus carpio</i>	Common Carp	4
	<i>Hybognathus regius</i>	Eastern Silvery Minnow	142
	<i>Notropis hudsonius</i>	Spottail Shiner	264
Engraulidae	<i>Anchoa mitchilli</i>	Bay Anchovy	196
Fundulidae	<i>Fundulus diaphanus</i>	Banded Killifish	304
	<i>Fundulus heteroclitus</i>	Mummichog	28
Ictaluridae	<i>Ameiurus nebulosus</i>	Brown Bullhead	2
	<i>Ictalurus punctatus</i>	Channel Catfish	13
Moronidae	<i>Morone americana</i>	White Perch	390
	<i>Morone saxatilis</i>	Striped Bass	23
Percidae	<i>Etheostoma olmstedii</i>	Tessellated Darter	37
	<i>Perca flavescens</i>	Yellow Perch	1
Portunidae	<i>Callinectes sapidus</i>	Blue Crab	13

Table 3. The geometric mean number taken per haul of alosine species in the Christina River.

	Alewife	American Shad	Blueback Herring
2014	0.02	0.45	0.61
2015	2.11	2.58	1.34
2016	0.15	0.20	0.58

Table 4. Daily catch per unit effort (CPUE: fish/haul) of Alosine fish species collected in the Christina River during the juvenile abundance estimate in 2016 using haul seine gear.

Date	Species	Catch Frequency	CPUE (fish/haul)	Average Total Length (size range)(mm)
7/8/2016	Alewife	0	0	0
7/26/2016	Alewife	0	0	0
8/8/2016	Alewife	1	0.2	82
8/24/2016	Alewife	6	1.2	71.3 (58-84)
9/7/2016	Alewife	23	4.6	84.6 (66-94)
9/23/2016	Alewife	0	0	0
10/7/2016	Alewife	0	0	0
10/21/2016	Alewife	0	0	0
11/4/2016	Alewife	0	0	0
2016 Total	Alewife	30	0.7	-
7/8/2016	American Shad	0	0	0
7/26/2016	American Shad	1	0.2	35
8/8/2016	American Shad	0	0	0
8/24/2016	American Shad	0	0	0
9/7/2016	American Shad	2	0.4	90.5 (90-91)
9/23/2016	American Shad	9	1.8	97.7 (84-107)
10/7/2016	American Shad	10	2	86.6 (82-89)
10/21/2016	American Shad	0	0	0
11/4/2016	American Shad	1	0.2	96
2016 Total	American Shad	23	0.5	-
7/8/2016	Blueback Herring	0	0	0
7/26/2016	Blueback Herring	1	0.2	46
8/8/2016	Blueback Herring	26	5.2	49.7 (40-61)
8/24/2016	Blueback Herring	5	1	53.6 (51-55)
9/7/2016	Blueback Herring	1	0.2	51
9/23/2016	Blueback Herring	16	3.2	59.6 (54-65)
10/7/2016	Blueback Herring	15	3	59.5 (51-66)
10/21/2016	Blueback Herring	2	0.4	61.5 (59-64)
11/4/2016	Blueback Herring	0	0	0
2016 Total	Blueback Herring	66	1.5	-

Table 5. Daily CPUE of alosine species from the 2016 Christina River haul seine.

Date	Station	Alewife	American Shad	Blueback Herring
7/8/2016	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	0	0
7/26/2016	1	0	0	0
	2	0	0	0
	3	0	1	0
	4	0	0	0
	5	0	0	1
8/8/2016	1	0	0	11
	2	0	0	5
	3	1	0	10
	4	0	0	0
	5	0	0	0
8/24/2016	1	0	0	0
	2	2	0	2
	3	4	0	0
	4	0	0	3
	5	0	0	0
9/7/2016	1	0	0	0
	2	23	0	1
	3	0	2	0
	4	0	0	0
	5	0	0	0
9/23/2016	1	0	0	1
	2	0	8	2
	3	0	1	12
	4	0	0	0
	5	0	0	1
10/7/2016	1	0	0	0
	2	63	38	15
	3	0	6	0
	4	0	0	0
	5	2	0	0
10/21/2016	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	0	2
11/4/2016	1	0	0	0
	2	0	0	0
	3	0	0	0
	4	0	0	0
	5	0	1	0

Table 6. Species and the number observed while electrofishing below Dam 1 on the Brandywine Creek. CPUE represents the number of fish caught per minute of electrofishing.

Fish Species	4/6/2016 Number Observed	4/18/2016 Number Observed	4/27/2016 Number Observed	5/9/2016 Number Observed	5/23/2016 Number Observed	Total Observed	CPUE
Alewife	0	0	0	1	0	1	0.01
American Eel	4	0	0	0	0	4	0.02
American Shad	0	0	0	3	0	3	0.03
Blueback Herring	0	0	1	0	4	5	0.05
Bluegill	1	6	1	1	0	9	0.06
Channel Catfish	1	4	4	0	1	10	0.08
Common Carp	9	17	6	4	0	36	0.24
Gizzard Shad	0	39	4	11	22	76	0.60
Hickory Shad	0	0	0	2	0	2	0.02
Largemouth Bass	0	1	0	0	0	1	0.01
Menhaden	0	0	0	1	0	1	0.01
Needlefish	0	0	0	1	0	1	0.01
Smallmouth Bass	3	0	3	0	0	6	0.05
Striped Bass	0	1	5	3	19	28	0.29
Tiger Muskie	1	3	1	1	0	6	0.04
Rock Bass	0	0	0	0	0	0	0.00
White Perch	0	1	3	14	0	18	0.19
White Sucker	2	2	6	4	4	18	0.17
Yellow Perch	0	2	10	2	4	18	0.18

Table 7. Species and the number observed while electrofishing between Dam 1 and Dam 2 on the Brandywine Creek. CPUE represents the number of fish caught per minute of electrofishing.

6/1/2016		
Fish Species	Number Observed	CPUE
Alewife	0	0
American Eel	15	0.6
American Shad	6	0.24
Blueback Herring	0	0
Blue Gill	8	0.32
Channel Catfish	2	0.08
Common Carp	5	0.2
Gizzard Shad	0	0
Hickory Shad	0	0
Largemouth Bass	0	0
Menhaden	0	0
Needlefish	0	0
Smallmouth Bass	2	0.08
Striped Bass	0	0
Tiger Muskie	2	0.08
Rock Bass	5	0.2
White Perch	0	0
White Sucker	17	0.68
Yellow Perch	0	0

Table 8. The geometric mean number taken per haul of American Shad in the Christina River and the geometric mean number taken per haul of American Shad in the NJDEP Striped Bass survey.

American Shad		
	DNREC	NJDEP
2014	0.45	0.46
2015	2.58	3.37

Figure 1. Christina River haul seine site locations

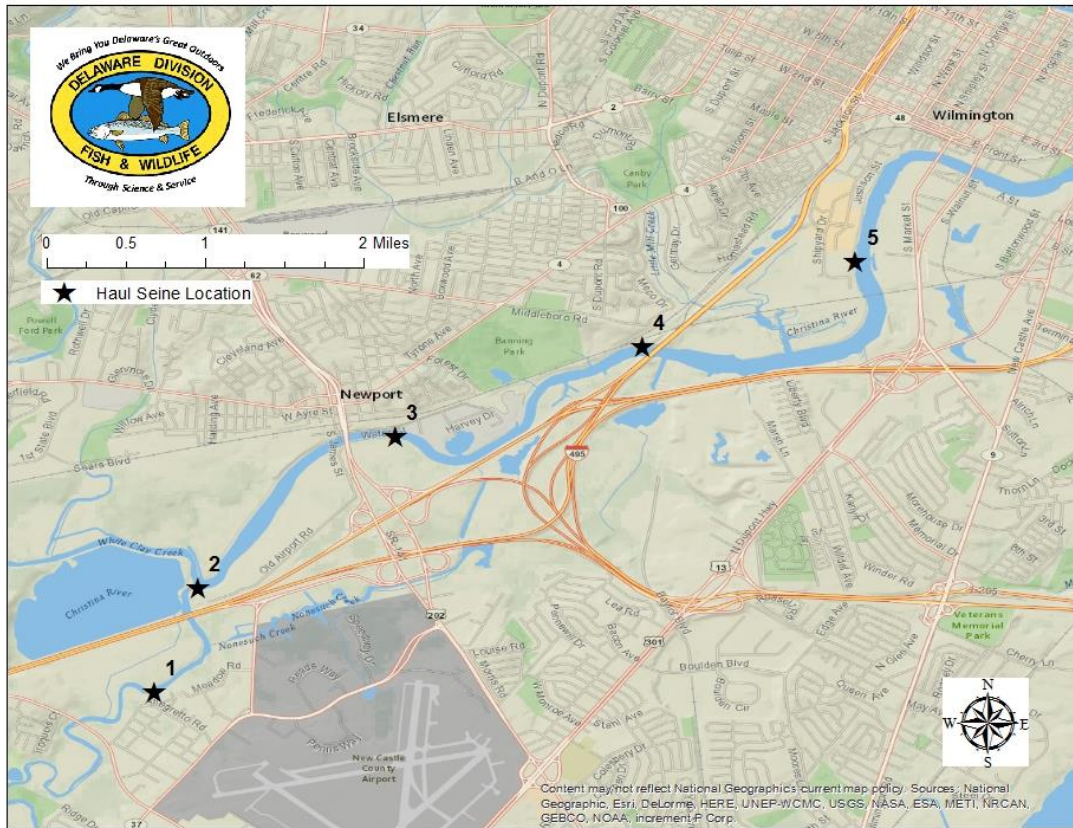


Figure 2. Christina River salinity values recorded by the USGS water quality monitoring station located in Newport, DE (01480065). The areas shaded in gray represent the range of salinity values from 2007-2015.

Christina River Daily Average Salinity Levels

