U.S. Fish & Wildlife Service Susquehanna River American Shad (*Alosa sapidissima*) Restoration: Potomac River Egg Collection, 2016

Joshua Newhard, Daniel Drake, Christopher Reily, Steve Minkkinen, Mike Mangold

U.S. Fish and Wildlife Service
Maryland Fish & Wildlife Conservation Office
177 Admiral Cochrane Drive
Annapolis, MD 21401

Abstract

During April and May 2016, monofilament gill nets were used to collect spawning ready American Shad (*Alosa sapidissima*) from the Potomac River, Maryland. Mature adults were strip-spawned on the river and fertilized eggs were provided to Pennsylvania's Van Dyke American Shad Hatchery in support of Susquehanna River American Shad restoration. Sampling consisted of 30 days, during which 2,132 adult American Shad were collected, with 1,033 of those adults used for spawning. A total of 165.6 L of American Shad eggs (~8.39 million) with a 25.5% fertilization rate resulted in approximately 2.14 million viable eggs that were used for stocking into the Susquehanna River.

Introduction

American Shad (*Alosa sapidissima*) are an anadromous, pelagic fish species that range along the Atlantic coast from Labrador, Canada to Florida, United States of America (U.S. Fish and Wildlife Service 2006). American Shad are the largest of the clupeids native to North America (Stier and Crance 1985) and an important planktivore and prey species for Bluefish (*Pomatomus saltatrix*) and Striped Bass (*Morone saxatilis*; U.S. Fish and Wildlife Service 2006). American Shad return to their natal river to spawn after four to six years maturing at sea. Spawning movements follow a latitudinal cline and, although variable, generally peak at water temperatures of 14 to 21 ^{o}C (Stier and Crance 1985). Generally, April is the peak spawning month for American Shad in the Potomac River, Maryland.

Shad were once a valuable resource for Native Americans and have been economically important since European colonization of North America. In Pennsylvania, American Shad are said to have once ruled the waters of the Susquehanna River and its tributaries (The Native Fish Conservancy 2005). However, over the past century, American Shad populations have declined for a number of reasons. Initial population declines resulted from increased commercial harvest coinciding with increases in human population and gear efficiency. Habitat loss (impoundments) and degradation (pollution) followed and remain today as significant challenges to restoration. Attempts to mitigate impoundment effects on American Shad and other Susquehanna River species began in 1866. In that year Pennsylvania enacted the Act of March 30, 1866, which formed what is today the Pennsylvania Fish and Boat Commission (PFBC), and began over a century of fish passage efforts on the Susquehanna River (The Native Fish Conservancy 2005).

The U.S. Fish and Wildlife Service (Service) is partnered with state, Federal, and hydro-power companies, through the Susquehanna River Anadromous Fish Restoration Cooperative to restore American Shad to the Susquehanna River watershed. The Service's current Potomac River egg harvest operation is part of this, nearly forty year, multi-agency restoration effort. The Service's Maryland Fish and Wildlife Conservation Office's (MDFWCO) role is to deliver viable American Shad eggs to the Van Dyke American Shad Hatchery near Thompsontown, Pennsylvania. There, the eggs are incubated until hatching and fry are grown and marked before stocking into the Susquehanna River drainage.

Study Area

The Potomac River is approximately 1.5 km wide at Marshall Hall, Maryland (rkm 150), where American Shad gill netting occurs. The collection site is bounded by Dogue Creek (North) and Gunston Cove (South) and has long been linked to Shad harvest and culture. The river is tidal within this area, but remains freshwater throughout the spring. Bottom habitat is characterized by an abrupt transition from the deep channel (≈ 18.3 m) area to relatively shallow depths (≤ 3.5 m). Channel substrate consists of firm, sandy, mud with intermittent shell. Sand increases in the shoal area forming a comparatively harder substrate.

Materials and Methods

Two boats with a crew of three each fished for American Shad nightly. Three different sized, monofilament, floating gill nets were used in 2016. A 14.0 cm (5.5 in) stretch mesh net was used to target ripe females and was 6.1 m deep by 91.4 m long (female net). The net used to target males was 11.7 cm (4.6 in) stretch mesh and 5.2 m deep by 91.4 m long (male net). A third type of net was used to target males and smaller females. This net had 12.7 cm (5.0 in) stretch mesh and was 5.5 m deep by 91.4 m long (unisex net). Each boat set up to five nets, with at least one net of each type per boat. Nets were joined in series and drifted parallel to shore in water depths ranging from approximately 6.1 to 12.2 m. Gill nets were set shortly before the evening's slack tide and fished approximately 45 minutes. Fishing was timed so that the nets' drift stalled parallel to a sharply defined shoal area where depth abruptly decreased to less than 4.0 m.

Methodology was altered on May 11th to attempt to reduce bycatch and net entanglement in commercial fishing gear. Only one or two nets were set at a time and fished for a total of 10-15 minutes per set. Nets were then pulled, emptied, and reset for approximately an hour total of fishing (i.e., 6 total net sets per hour). This change in methodology allowed for a greater flexibility in the choice of fishing location within the site, and locations could be switched rapidly if they were unproductive.

Tidal condition (transitioning high or low) was noted and surface temperature (^{o}C), dissolved oxygen (mg/L), conductivity (microsiemens/cm; µs/cm), and salinity (ppt) were recorded (Yellow Springs Instruments Model Pro 2030) each night (Figure 1). The number of running, green, or spent female American Shad, ripe male American Shad, and all bycatch (by species) was recorded (Table 1; Figure 2). Gill net effort (minutes fished) was recorded but varied since the goal was to maximize catch during each sampling event. American Shad catch per unit effort (CPUE) was calculated by sex (male, ripe female, green female) and net type fished (male, female, unisex) per total net square footage and time fished (CPUE= [n/hr/m^2]). For ease of interpretation, all CPUE values were multiplied by a scalar of 1,000. A sub-sample of American Shad (~ 5% of fish kept for spawning) were measured for total length (nearest mm) and weight (nearest 0.01 kg), and otoliths were extracted for aging, as a permit requirement of the Potomac River

Fisheries Commission (PRFC). In addition, we stocked 9% (14 L) of all eggs stripped from American Shad back into the Potomac River, as another permit requirement by PRFC.

Results

During spring 2016, the Potomac River was sampled a total of 30 days from 3 April through 19 May. From early to mid-April, surface water temperature remained below 15°C, until temperatures rose in late April, then stayed between 15-20°C for the remainder of the sampling period (Figure 1). Surface water temperatures ranged from 11.7 to 19.3 ^oC ($\bar{x}$ = 16.1 ^oC) while dissolved oxygen ranged from 6.6 to 13.1 mg/L ($\bar{x}$ = 9.8 mg/L; Figure 1). Water conductivity was fairly stable, ranging from 178 to 329 μs/cm ($\bar{x}$ = 262 μs/cm).

Throughout the 30 day sampling period, we made 21 egg shipments between 13 April and 19 May (70% of sampling days). A total of 165.6 L (range = 2.6–16.0 L, $\bar{x}$ = 7.9 L/shipment) of eggs were shipped from the Potomac River (J. Tryninewski, PFBC, personal communication). The overall egg viability was 25.5%, although daily shipments had a range of 0.0–62.1%. This resulted in the production of 2.139 million fry that were stocked into selected tributaries of the Susquehanna River (J. Tryninewski, PFBC, personal communication).

Gill netting captured 17,808 fish from the Potomac River, representing fifteen fish species (Table 1). Gizzard Shad comprised 83.1% of all fish caught, with American Shad the next largest portion of the catch (11.9%). Green female American Shad were slightly more common than ripe females with a ratio of 1.3:1, but ripe females were more common than ripe males with a ratio of 2.1:1 (Figure 2; Table 2).

Catch per-unit-effort was highest in our male (11.7 cm stretch mesh) net. These nets had the highest CPUE for males and ripe and green females compared to all other net types (Table 3). In prior sampling years, male nets typically only had the highest CPUE for male American Shad, and the unisex net had the highest CPUE for ripe and green American Shad.

Discussion

The 2016 fishing season had challenges that made fishing the same methods more difficult and less productive than in previous years. The biggest obstacle was the marked increase in commercial gear present in and around the sampling area for the duration of the season. Compared to past seasons there were significantly more buoys marking commercial fishing gear (including trotlines) within or near the channel along the entire length of the shad fishing area. Due to the direction and curvature of the channel, it is difficult to predict how our nets would drift after slack tide, regardless of incoming or outgoing tides. Many sampling nights saw one or both crews coming into contact with at least one buoy or trotline. In an attempt to reduce commercial gear entanglement, nets were often set in shallow water (<5 m) causing the nets to frequently snag on submerged debris.

Another challenge faced this year was the extraordinary amount of gizzard shad bycatch (Table 1). This year, gizzard shad catch was more than seven times the average yearly catch of gizzard shad from 2006-2015. Large numbers of gizzard shad generally coincided with lower viabilities and lower volumes of egg shipments. The highest and most consistent viabilities occurred after the change in methodology in early May (see methods), which significantly reduced bycatch. Based on the observations of the crews and previous years data, it is likely that the extremely high volume of gizzard shad caught using 45 minute net sets increased visibility and reduced available mesh for the nets in the water column. This potentially alerted the target species to the presence of the fishing gear and/or reduced the ability of the nets to entangle American shad. Another possible manner in which the gizzard shad could have reduced viabilities is in the amount of time spent removing them from the nets. There were over 500 gizzard shad caught in one night 12 times during the season; five evenings saw over 1,000 gizzard shad caught in a night.

Due to the combination of frequent commercial gear entanglement and an unusually high abundance of gizzard shad, it is likely the time spent emptying the net of bycatch and freeing it from obstacles prolonged the time American shad were entangled. This likely caused significant stress or death which ultimately reduced fitness for strip spawning. Furthermore, the more time spent removing bycatch from nets resulted in longer holding times for American shad onboard the boat in tanks, which may also reduce fitness for strip spawning.

CPUE values for the male nets during the 2016 egg collection effort were higher for both sexes of American shad. In past years it was typically expected to catch more females in either unisex or female nets. American shad catch data from experimental gill netting in the Potomac River targeting spawning striped bass conducted from 1985-2016 (B. Versak, MD DNR, personal communication 2016) indicate that 34% (627 of 1866) of captured American shad over the time series were collected in 7.6 cm and 9.5 cm meshes (our smallest mesh used is 11.7 cm) and the mean lengths of those fish were ~40mm less than the mean length of fish captured in 11.4 cm mesh (Table 3). It is possible that our smallest mesh size did not effectively capture the spawning male population in 2016. Although male nets captured the majority of fish for this season, crews were often not capturing enough males for an optimal spawning ratio of 3:1 (Figure 4). Attempts will likely be made in 2017 using 10.2 cm (4 in) mesh nets to investigate availability of additional male fish on occasions when target M:F ratios are not met.

Changing the methods in response to the challenges outlined above contributed to lower gizzard shad bycatch and corresponded with increased American Shad egg viabilities (Figure 3). The three nights of fishing prior to the method alteration (May 5th, 9th and 10th) saw an increase in the ratio of males to females (Figure 4), a reduction in gizzard shad bycatch (Figure 3), and increased egg viabilities making it unclear whether the change in methods was solely responsible for improved success. It is also possible fish had simply remained in the area long enough for eggs to ripen at the ideal spawning temperature by that time (see Fig. 1). However, this year temperatures were relatively flat throughout much of the sampling period. Temperature did not vary much after 28 April 2016 (Fig. 1). In the past, steady water temperatures have generally coincided with lower than normal egg volumes and viabilities. We have typically seen higher egg volumes later in the season when there is a general increase in water temperature over the sampling period.

Regardless of coincidental environmental changes, the reduced time and lengths of nets being fished allowed for a more efficient way of handling bycatch and allowed more control in avoidance of commercial fishing gears. The reduction in time spent pulling nets and removing large numbers of fish allowed for more rapid removal of American Shad from the net. An additional benefit of the altered methods was the time spent between net sets. This extra time allowed crew members to provide more immediate attention to the American shad awaiting spawning in the holding tanks. The reduction in stress is a likely cause for the increased viability of the egg shipments. It also enabled each crew to be able to reset their position within the fishing area and fish more productive spots repeatedly or use the time to change position in the event of less productive sets.

Conclusion

The Service provided Pennsylvania with 165.6 L of eggs, with an overall viability of 25.5% (~2.139 million viable eggs; see Project Summary results below from previous years). The 2016 overall viability of 25.5% was below the ten year average (36.3%) and was the third lowest viability in the history of the program; 2013 was the lowest at 21%.

Project Summary

Over the past eleven years the USFWS has provided Pennsylvania with over 2,151 liters of eggs with an average viability of 36.3%, resulting in the production of nearly 37 million viable Shad eggs.

Year	Volume (L)	Viable Eggs (N)	Viability (%)
2016	165.6	2,138,510	26%
2015	170.6	2,044,013	23%
2014	316.7	5,671,992	39%
2013	118.1	1,603,498	21%
2012	258.0	5,664,920	51%
2011	137.4	2,714,435	44%
2010	375.0	6,874,712	39%
2009	132.2	1,885,500	30%
2008	194.4	3,491,069	41%
2007	183.9	2,875,455	42%
2006	99.3	2,003,222	44%

Acknowledgements

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Table 1. List of species and number sampled (count) in gill nets from the Potomac River, MD during spring 2016.

Common Name	**Scientific Name**	**Count**
American Shad	*Alosa sapidissima*	2,132
Atlantic Menhaden	*Brevoortia tyrannus*	2
Blue Catfish	*Ictalurus furcatus*	144
Blueback Herring	*Alosa aestivalis*	2
Channel Catfish	*Ictalurus punctatus*	1
Common Carp	*Cyprinus carpio*	1
Gizzard Shad	*Dorosoma cepedianum*	14,844
Hickory Shad	*Alosa mediocris*	6
Largemouth Bass	*Micropterus salmoides*	4
Longnose Gar	*Lepisosteus osseus*	28
Northern Snakehead	*Channa argus*	2
Quillback	*Carpiodes cyprinus*	6
Striped Bass	*Morone saxatilis*	636

Table 2. Daily American Shad (*Alosa sapidissima*) catch totals, with number of liters stocked/shipped to Van Dyke Hatchery and the associated viability of the shipment for spring 2016 (Note: Viability is only for eggs shipped to hatchery, for eggs stocked the viability is unknown).

Date	Males	Ripe Females	Green Females	Liters Stocked	Liters Shipped	Viability
4/3/2016	11	5	60	1		
4/4/2016	16	5	11	2		
4/5/2016	12	11	34			
4/10/2016	5	1	32	0.3		
4/11/2016	5	0	39			
4/12/2016	27	22	84	5.4		
4/13/2016	13	19	60		5.3	54.5
4/14/2016	5	14	81		2.6	31.7
4/17/2016	25	53	102		14.5	9.7
4/18/2016	2	33	78			
4/19/2016	3	9	28		4.8	57.4
4/20/2016	11	33	32		8.5	0.3
4/21/2016	4	33	33			
4/24/2016	16	25	65		6	0
4/25/2016	20	64	68		13.7	45
4/26/2016	1	6	8	2.25		
4/27/2016	5	40	25		5.1	10.8
4/28/2016	8	22	4		10	29.3
5/1/2016	35	10	12		2.9	56.7
5/2/2016	4	29	18		6.1	1.1
5/4/2016	6	52	4		16	10.6
5/5/2016	10	17	2		4.5	62.1
5/9/2016	2	10	6		4.9	57.8
5/10/2016	9	17	5		5.6	60.8
5/11/2016	18	37	8		15	56.2
5/12/2016	26	33	11	2.25	11.4	54.4
5/16/2016	3	21	18	0.75	5.3	55.8
5/17/2016	8	29	8		10.1	14.7
5/18/2016	9	24	0		6.3	20.3
5/19/2016	12	28	0		7.1	16.2
TOTALS	**331**	**702**	**936**	**14**	**165.7**	

Table 3. Average daily catch per unit effort (CPUE; fish/hour/m^2) for spawning condition American Shad caught during Potomac River, MD gillnetting in spring 2016. Note: all values were multiplied by a scalar of 1,000.

CPUE		
Males	Male Net	9.85
	Unisex Net	1.54
	Female Net	0.88
Ripe Females	Male Net	11.20
	Unisex Net	7.09
	Female Net	3.78
Green Females	Male Net	9.08
	Unisex Net	7.07
	Female Net	5.01

Table 4. MD DNR American shad (AS) minimum, mean, and maximum total length (TL; mm) data by mesh size from Potomac River experimental gill net striped bass sampling from 1985-2016.

Mesh Size (in)	Mesh Size (cm)	Minimum TL	Mean TL	Maximum TL	Collected AS
3.00	7.6	389	442	493	106
3.75	9.5	390	442	516	521
4.50	11.4	444	485	532	729
5.25	13.3	464	505	545	318
6.00	15.2	481	508	533	56
6.50	16.5	480	509	529	55
7.00	17.8	472	488	502	29
8.00	20.3	462	480	499	29
9.00	22.9	477	503	527	12
10.00	25.4	473	479	488	11

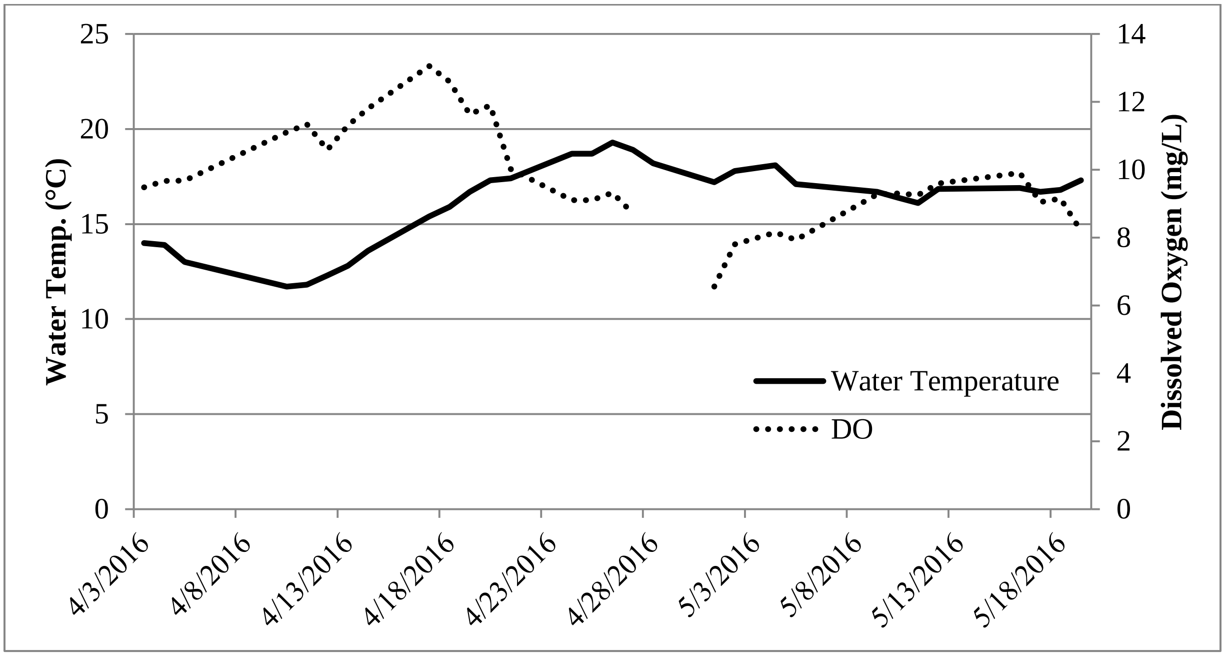

Figure 1. Spring 2016 Potomac River, Maryland surface water temperature (^{o}C) and dissolved oxygen (mg/L) measurements taken during American Shad (*Alosa sapidissima*) gill netting.

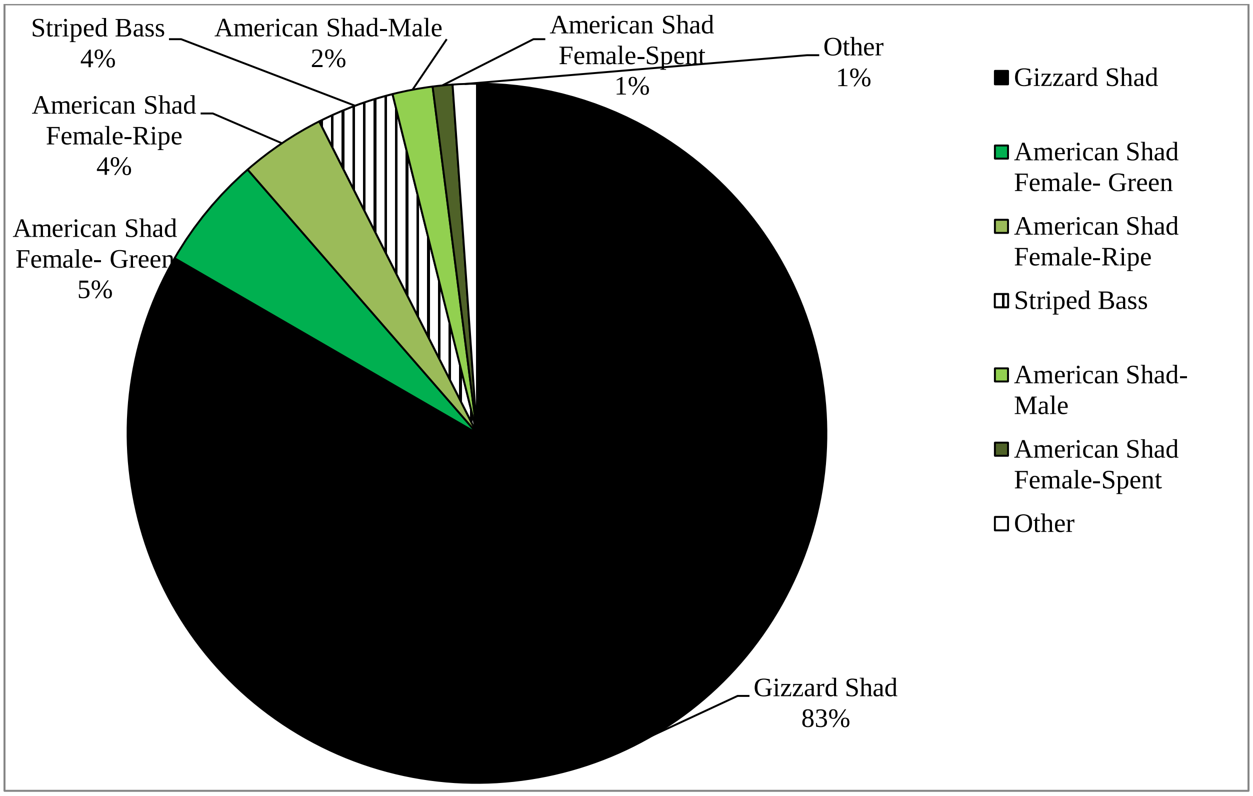

Figure 2. Spring 2016 species composition from Potomac River, MD gill net sampling. Other species, scientific names, and counts are listed in Table 1.

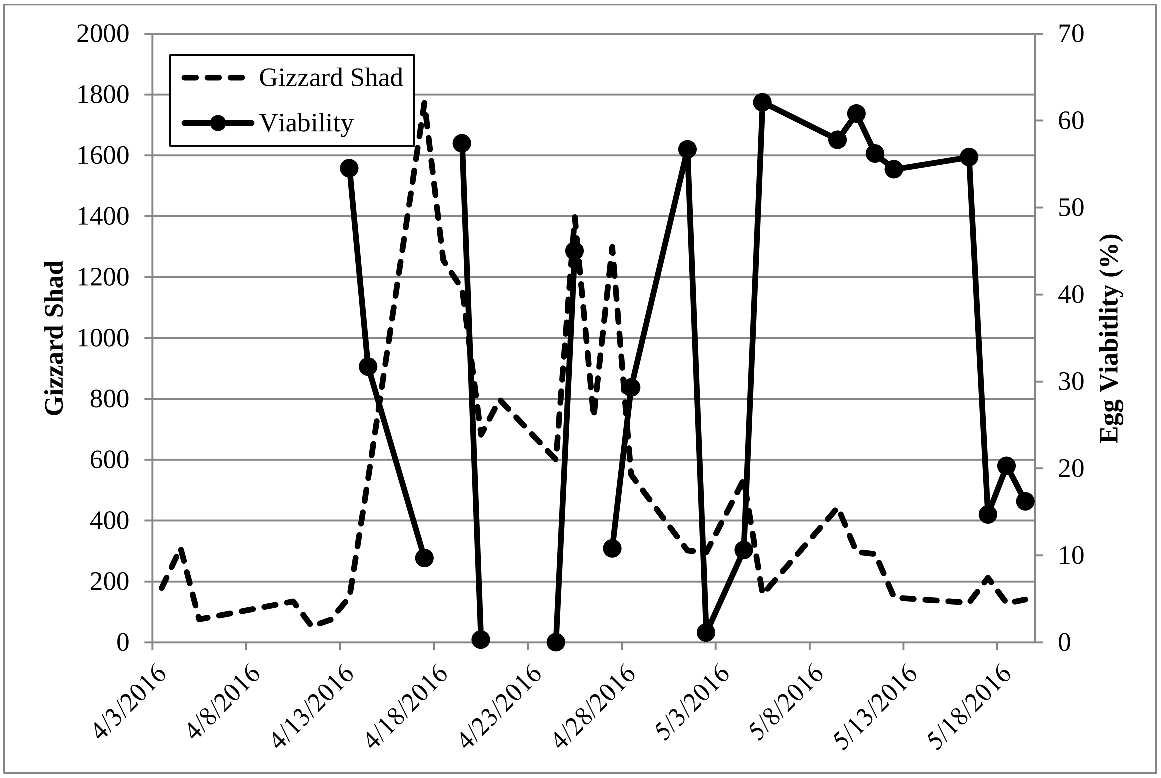

Figure 3. 2016 Potomac River Gizzard shad bycatch and American shad egg shipment viabilities.

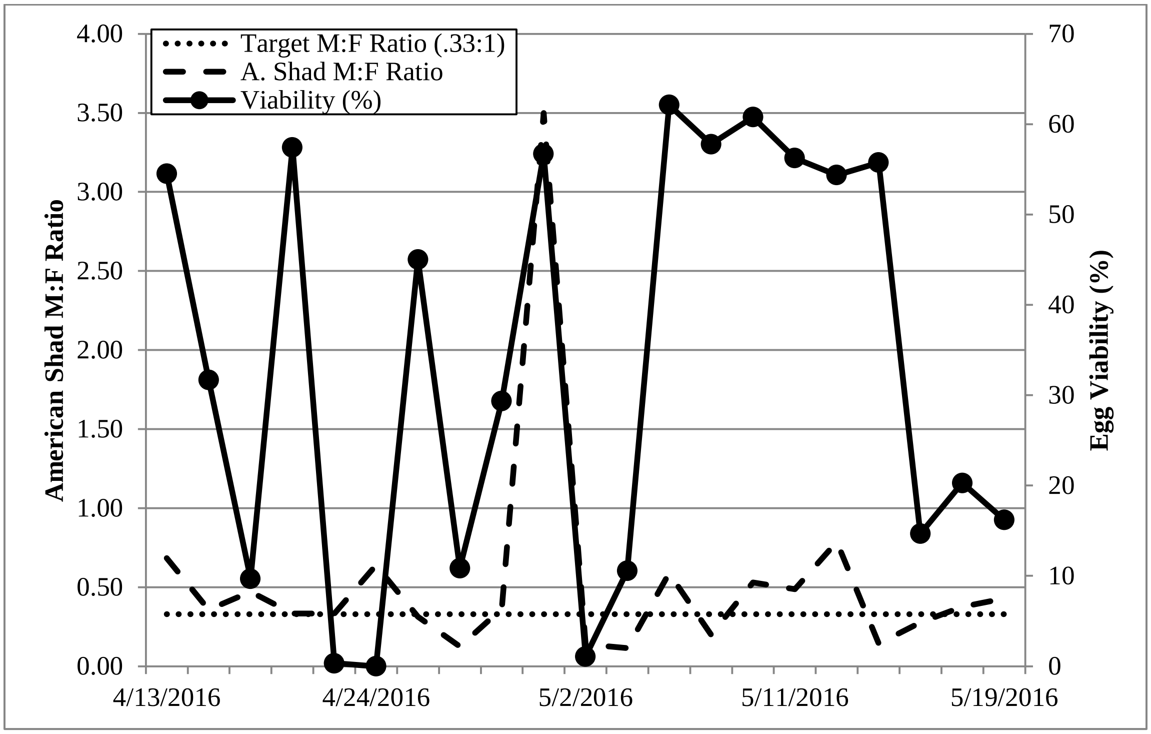

Figure 4. 2016 American shad male to female ratios and egg shipment viabilities. Note: Only fishing events where egg shipments were made are shown.