

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2015

J. D. Tryninewski

Pennsylvania Fish and Boat Commission

Fish Production Services

Benner Spring Fish Research Station

State College, PA

INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous Fishes since 1976 as part of an effort to restore American Shad (*Alosa sapidissima*) to the Susquehanna River Basin. The objectives of the Van Dyke Station were to research culture techniques for American Shad and to rear juveniles for release into the Juniata and Susquehanna Rivers. The program goal is to develop a stock of shad imprinted to the Susquehanna drainage, which will subsequently return to the river as spawning adults. With the completion of the York Haven Dam fish passage facilities in 2000, upstream hydroelectric project owners were no longer responsible for funding the hatchery effort. Funding was provided by the Pennsylvania Fish and Boat Commission.

In 2003, a new effort in migratory fish restoration was undertaken. Adult Hickory Shad (*Alosa mediocris*) were collected and tank-spawned as part of the initial efforts to culture, release and restore runs of Hickory Shad to the Susquehanna and Delaware River basins. No Hickory Shad culture occurred in 2010, or 2012 through 2015 due to budget constraints.

Similar to previous years, production goals for American Shad for 2015 were to stock 10-20 million American Shad larvae. All Van Dyke hatchery-reared American Shad larvae were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by naturally spawning wild adults. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

MATERIAL AND METHODS

The fish culture practices and methods utilized at the Van Dyke hatchery, specific to American Shad propagation, marking / tagging and stocking are summarized in Hendricks (2003).

The collection of American Shad eggs from wild broodstock was accomplished through gillnetting and strip spawning on the Potomac and Delaware rivers, and via tank spawning on the Susquehanna River. Strip spawning relies on the collection of ripe adult shad, which are typically captured on known spawning grounds during evening hours. Eggs from two to three ripe females and milt from one to three males are mixed in a dry shallow bowl. River water is then introduced to activate the sperm and facilitate fertilization. After a few minutes of fertilization, the eggs are thoroughly rinsed and allowed to water harden for at least one hour prior to packaging for shipment to the hatchery. Tank spawning of Susquehanna River American Shad broodstock is accomplished by capturing adult shad from the tailrace of Conowingo Dam (primarily via fish lifts and occasionally by angling). Ripe and gravid shad are injected with a hormone treatment to induce ovulation, and then allowed to spawn naturally in large, round tanks, similar to methods used by Mylonas et al. (1995), Chapman and Chapman (1997) and Fletcher et al. (2001). Peak spawning activity and egg yield usually occurs within two days of initiating a spawning trial. Spawning eggs are collected from the tank's effluent, packaged and shipped to the hatchery for incubation. Egg shipments received at the Van Dyke Hatchery were tempered at 2 °C per half hour to match incubation water temperature, disinfected in a 50 mg/L free iodine bath for ten minutes, and enumerated following a modification of von Bayer's (1908) method to estimate the total number of eggs (Wiggins et al. 1985).

Egg incubation, larvae culture and feeding practices at the Van Dyke hatchery follow methods summarized by Howdy (1985), Wiggins et al. (1984), Wiggins et al. (1985), and Wiggins et al. (1986). Eggs are incubated at 16°C for seven to eight days and treated daily with formalin at 1:600 to prevent fungal growth. A synchronized hatch is induced by exposing the eggs (while in an incubation jar) to direct sunlight. Larvae are hatched directly into circular culture tanks (6 L/min flow at 18 °C) with complete hatch occurring in a few hours. A daily diet of commercially produced dry feed (100-150 micron size) and live brine shrimp nauplii (cultured on station) were fed to shad larvae beginning at three days of age (approximate age of yolk sac absorption). Dead larvae and detritus were siphoned from each culture tank daily and sampled to estimate daily mortality.

All shad larvae produced at the Van Dyke hatchery are marked (tagged) using a four hour immersion treatment in oxytetracycline (OTC) antibiotic. The OTC is incorporated into the calcium of growing bone tissue, which for American Shad larvae of less than thirty days of age are their otoliths (sagittae) (Lorson and Mudrak, 1987). OTC marking of hatchery shad otoliths allows for the differentiation between hatchery and wild produced fish and thereby making it possible to

estimate respective contributions to stock restoration. Lorson and Mudrak (1987) developed the mass-marking technique for shad, which was later refined by Hendricks et al. (1991). Currently, the four hour immersion (static bath) treatments are conducted at 426 mg/L OTC and are administered as early as three days of age. Multiple OTC marks sequences are produced in as few as three day increments and are used to identify stocking site, egg source river, and to produce known-age fish for age validation.

American Shad larvae are stocked when each lot or culture tank has received its complete OTC mark sequence and as river and weather conditions allow. Larvae are gently water-brailed from their culture tanks to stocking coolers (or buckets) lined with a heavy plastic bag at an approximate density of 20,000 larvae per cooler (approximately 15 L water). The stocking bags are filled with oxygen, tightly sealed and transported to the stocking location. Stocking coolers are tempered to within 1 °C of receiving water by water-brailing prior to the larvae being released.

EGG SHIPMENTS

A total of 29 shipments of American Shad eggs, measuring 307 L in volume and containing some 16.3 million eggs, were received at Van Dyke in 2015 (Table 1), which continues a declining trend observed in recent years (2010 – present) (Table 2). The overall egg viability, or the percentage of eggs that ultimately hatch, was 17% and yielded some 2.8 million hatched eggs. The overall egg viability for 2015 was the lowest recorded since 1976 and was well below the long-term average of 45% (1976-2014).

Gill-netting and strip-spawning operations on the Potomac River in 2015 produced 8.8 million American Shad eggs over 12 shipments between 14 April and 8 May. More than 23.1% of these eggs were viable, yielding some 2.0 million eggs for fry culture (Table 1). Egg viability in 2015 was the second lowest recorded since 2006 (range: 21.3% to 50.7%), and was below the long-term average (2006-2014) of 38.9% (Figure 2).

Delaware River gill-netting and strip-spawning operations produced nearly 4 million eggs over nine shipments from 6 May to 22 May 2015 (Table 1). The overall egg viability in 2015 was 12.3% and accounted for some 489,000 live eggs for fry culture (Figure 2); which was the least number of viable eggs produced for fish culture since 1983 and was well below the long-term egg viability average of 40.9% (1982-2014).

American Shad eggs were also obtained from a tank-spawning operation at the Conowingo Dam, Susquehanna River in 2015. Tank-spawning operations were conducted by Normandeau Associates, with brood stock collected from the West Fish Lift. All American Shad brood stock received hormone injections prior to spawning trials in either a 10 or 12 foot diameter tank. The tank-spawn array at Conowingo uses water pumped directly from the river and is subject to natural fluctuations in water temperatures, turbidity and quality. Spawning trials produced 3.4 million eggs which were received at Van Dyke in eight shipments from 6 May through 23 May (Table 1). Overall egg viability in 2015 was 7.9 %, yielding some 273,000 live eggs for fish culture; this was the lowest viability recorded in the 15 years of tank-spawning at Conowingo Dam (Figure 2). Despite the low egg viability and limited quantity of eggs produced, the Conowingo Dam tank-spawning program is the only source of Susquehanna River American Shad eggs for restoration stocking efforts in the Susquehanna Basin.

The American Shad egg collection program in the Hudson River, NY was last conducted in 2006. Concerns over declines in the Hudson River American Shad stock led to the discontinuation of this program. The loss of the Hudson River as an egg source is unfortunate because of its consistent production of high quality eggs. Egg production from the Potomac and Susquehanna rivers have been consistently below the historical production from the Hudson River and it has become apparent that additional or expanded sources of eggs will be required to meet the goal of 10-15 million larvae stocked annually.

Overall, the general quality of eggs received at Van Dyke in 2015 was of moderate to poor quality. A total of seven shipments were found to have no viable eggs and, as a result, were discarded (four shipments from the Potomac, one from the Susquehanna and two from the Delaware) (Table 1). Despite relatively poor egg quality seen in 2015, a few shipments were of impressive quality; five shipments (four from the Potomac and one from the Delaware) had viability estimates between 50% and 66%.

SURVIVAL

Survival of individual tanks followed patterns similar to those observed in the past, where the majority of the tanks experienced their highest mortality between nine and 15 days of age

(Figure 3). No tanks suffered complete mortality in 2015 and overall survival of viable eggs to stocking was estimated at 85.7%.

The fluidized bed system installed in 2008 worked extremely well and the pH of the fish culture water ranged from 6.8 to 7.3 with a mean of 7.1. Daily monitoring of gas saturation and adjustment of the oxygen injection system maintained nitrogen, oxygen and total gas saturation at acceptable levels. Oxygen saturation averaged 100.2% with a maximum of 112.1%. The high oxygen saturation value occurred on 28 May, following a period of about eight days where warming pond temperatures decreased from 64°F to 55°F and then increased to 62°F; the decrease in warming pond temperatures required the fish culture heating and oxygen injection systems to be adjusted several times over a short period of time which likely resulted in the elevated oxygen saturation (an over correction). Oxygen injection was first tuned off, and then slowly increased following frequent monitoring of gas saturation. Nitrogen saturation averaged 100.0% with a maximum of 103.2%. The highest nitrogen saturation value also occurred on 10 April during the initial period of balancing oxygen saturation and water temperatures, prior to eggs or fry being on station. Total gas saturation averaged 99.7% with a maximum of 102.2% (occurred during initial balancing period on 10 April). No incidents of gas bubble disease occurred and larvae stocked in 2015 appeared active and robust.

LARVAL PRODUCTION

Production and stocking of American Shad larvae, summarized in Tables 2, 3, 4 and 5, totaled 2.44 million in 2015. The Susquehanna Basin received nearly 2 million shad larvae in 2015. A majority of which (1.05 million) were released into the Juniata River at Thompsontown and the Lewistown Narrows, PA. Some 272 thousand larvae were released into the Susquehanna River at Clemson Island, PA. The North Branch Susquehanna River at Tunkhannock, PA received more than 274 thousand. The West Branch Susquehanna River at Williamsport, PA was stocked with some 243 thousand larvae while Bald Eagle Creek at Lock Haven, PA (a tributary to the West Branch) received 149 thousand. Due to the inability to test and certify that the larvae were VHS free, no larvae were stocked in the Potomac River or New York waters of the Susquehanna River.

American Shad larval releases for the Delaware River Basin were limited to the Lehigh and Schuylkill Rivers in 2015. The Lehigh River received some 247 thousand larvae at Cementon, PA while the Schuylkill River was stocked with nearly 199 thousand at Reading, PA.

TETRACYCLINE MARKING

All American Shad larvae stocked received marks produced by immersion in tetracycline (Table 6). Immersion marks for American shad were administered by 4-hour bath treatments in 426 ppm oxytetracycline.

All American Shad larvae were marked according to stocking site and/or egg source (Table 6). Some 243 thousand larvae received marks on days 3 and 18 and were stocked into the West Branch Susquehanna River. Bald Eagle Creek, a tributary to the West Branch, received some 149 thousand larvae marked on days 3, 6, 9, 12 and 15. Nearly 850 thousand larvae (Potomac River egg source) marked on days 3 and 6 were released into the Juniata River while an additional 205 thousand larvae marked on days 3, 6 and 9 (Susquehanna River egg source) were also released into the Juniata River. The North Branch Susquehanna River in Pennsylvania received nearly 274 thousand larvae, marked on days 3, 6, 9, and 15. The Lehigh River received 247 thousand larvae marked on days 9, 12 and 15. The Schuylkill River received 198 thousand larvae marked on days 3, 6, 9 and 12.

Verification of mark retention was accomplished by allowing sampled groups of marked larvae to grow-out for an additional period of time in culture tanks at the Van Dyke Hatchery. Following a grow-out period of at least a week beyond the last immersion mark, larvae were sampled and frozen for later analysis. Upon examination, larvae were placed between two microscope slides and gently crushed to expose and position otoliths in a flat (lateral) viewing plane. An epi-fluorescent microscope with a UV light source was then used to locate and identify the tetracycline marks.

Raceway culture at the Benner Spring State Fish Hatchery was not conducted in 2015 due to the presence of an aquatic invasive species, the New Zealand mud snail, in Spring Creek (source water shad raceway culture).

All groups of American Shad larvae examined exhibited the intended mark in 100% of the specimens in 2015; no anomalies or erroneous marks were noted during examinations.

SUMMARY

A total of 29 shipments of American Shad eggs (16 million eggs) were received at Van Dyke in 2015. Total egg viability was 17.2% and survival of viable eggs to stocked larvae was 85.7%, resulting in the production of some 2.4 million larvae. Larvae produced from eggs collected from the Susquehanna and Potomac Rivers were stocked into the Juniata River (1.05 million), the Susquehanna River (272 thousand), the North Branch Susquehanna River (274 thousand), the West Branch Susquehanna River (243 thousand), Bald Eagle Creek (149 thousand). Delaware River source American Shad larvae were stocked into the Lehigh (247 thousand) and Schuylkill (198 thousand) Rivers. No American shad larvae were stocked into the Delaware River because stocking goals in the Lehigh and Schuylkill Rivers were not met.

No major larvae mortality events occurred due to disruption of flows or abrupt changes in water quality conditions. Close monitoring of the quality / condition of fish culture water (i.e. total gas saturation, water temperature and pH) likely contributed to high survival. Further, an additional factor that may have contributed to high larvae survival may be linked to there being fewer larvae on station; affording hatchery staff additional time to monitor, adjust and ensure efficient feed delivery.

All American shad larvae cultured at Van Dyke were marked by 4-hour immersion in oxytetracycline at 426 ppm concentration. Marks for American Shad were assigned based on release site and/or egg source river. Mark retention evaluation found 100% of larvae examined exhibited intended marks.

RECOMMENDATIONS FOR 2016

1. Disinfect all egg shipments at 50 ppm free iodine for 10 minutes.
2. Slow temper eggs collected at river temperatures below 55°F.
3. Continue using dosing pump system (closed system) to deliver formalin to egg battery to control fungus.
4. Routinely feed all larvae beginning on day 3 post-hatch.
5. Continue to hold egg jars on incubation battery until eggs begin hatching (usually day 7), before transferring to the tanks. Transfer incubation jars to the tanks on day 7 without sunning. Sun the eggs on day 8 to force synchronized hatch.

6. Continue to siphon eggshells from the rearing tank within hours of egg hatch.
7. Continue to feed left over AP-100 only if freshly manufactured supplies run out.
8. Use MSXXX jars preferentially to promote egg layering and maintain good egg survival.
9. Continue to collect American Shad eggs from the Potomac River as an additional source of out-of-basin eggs.
10. Continue to mark American Shad larvae at 426 ppm OTC using PENNOX 343 (FDA approved for marking finfish).
11. Continue to utilize the fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and reduce dissolved aluminum.
12. Continue to regularly measure and record pH of fish culture water.
13. Begin measuring and recording hardness and alkalinity of fish culture water on a regular basis to monitor fish culture water quality.
14. Continue to utilize additional packed column de-gassers to reduce the need for oxygen injection.
15. Continue to measure and record oxygen and nitrogen saturation on a daily basis. Use the oxygen injection system only when needed and monitor oxygen saturation and larval condition when the system is in use.
16. Mark all tanks of larvae beginning at 11:00AM, to ensure consistency in daily mark application.
17. Investigate the potential of increasing egg production at the Conowingo Dam by constructing a new tank-spawn facility with the capability of controlling temperatures in order to tank-spawn without the use of hormone injections.

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Figure 1. American Shad eggs incubated at Van Dyke, 1983-2015.

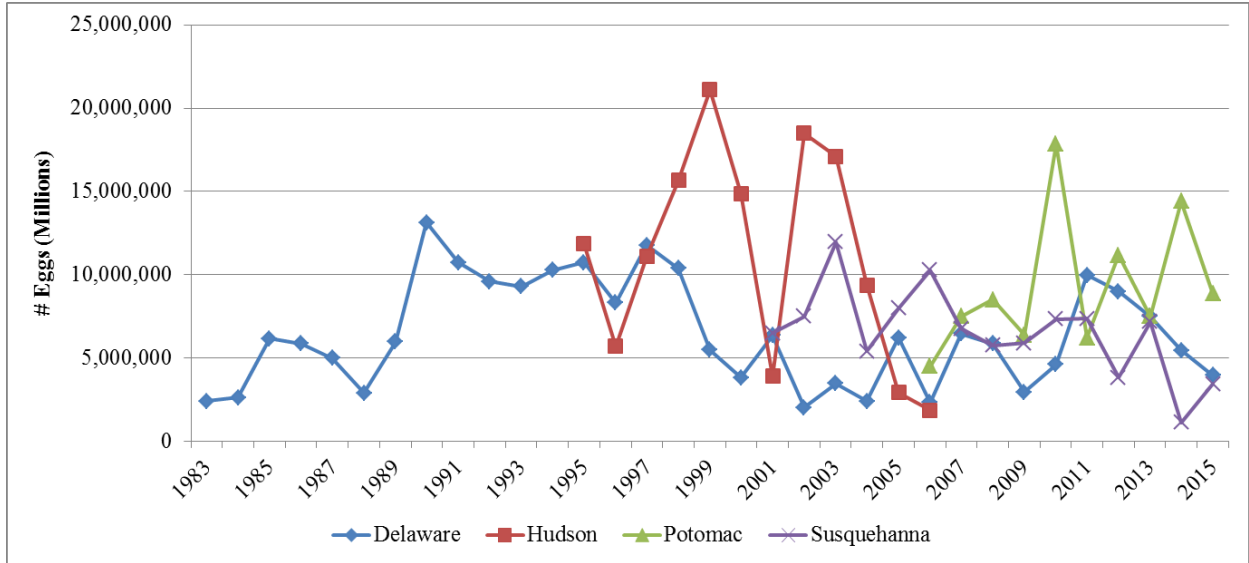


Figure 2. Egg viability (percentage of collected eggs that ultimately hatch) for American Shad strip spawning operations on the Potomac, Delaware and Hudson Rivers and tank spawning on the Susquehanna River, 1983-2015.

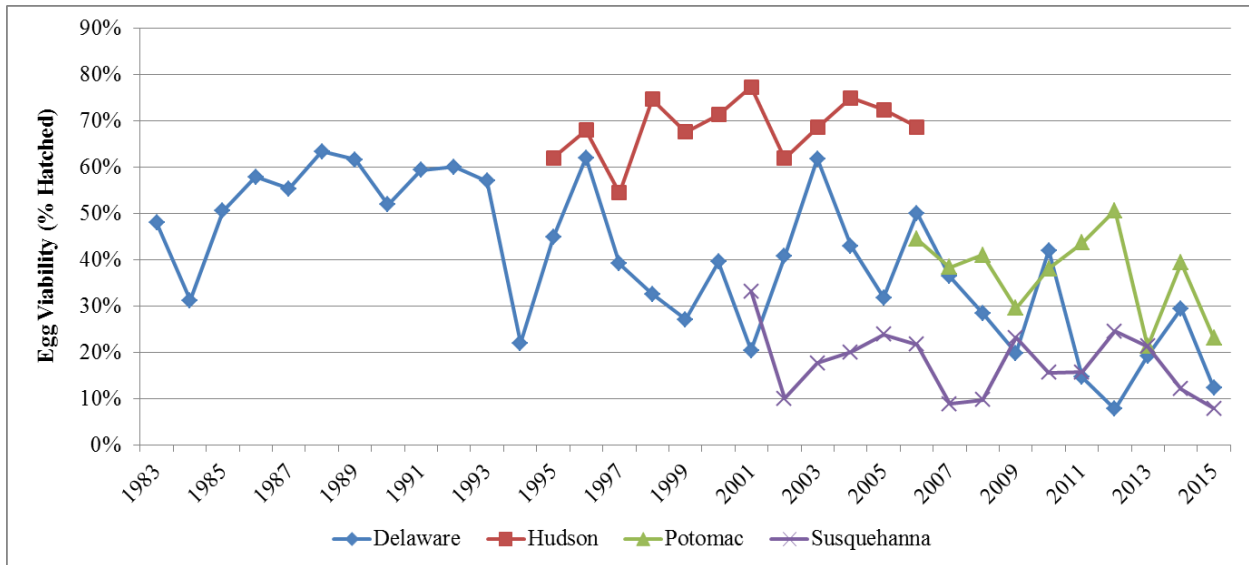


Table 1. Egg shipments received at Van Dyke, 2015.

No.	Species	River	Date Spawnd	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American Shad	Potomac	4/14/15	4/15/15	7.05	440,049	0	0.0%
2	American Shad	Potomac	4/16/15	4/17/15	8.1	454,502	96,166	21.2%
3	American Shad	Potomac	4/22/15	4/23/15	5.66	279,084	184,799	66.2%
4	American Shad	Potomac	4/23/15	4/24/15	10.6	493,635	0	0.0%
5	American Shad	Potomac	4/26/15	4/27/15	7	225,664	135,341	60.0%
6	American Shad	Potomac	4/27/15	4/28/15	7.4	507,637	25,521	5.0%
7	American Shad	Potomac	4/28/15	4/29/15	37.5	1,516,731	772,677	50.9%
8	American Shad	Potomac	4/29/15	4/30/15	38.35	1,664,304	548,404	33.0%
9	American Shad	Potomac	5/3/15	5/4/15	10	613,359	0	0.0%
10	American Shad	Potomac	5/4/15	5/5/15	8	432,861	272,501	63.0%
11	American Shad	Susquehanna	5/6/15	5/6/15	4.9	217,394	0	0.0%
12	American Shad	Potomac	5/6/15	5/7/15	8	591,603	0	0.0%
13	American Shad	Delaware	5/6/15	5/7/15	9.9	381,834	238,027	62.3%
14	American Shad	Potomac	5/7/15	5/8/15	22.8	1,631,094	8,603	0.5%
15	American Shad	Deleware	5/7/15	5/8/15	9.6	359,006	31,706	8.8%
16	American Shad	Delaware	5/10/15	5/11/15	8.3	413,130	27,688	6.7%
17	American Shad	Susquehanna	5/11/15	5/11/15	6.2	317,392	36,743	11.6%
18	American Shad	Delaware	5/11/15	5/12/15	12.5	800,820	15,852	2.0%
19	American Shad	Susquehanna	5/12/15	5/12/15	3.5	246,237	97,959	39.8%
20	American Shad	Delaware	5/12/15	5/13/15	9.4	854,985	6,873	0.8%
21	American Shad	Delaware	5/13/15	5/14/15	10.5	484,292	16,239	3.4%
22	American Shad	Delaware	5/14/15	5/15/15	12.3	450,525	125,828	27.9%
23	American Shad	Susquehanna	5/5/15	5/15/15	14.7	878,118	8,534	1.0%
24	American Shad	Susquehanna	5/17/15	5/17/15	7.8	414,366	1,539	0.4%
25	American Shad	Delaware	5/17/15	5/18/15	2.15	85,497	0	0.0%
26	American Shad	Susquehanna	5/19/15	5/19/15	11.2	686,962	111,524	16.2%
27	American Shad	Susquehanna	5/21/15	5/21/15	5.7	425,001	0	0.0%
28	American Shad	Delaware	5/21/15	5/22/15	3.8	143,582	26,891	18.7%
29	American Shad	Susquehanna	5/22/15	5/23/15	4.2	259,877	17,063	6.6%
Totals					Volume	Eggs	Viable	Percent
			# Shipments	(L)	Eggs	Eggs	Viable	
American Shad	Potomac		12	170.5	8,850,523	2,044,013	23.1%	
	Delaware		9	78.5	3,973,670	489,105	12.3%	
	Susquehanna		8	58.2	3,445,348	273,362	7.9%	
Grand total			29	307.1	16,269,541	2,806,480	17.2%	

Table 2. Annual summary of American Shad production, 1976-2015.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Viability (%)	No. of Viable Eggs (exp.6)	No. of Fry stocked (exp.3)	No. of Fingerling stocked (exp.3)	Total stocked (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969	35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629	34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526	5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048	98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996	30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876	61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274	81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267	60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034	253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963	233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870	79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720	* 140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930	* -	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466	* -	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757	2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412	-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535	-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524	7	6,531	0.31	0.88
2002	943	35.6	38.8	13.8	2,589	-	2,589	0.07	0.19
2003	1005	33.0	49.4	16.3	12,742	-	12,742	0.39	0.78
2004	462	17.3	54.0	9.3	5,637	-	5,637	0.33	0.60
2005	372	17.1	36.6	6.0	5,208	1	5,209	0.30	0.87
2006	394	19.0	35.2	6.7	4,945	-	4,945	0.26	0.74
2007	404	20.7	27.7	5.8	2,509	-	2,509	0.12	0.43
2008	441	20.1	28.3	5.7	4,020	-	4,020	0.20	0.71
2009	282	15.2	25.2	3.8	3,073	-	3,073	0.20	0.81
2010	576	29.8	31.8	9.9	5,471	3	5,474	0.18	0.55
2011	416	23.6	22.6	5.3	4,170	9	4,179	0.18	0.78
2012	435	24.0	30.4	7.3	3,939	2	3,940	0.16	0.54
2013	399	22.2	20.6	4.6	3,103	0	3,103	0.14	0.68
2014	466	21.0	35.3	7.4	4,865	0	4,865	0.23	0.66
2015	307	16.2	17.2	2.8	2,441	0	2,441	0.15	0.87

*Includes fry reared at Manning Hatchery.

Total (exp.3) 278,969

Total OTC marked since 1985 (exp.3) 247,572

Table 3. American Shad eggs (millions) used in Pennsylvania's shad restoration program, by egg source, 1971-2015.

Year	Susquehanna		Susquehanna	Susquehanna	Susquehanna	Susquehanna	Connecticut	Pamunkey	Mattaponi	James	Savannah	Columbia	Potomac	Total
	Hudson Gill Net	Delaware Gill Net	Conowingo Tank Spawn	Lapidum Gill Net	Muddy Run Gill Net	Lamar Tank Spawn	Gill Net	Gill Net	Gill Net	Gill Net	Gill Net	Gill Net	Gill Net	
1971				8.4										8.4
1972				7.1										7.1
1973				4.7			4.3	8.5	6.5				34.6	58.6
1974							0.5	9.8	6.8	19.2		8.2	5.6	50.0
1975								1.9		7.2		18.4	5.7	33.2
1976		4.1										54.8		58.9
1977							0.4	4.4	0.6	3.4				17.6
1978								6.9		10.1		0.0		17.0
1979								3.2		5.0		0.0		8.2
1980								6.7		6.8		0.0		13.6
1981								4.6		1.3		5.8		11.6
1982								2.0		1.3		22.6		25.9
1983	1.2	2.4						5.5		5.9		19.5		34.5
1984		2.6						9.8		0.7		27.9		41.1
1985		6.2						5.3		2.1		12.1		25.6
1986		5.9						5.6		1.1		40.0		52.5
1987		5.0						4.4		0.1		23.5		33.0
1988		2.9						1.9		0.0		26.9		31.8
1989	11.2	6.0						1.9		0.5		23.1		42.7
1990	14.5	13.1				0.3		0.5			0.1			28.6
1991	17.7	10.7				0.3	1.1							29.8
1992	3.0	9.6					5.7			0.2				18.5
1993	3.0	9.3					7.4	1.8						21.5
1994	6.3	10.3					4.1	0.5	0.0					21.2
1995	11.9	10.8												22.6
1996	5.7	8.3				0.4								14.4
1997	11.1	11.8												22.8
1998	15.7	10.4				1.7								27.7
1999	21.1	5.5												26.6
2000	14.9	3.8												18.7
2001	3.9	6.3	5.8			5.1								21.1
2002	18.5	2.0	7.1			8.0								35.6
2003	17.1	3.6	11.7	0.6	0.0									33.0
2004	9.4	2.4	4.7	0.8										17.3
2005	2.9	6.2	8.0											17.1
2006	1.9	2.3	10.3										4.5	19.0
2007		6.5	6.8										7.5	20.7
2008		5.9	5.7										8.5	20.1
2009		3.0	5.9										6.4	15.2
2010		4.6	7.3										17.8	29.8
2011		10.0	7.4										6.2	23.6
2012		9.0	3.8										11.2	24.0
2013		7.5	7.2										7.5	22.2
2014		5.5	1.1										14.4	21.0
2015		4.0	3.4										8.9	16.3
Total	190.8	217.4	96.3	21.6	0.0	15.7	23.5	85.1	13.9	64.8	0.1	291.6	138.8	1,159.8

Table 4. American Shad stockings, 2015.

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age (d)	Size
5/19/15	A1	American Shad	54,302	Juniata River	3,6	Potomac	24	Fry
5/19/15	A2	American Shad	161,593	Juniata River	3,6	Potomac	19	Fry
5/19/15	A3	American Shad	131,849	Juniata River	3,6	Potomac	15	Fry
5/29/15	A4	American Shad	274,425	N. Branch Susq. River	3,6,9,15	Potomac	23	Fry
5/20/15	B1	American Shad	272,686	Susquehanna River	9	Potomac	14	Fry
5/28/15	B2	American Shad	149,368	Bald Eagle Creek	3,6,9,12,15	Potomac	22	Fry
5/26/15	B3	American Shad	229,645	Juniata River	3,6	Potomac	19	Fry
5/28/15	B4	American Shad	243,189	W. Branch Susq. River	3,18	Potomac	21	Fry
5/27/15	C1	American Shad	267,155	Juniata River	3,6	Potomac	16	Fry
6/8/15	C2	American Shad	212,775	Lehigh River	9,12,15	Delaware	25	Fry
5/26/15	C3	American Shad	5,251	Juniata River	3,6	Potomac	9	Fry
6/8/15	C4	American Shad	34,875	Lehigh River	9,12,15	Delaware	19	Fry
5/27/15	D1	American Shad	5,000	Juniata River	3,6,9	Susquehanna	11	Fry
5/30/15	D2	American Shad	93,845	Juniata River	3,6,9	Susquehanna	11	Fry
5/11/15	D3	American Shad	179,548	Schuylkill River	3,6,9,12	Delaware	19	Fry
5/9/15	D4	American Shad	6,314	Juniata River	3,6,9	Susquehanna	12	Fry
5/9/15	A1	American Shad	99,950	Juniata River	3,6,9	Susquehanna	16	Fry
5/11/15	A3	American Shad	19,307	Schuylkill River	3,6,9,12	Delaware	13	Fry

Table 5. Summary of juvenile Alosines stocked from the Van Dyke Hatchery, 2015.

	Site	Fry
Amerian Shad	Thompstontown, Juniata River	507,051
	Lewistown Narrows, Juniata River	547,853
Releases	Juniata River Subtotal	1,054,904
	Susquehanna River, Clemson Island	272,686
	North Branch Susquehanna River, Tunkhannock	274,425
	West Branch Susquehanna River, Williamsport	243,189
	Bald Eagle Creek (trib. to W.Br. Susquehanna River), Lock Haven	149,368
	Susquehanna River Basin Subtotal	1,994,571
	Schuylkill River, Reading	198,855
Lehigh River, Cementon	247,649	
	Delaware River Basin Subtotal	446,504
	Total American Shad	2,441,075

Table 6. Summary of marked Alosines stocked in Pennsylvania, 2015.

Number	Size	Immersion mark (days)	Stocking Location	Egg Source	Immersion mark
243,189	Fry	3,18	West Branch Susquehanna River	Potomac	426ppm OTC
149,368	Fry	3,6,9,12,15	Bald Eagle Creek	Potomac	426ppm OTC
205,109	Fry	3,6,9	Juniata River	Susquehanna	426ppm OTC
849,794	Fry	3,6	Juniata River	Potomac	426ppm OTC
274,425	Fry	3,6,9,15	North Branch Susquehanna River (PA)	Potomac	426ppm OTC
272,686	Fry	9	Susquehanna River (Clemson Is.)	Potomac	426ppm OTC
1,994,571 Total Susquehanna River Basin					
247,649	Fry	9,12,15	Lehigh River	Delaware	426ppm OTC
198,855	Fry	3,6,9,12	Schuylkill River	Delaware	426ppm OTC
446,504 Total Delaware River Basin					
2,441,075 Total American shad stocked					