

ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER - 2012

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INTRODUCTION

This report summarizes the results of bio-monitoring activities for juvenile alosines conducted in the Susquehanna River and its tributaries in 2012.

The Conowingo West Fish Lift continued to be used as a source of adult American shad and river herring to support monitoring activities and tank spawning. A total of 1,486 adult shad were collected at the Conowingo West Lift. The majority were released back into the Conowingo tailrace, with 492 retained for tank spawning.

Since the completion of fish passage facilities at Holtwood and Safe Harbor in 1997, the Conowingo East Lift has operated in fish passage mode. American shad had access to the Inlatable Dam at Sunbury on the Susquehanna main stem, and Warrior Ridge or Raystown Dams on the Juniata. Portions of large tributaries including Muddy Creek, West Conewago Creek, Conestoga River, Conodoguinet Creek, and Swatara Creek were also accessible to American shad.

During the 2012 spring migration, Conowingo East Lift passed 23,629 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 4,238, 3,089, and 224 American shad, respectively. Some 25 blueback herring and 27 alewife were passed at Conowingo Dam.

No river herring were passed at Holtwood, Safe Harbor or York Haven Dams. No hickory shad were passed at any of the Susquehanna River dams.

Juvenile American shad in the Susquehanna River above Conowingo Dam are derived from two sources, natural reproduction of adults passed at the lower river hydroelectric projects, and hatchery produced, marked larvae from Pennsylvania Fish and Boat Commission's (PFBC) Van Dyke Hatchery in Pennsylvania. Juveniles occurring in the river below Conowingo and the upper Chesapeake Bay may result from natural spawning below or above dams and hatchery fry stockings either in Maryland or from upstream releases in Pennsylvania.

During the 2012 production season, the PFBC Van Dyke Research Station for Anadromous Fish produced 3.4 million shad larvae which were released in the Susquehanna Basin in Pennsylvania. Larval releases occurred from 25 May to 13 June with most releases (27 tanks) preceding a spike in flow on June 3, and the remainder (4 tanks) occurring during receding flows thereafter (Figure 3).

Larvae were released in the following locations and numbers:

Juniata River	2,844,223
North Branch Susquehanna River (PA)	149,672
West Branch Susquehanna River	172,320
Bald Eagle Creek	271,120

The production goal of 10 million larvae was not met, primarily due to the loss of the Hudson River as an egg source.

METHODS

Sampling for juvenile American shad was conducted at locations in the Susquehanna River Basin during the summer and fall in an effort to document in-stream movement, out-migration, abundance, growth, and stock composition/mark analysis. Juvenile recoveries from all sources were provided to the PFBC for otolith analysis. Otoliths were analyzed for tetracycline marks to determine hatchery versus wild composition of the samples.

After 2009, Lift net collections in the forebay at Holtwood were permanently discontinued due to construction of the new powerhouse and the associated reconfiguration of the forebay. An additional haul seine site at City Island in Harrisburg was added in 2010 to compensate for the loss of the lift netting. Geometric mean catch-per-unit effort (GM CPUE) was calculated as an index of juvenile abundance for haul seine collections. Ideally, CPUE would be calculated using data from individual lifts or seine hauls. Unfortunately, this data is not available prior to 1995 for lift netting and prior to 1997 for haul seining. As a result, geometric means could not be computed in the usual way for those years. Combined daily catch for each gear is available and was used as a surrogate to compute GM means. ASMFC stock assessment (ASMFC 2007) recommends use of area-under-the-curve (AUC) methods in cases where sampling is targeted at migrants moving through an area. Because the Holtwood dam lift net collected juvenile shad during the directed outmigration, AUC measures of juvenile abundance were calculated for lift net collections.

Haul Seining - Main Stem

Haul seining in the lower Susquehanna River was scheduled once each week beginning mid-July and continuing through October. High flows were experienced in the river due to Hurricane Sandy and the last sampling date was postponed until November 8. Sampling occurred at the Columbia Borough boat launch and City Island in Harrisburg. Sampling consisted of 6 hauls per date beginning at sunset and continuing into the evening with a net measuring 400 ft x 6 ft with 3/8 in stretch mesh.

Peach Bottom Atomic Power Station (PBAPS) and Conowingo Dam

Intake screens were monitored for impinged alosines at Peach Bottom APS in 2012. Intake screen sampling was conducted from 2 November to 7 December, 2012. Eight sampling events were conducted during the outmigration period. Nine sampling events were cancelled due to maintenance activities at the site. Conowingo Hydroelectric Station's cooling water intake strainer sampling was conducted twice weekly (Monday and Friday) from 3 October through 21 November 2011. Sampling occurred twice weekly during this period for a total of 15 sampling events.

Safe Harbor Dam Strainers

Juvenile American shad were collected from strainers at Safe Harbor Hydroelectric station, frozen whole and provided to PFBC for otolith analysis.

Susquehanna River Mouth and Flats

Maryland DNR sampled the upper Chesapeake Bay using haul seines in the summer and fall.

Disposition of Samples

Sub-samples of up to 30 juveniles per day were used for otolith analysis. Samples of shad from most collections were returned to the PFBC's Benner Spring Fish Research Station for analysis of tetracycline marks on otoliths. Otoliths were surgically removed from the fish, cleaned and mounted on slides, ground to the focus on the sagittal plane on both sides, and viewed under ultraviolet light to detect fluorescent rings indicating tetracycline immersion treatments.

RESULTS

Haul Seining - Main Stem

One juvenile American shad was captured by haul seine at the Columbia boat launch (Figure 1, Table 1) and none were collected at City Island (Figure 2, Table 4). The Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) for the Columbia site was 0.01 (Tables 2 and 5). Table 3 lists weekly catches of American shad by haul seine at Columbia from 1989 to 2012. Catches generally peaked in August and September, except in 1989 and 1992 when catches peaked in July, in 2010 when catches peaked in October and in 2005 -2012 when there was no peak. The Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) for the City Island site was 0.00 (Tables 4 and 5). Table 6 lists weekly catches of American shad by haul seine at City Island from 2010 to 2012.

Lift Netting at Holtwood

Lift netting did not occur in 2012 due to construction activities in the Holtwood forebay. Geometric Mean CPUE (individual lift), GM CPUE (combined daily) and Area under the curve (AUC) for collections from 1985 to 2009 are listed in Table 7. Historical weekly catches peaked in October, except in 1985, 1997, 2000, and 2001 when catches peaked in November (Table 8).

Peach Bottom APS, and Conowingo Dam

Peach Bottom intake screens produced 29 juvenile American shad (Tables 9 and 10). One was collected on Nov 1, 26 on Nov. 2, two on Nov. 5 and one on Nov. 19.

Cooling water intake strainers at Conowingo produced one American shad collected on November 1 (Tables 11 and 12).

Safe Harbor Dam Strainers

In 2012, Safe Harbor Dam Strainers produced 35 American shad. Thirty-three were recovered on October 30, four on October 31 and two on November 1.

Susquehanna River Mouth and Flats

In 2012, 13 juvenile American shad were captured at seven permanent sites and five auxiliary sites (Table 13). This low recruitment is thought to be related to a dry spring.

OTOLITH MARK ANALYSIS

Results of otolith analysis are presented in Table 14. For all sites combined, hatchery contribution was 83%. Juvenile shad were captured from releases at all sites including the Juniata R./Raystown Branch (24.3%), the Raystown Branch Juniata R. (Susquehanna source eggs; 6.9%), the North Branch Susquehanna River (15.5%), Bald Eagle Creek (10.3%) and the West Branch Susquehanna River (12.1%). See Job III, Appendix 1 for a discussion of the relative survival of the uniquely marked groups of larvae.

DISCUSSION

River conditions for the Susquehanna River Basin during 2012 could be characterized as typical with several peak flows in May and another peak in late October due to Hurricane Sandy (Figure 3).

Abundance – Main Stem

In 2012, only one juvenile shad was collected by haul seine. This is well below the numbers captured during 1990 to 2001 when an average of 330 juvenile shad were captured by haul seine.

GM CPUE for haul seine at Columbia for individual hauls and combined daily hauls, was 0.01 and 0.01, respectively (Table 2). GM CPUE for haul seine at City Island for individual hauls and combined daily hauls were both 0.00 (Table 5). Juvenile shad abundance has been well below normal for eleven consecutive years (Figure 4), a disturbing trend that will impact upstream fish passage counts until at least 2017. In 2002, problems at the Van Dyke Hatchery resulted in release of comparatively few healthy larvae. In 2003 and 2004, high river flows had a negative impact on survival of stocked hatchery larvae and on fish passage efficiency. Poor catch rates for juvenile shad in 2005 may have been due, in part, to fewer larvae stocked. In 2006, poor catch rates were attributed to fewer larvae stocked (compared to the decade of the 1990's) and the late June flood which, undoubtedly, impacted survival. In 2007, flows were low and decreased steadily during the entire season. Poor catch rates in 2007 were attributed to decreased egg deliveries, poor survival in the hatchery (see Job III), and poor fish passage. The poor catch rates in 2008 to 2012 are troubling. The number of larvae stocked during those years averaged 3.3 million. This represents 42% of the average number of larvae stocked during 1993 to 2001. In comparison, CPUE for 2008 to 2012 was less than 1% of the CPUE for 1993 to 2001. It is clear that survival of hatchery-reared American shad larvae in the Susquehanna River Basin has plummeted in recent years. The cause of this phenomenon is unknown. We do know that YOY smallmouth bass have suffered outbreaks of *Columnaris* bacterial infections which have caused high mortalities and inhibited smallmouth year class strength for 2005 to 2012. The suspected cause of this is low dissolved oxygen in shallow water habitats where smallmouth bass YOY are found. American shad larvae and juveniles are generally not found in these shallow water habitats, preferring deeper water. No *Columnaris* symptoms have been noted on juvenile American shad and it is unknown if smallmouth bass and shad survival are in any way related.

SUMMARY

- One juvenile American shad was collected by haul seine at Columbia, while none were collected by haul seine at City Island. A total of 29 were collected in intake screens at

Peach Bottom Nuclear Power Station, One was collected in strainers at Conowingo Dam and 35 were collected in strainers at Safe Harbor Dam.

- Haul seine GM CPUE at Columbia (combined daily lifts) of 0.01 was among the lowest recorded for that gear type since 1990 and continues a disturbing trend since 2002.
- Lift-net collections in the Holtwood Dam forebay were permanently discontinued due to construction associated with Holtwood re-development.
- Otoliths from all sites combined were 83% hatchery origin and 16% wild, confirming that some natural reproduction of shad occurred in 2012.
- Production of hatchery larvae from the Van Dyke Hatchery was 3.4 million.
- **Based on haul seine CPUE at Columbia, survival of hatchery-reared American shad larvae was 119 times lower during 2008 to 2012 than during 1993 to 2001 indicating that survival of hatchery-reared larvae has plummeted in recent years. The cause of this is not known.**

ACKNOWLEDGMENTS

Normandeau Associates (Drumore, PA) was contracted by the PFBC to perform juvenile collections. Many individuals supplied information for this report. Cassie Miller and Amanda Lower processed shad otoliths.

LITERATURE CITED

ASMFC 2007. American Shad Stock Assessment Report for Peer Review. Volume I. Stock Assessment Report No. 07-01 (Supplement) of the Atlantic States Marine Fisheries Commission. Atlantic States Marine Fisheries Commission, Bethesda, MD.

FIGURES

Figure 1. Location of the haul seine stations sampled in the lower Susquehanna River near Columbia, Pennsylvania in 2012

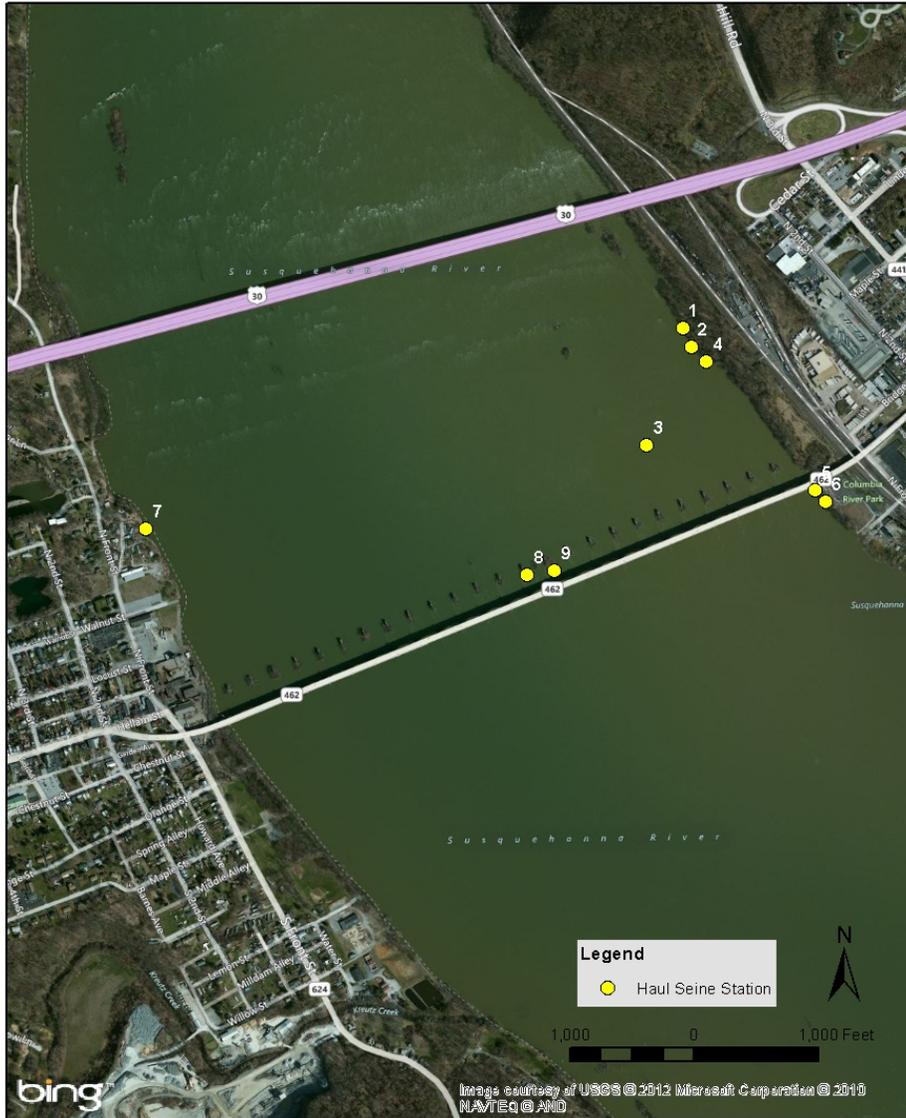


Figure 1.

Location of the haul seine stations sampled in the lower Susquehanna River near Columbia, Pennsylvania in 2012.

Figure 2. Location of the haul seine stations sampled in the middle Susquehanna River around City Island near Harrisburg, Pennsylvania in 2012.

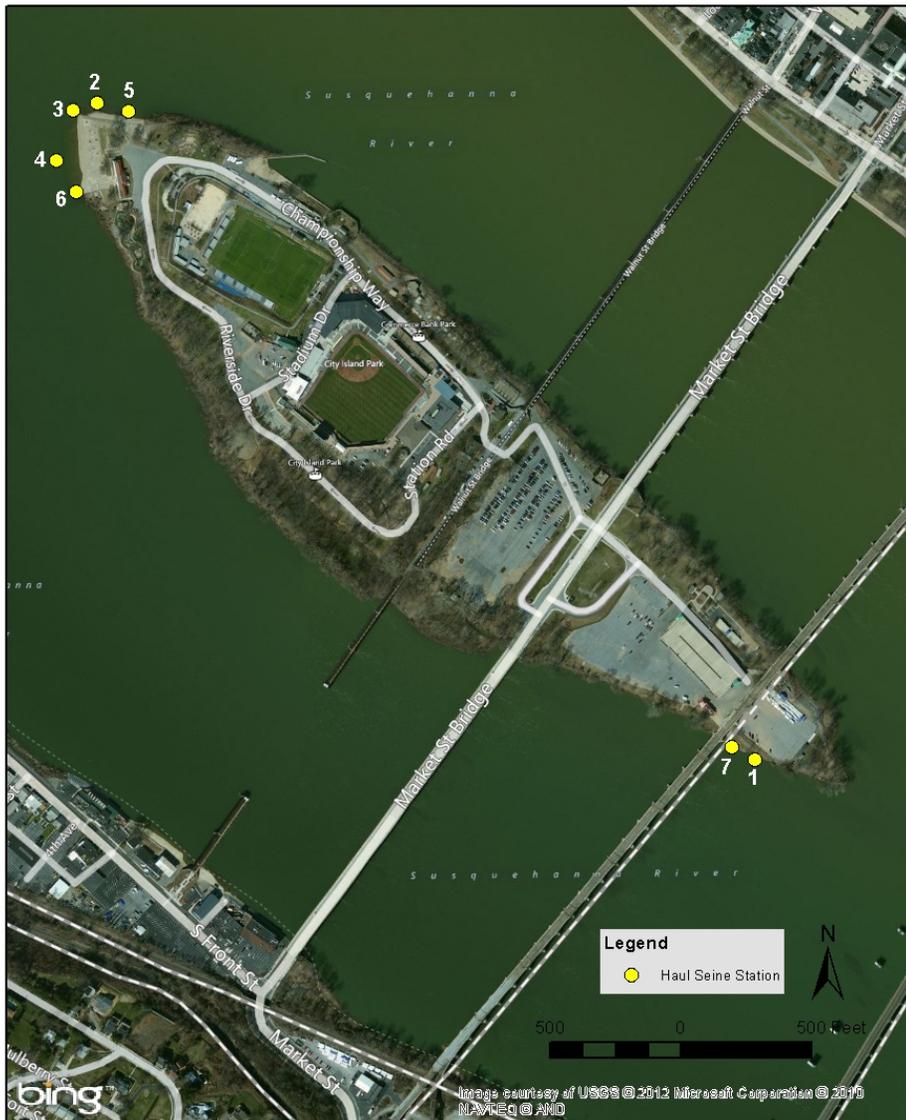


Figure 1.

Location of the haul seine stations sampled in the middle Susquehanna River around City Island near Harrisburg, Pennsylvania in 2012.

FIGURE 3. DISCHARGE (CFS) IN THE SUSQUEHANNA RIVER AT MARIETTA, APRIL 1, 2012 TO NOVEMBER 30, 2012.

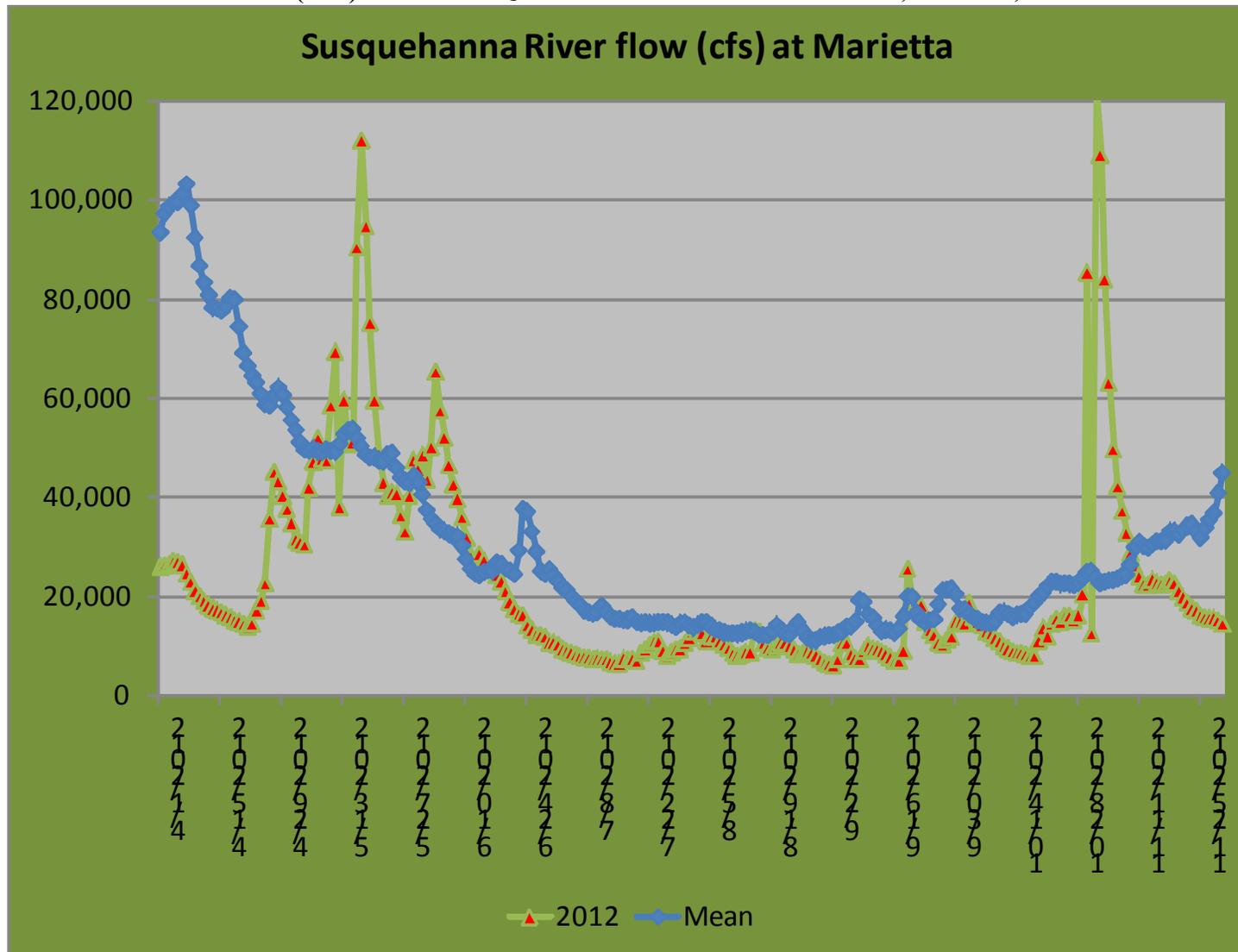
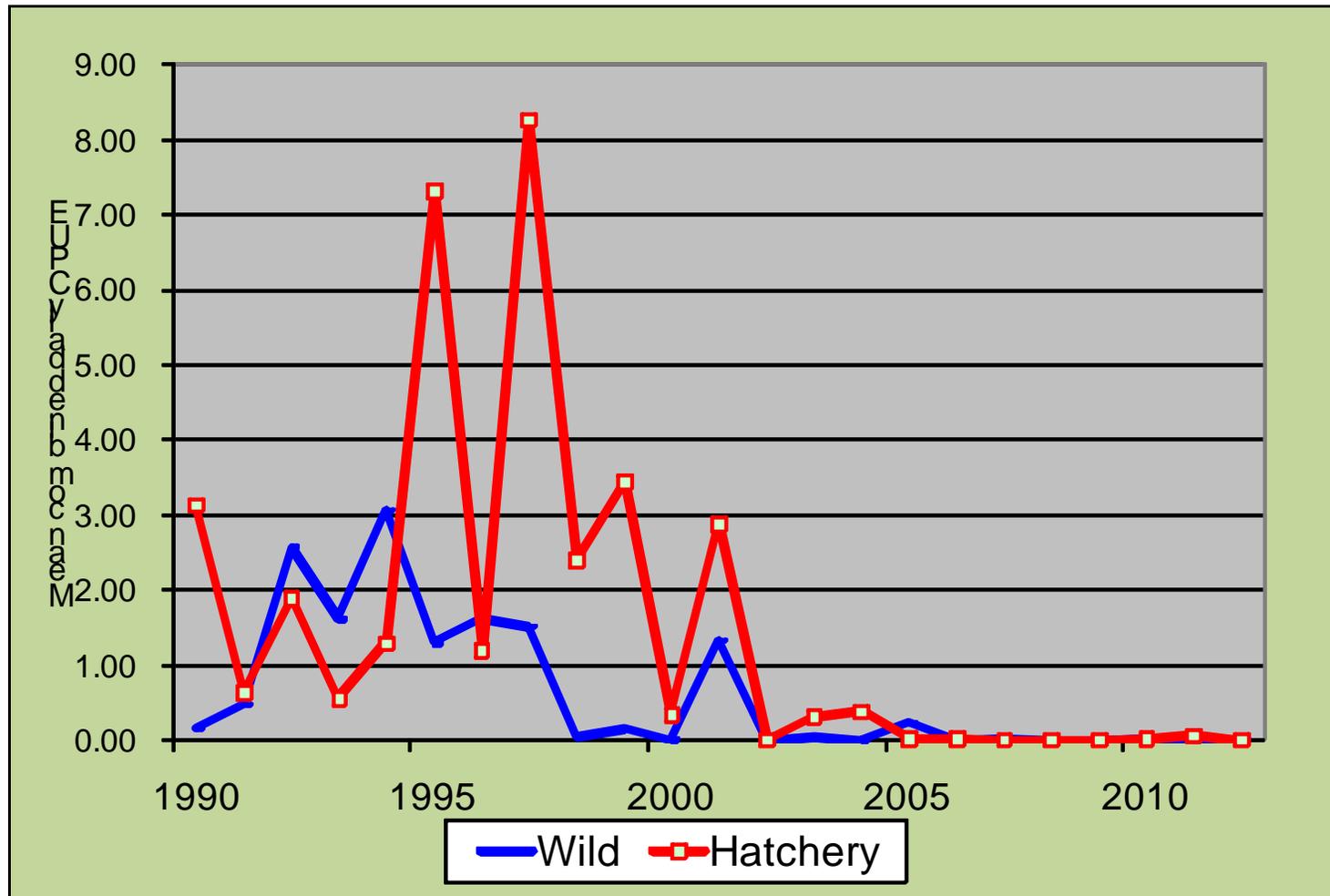


FIGURE 4. ANNUAL YOY AMERICAN SHAD CPUE FOR HAUL SEINE COLLECTIONS IN THE SUSQUEHANNA RIVER AT COLUMBIA.



TABLES

Table 1. Number and percent composition of the fish collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2012.

Date	23-Jul	30-Jul	7-Aug	13-Aug	21-Aug	28-Aug	5-Sep	11-Sep	17-Sep	25-Sep	2-Oct	9-Oct	16-Oct	23-Oct	8-Nov	Total	%
Daily Mean River Flow (cfs)	10,800	12,300	10,600	8,920	11,150	8,920	9,720	9,130	7,130	12,100	16,300	11,500	9,660	15,200	31,700		
Water Temperature (°C)	26.0	28.5	28.2	27.5	23.0	27.5	26.0	22.5	20.0	16.5	18.0	15.0	14.2	14.0	5.0		
Secchi Disk (in)	96	80	60	30	28	50	45	55	70	50	18	80	80	55	32		
American shad	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1%
Gizzard shad	18	7	10	53	35	11	2	-	3	150	56	18	14	76	-	453	29.1%
Spotfin shiner	28	12	10	4	10	6	4	1	13	8	8	20	5	37	-	166	10.7%
Common carp	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	2	0.1%
River chub	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	2	0.1%
Golden shiner	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1%
Comely shiner	-	7	13	16	28	16	22	6	22	9	5	110	139	169	48	610	39.2%
Spottail shiner	-	-	-	4	-	11	5	6	21	7	3	2	24	18	3	104	6.7%
Bluntnose minnow	-	1	-	-	-	1	-	-	2	-	3	1	-	16	1	25	1.6%
Fallfish	-	-	1	-	3	1	1	1	5	2	3	3	1	5	-	26	1.7%
White sucker	-	3	-	-	3	7	1	1	-	1	-	-	-	-	-	16	1.0%
Northern hog sucker	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2	0.1%
Shorthead redhorse	6	-	3	-	-	-	-	1	-	-	-	-	-	-	-	10	0.6%
Channel catfish	-	2	-	1	-	-	1	-	-	-	1	-	-	-	-	5	0.3%
Banded killifish	-	1	3	4	-	-	-	1	-	1	-	-	-	-	-	10	0.6%
Rock bass	-	-	-	-	-	-	1	-	-	1	-	-	2	-	-	4	0.3%
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	0.1%
Green sunfish	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	2	0.1%
Bluegill	-	-	1	-	-	2	6	-	3	11	5	11	3	17	1	60	3.9%
Smallmouth bass	-	-	2	2	-	27	1	-	-	1	-	-	-	-	-	33	2.1%
Largemouth bass	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1%
Greenside darter	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	0.1%
Tessellated darter	2	3	2	2	1	-	3	-	-	-	-	6	-	-	1	20	1.3%
Walleye	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	0.1%
Total	54	37	47	88	83	82	48	17	69	191	85	174	190	338	54	1,557	100.0%
No. of Species	3	9	11	10	9	9	12	7	7	10	9	10	8	7	5	24	

Table 2. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, Susquehanna River, 1990-2012.

		Total				Wild			Hatchery		
			Mean	GM	GM		Mean	GM		Mean	GM
			Combined	Combined	Individual		Combined	Combined		Combined	Combined
			Daily	Daily	Haul		Daily	Daily		Daily	Daily
	No.	No.	CPUE	CPUE	CPUE*	No.	CPUE	CPUE	No.	CPUE	CPUE
Year	Hauls	Fish	(Wild)	(Wild)	(Wild)	Fish	(Wild)	(Wild)	Fish	(Hatchery)	(Hatchery)
1990	87	285	4.40	1.23		0	0.15	0.11	272	4.25	1.18
1991	144	170	1.01	0.54		80	0.48	0.35	90	0.53	0.21
1992	92	269	4.24	1.45		146	2.49	0.78	172	2.63	0.91
1993	111	218	1.90	1.22		174	1.61	1.01	44	0.29	0.19
1994	110	390	4.74	2.29		254	3.19	1.38	322	3.64	2.04
1995	48	409	8.92	7.89		58	1.29	1.06	351	7.63	6.85
1996	105	283	2.89	2.05		157	1.61	1.20	126	1.28	0.99
1997	90	879	9.77	6.77	3.36	136	1.51	1.24	743	8.26	5.65
1998	94	230	2.51	1.03	0.50	5	0.05	0.05	225	2.46	0.97
1999	90	322	3.58	1.16	0.67	13	0.15	0.13	309	3.43	1.06
2000	90	31	0.34	0.26	0.14	0	0.00	0.00	31	0.34	0.26
2001	90	377	4.19	3.04	1.52	119	1.32	1.25	258	2.87	2.14
2002	84	-	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
2003	48	17	0.35	0.28	0.20	2	0.04	0.04	15	0.31	0.25
2004	66	25	0.38	0.25	0.17	0	0.00	0.00	25	0.38	0.25
2005	90	23	0.26	0.24	0.16	21	0.23	0.24	2	0.02	0.02
2006	66	1	0.02	0.01	0.01	0	0.00	0.00	1	0.02	0.01
2007	66	2	0.02	0.02	0.02	2	0.02	0.02	0	0.00	0.00
2008	90	0	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
2009	84	0	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
2010	84	3	0.04	0.03	0.03	2	0.02	0.02	1	0.01	0.01
2011	50	3	0.06	0.06	0.04	0	0	0	3	0	0
2012	90	1	0.02	0.01	0.01	otoliths ground out			otoliths ground out		

TABLE 3. WEEKLY CATCH OF JUVENILE AMERICAN SHAD BY HAUL SEINE FROM THE LOWER SUSQUEHANNA RIVER NEAR COLUMBIA, 1989 THROUGH 2012.

Month	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
1-7 Jul	-	-	-	0	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
8-15 Jul	1,048	-	0	120	0	27	-	2	44	-	0	7	-	-	-	0	-	-	-	-	-	-	-	-	1,248
16-23 Jul	-	-	0	6	-	70	53	18	28	24	0	3	46	0	0	0	2	*	0	0	0	-	0	0	250
24-31 Jul	45	31	-	-	0	60	24	15	22	144	1	0	42	0	0	*	0	*	2	0	0	-	1	0	387
1-7 Aug	-	0	0	20	0	24	29	32	14	30	1	2	70	0	*	*	5	0	0	0	*	-	1	1	229
8-15 Aug	61	0	0	2	8	13	35	56	20	0	0	6	37	0	*	0	1	0	0	0	0	-	1	0	240
16-23 Aug	7	69	0	16	0	46	40	43	171	9	0	1	36	0	0	*	2	0	0	0	0	0	0	0	440
24-31 Aug	-	-	-	-	13	-	42	39	120	10	10	0	36	0	8	16	2	0	0	0	0	0	0	0	296
1-7 Sep	-	25	12	-	20	-	43	34	129	3	*	0	23	0	5	5	3	*	0	0	0	0	*	0	302
8-15 Sep	-	97	16	-	41	75	65	4	135	3	264	0	31	0	4	4	0	0	0	0	0	0	*	0	739
16-23 Sep	-	28	30	-	27	14	46	12	59	4	17	0	15	0	0	*	1	0	0	0	0	0	0	0	253
24-30 Sep	-	0	73	-	11	5	15	15	32	0	20	1	34	0	*	*	2	0	0	0	0	0	*	0	208
1-7 Oct	-	0	69	2	22	5	19	10	91	3	1	0	6	0	*	0	0	0	0	0	0	*	*	0	228
8-15 Oct	-	0	7	-	0	2	31	3	0	0	3	11	1	0	0	0	2	0	0	0	0	1	*	0	61
16-23 Oct	-	-	5	-	-	10	-	-	14	0	5	0	0	*	*	0	3	1	0	0	0	0	*	0	38
24-31 Oct	-	-	0	0	-	-	0	0	-	-	-	-	0	0	*	0	*	-	-	-	-	2	-	*	2
1-7 Nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	0	-	*	0
8-15 Nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	0	0
16-23 Nov																						0			0
24-30 Nov																									0
1-7 Dec																									0
TOTAL	1,161	250	212	166	142	353	442	283	879	230	322	31	377	0	17	25	23	1	2	0	0	3	3	1	4,923

* No sampling due to high river flow.

Table 4. Number and percent composition of the fish collected by haul seine from the middle Susquehanna River at City Island, Harrisburg, Pennsylvania in 2012.

Date	18-Jul	25-Jul	2-Aug	9-Aug	16-Aug	23-Aug	30-Aug	6-Sep	13-Sep	20-Sep	27-Sep	4-Oct	11-Oct	18-Oct	25-Oct	Total	%
Daily Mean River Flow (cfs)	5,160	5,570	8,700	7,150	8,830	8,640	5,960	6,160	7,400	16,200	8,760	11,900	8,300	6,850	13,600		
Water Temperature (°C)	28.0	29.5	28.5	30.6	28.0	28.0	26.5	25.5	22.5	20.0	21.0	19.0	14.5	15.5	16.0		
Secchi Disk (in)	45	50	55	40	55	36	50	45	50	40	50	50	50	50	65		
Gizzard shad	1	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	0.2%
Tiger Muskie	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	+
Central stoneroller	-	1	-	3	-	-	5	-	1	5	9	-	4	1	-	29	1.1%
Spotfin shiner	41	11	65	47	20	15	-	26	93	15	22	21	97	143	80	696	27.3%
Common shiner	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	2	0.1%
River chub	5	-	-	-	-	22	-	6	-	-	1	1	-	1	-	36	1.4%
Comely shiner	-	2	15	3	5	1	3	6	18	3	17	179	81	57	62	452	17.7%
Spottail shiner	6	1	32	16	3	11	4	10	-	-	21	-	1	10	5	120	4.7%
Swallowtail shiner	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	7	0.3%
Bluntnose minnow	8	-	-	8	-	-	6	2	3	-	8	12	18	-	-	65	2.5%
Fallfish	32	10	12	2	8	11	9	12	23	22	19	10	31	6	32	239	9.4%
Quillback	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	+
White sucker	1	1	-	-	-	1	-	-	1	-	-	-	-	-	-	4	0.2%
Shorthead redhorse	-	-	-	-	5	-	-	-	2	-	-	-	-	-	-	7	0.3%
Channel catfish	1	-	-	-	-	-	-	-	4	-	1	-	-	-	-	6	0.2%
Banded killifish	2	23	17	26	38	61	88	52	114	57	55	44	74	45	15	711	27.9%
Rock bass	-	2	-	-	-	1	1	-	1	14	-	19	3	-	1	42	1.6%
Redbreast sunfish	-	1	-	1	-	-	7	5	3	19	-	4	-	2	1	43	1.7%
Green sunfish	-	1	-	-	-	2	-	-	-	-	1	3	1	-	8	16	0.6%
Bluegill	-	1	5	-	-	4	-	-	2	-	-	7	3	-	4	26	1.0%
Smallmouth bass	2	2	2	1	2	2	5	5	2	12	1	-	1	-	1	38	1.5%
Largemouth bass	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	0.1%
Greenside darter	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	+
Walleye	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.1%
Total	102	56	149	107	81	132	128	124	267	150	156	307	314	268	210	2,551	99.9%
No. of Species	11	12	8	9	7	12	9	9	13	9	12	11	11	9	11	23	

Table 5. Index of abundance for juvenile American shad collected by haul seine from the middle Susquehanna River at City Island, Harrisburg, Pennsylvania in 2012.

			Mean	GM	GM		Mean	GM		Mean	GM
			Mean	GM	GM		Combined	Combined		Combined	Combined
			Combined	Combined	Individual	No.	Daily	Daily	No.	Daily	Daily
	No.	No.	Daily	Daily	Haul	Wild	CPUE	CPUE	Hatchery	CPUE	CPUE
Year	Hauls	Fish	CPUE	CPUE	CPUE*	Fish	(Wild)	(Wild)	Fish	(Hatchery)	(Hatchery)
2010	89	2	0.02	0.02	0.02	0	0.00	0.00	2	0.02	0.02
2011	42	2	0.05	0.04	0.034	0	0.00	0.00	2	0.05	0.05
2012	90	0	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00

TABLE 6. WEEKLY CATCH OF JUVENILE AMERICAN SHAD BY HAUL SEINE FROM THE MIDDLE SUSQUEHANNA RIVER AT CITY ISLAND, HARRISBURG, PENNSYLVANIA, 2010-2012.

Month	2010	2011	2012	Total
1-7 Jul				0
8-15 Jul		0		0
16-23 Jul		0	0	0
24-31 Jul		0	0	0
1-7 Aug		1	0	1
8-15 Aug	0	1	0	1
16-23 Aug	1	0	0	1
24-31 Aug	0	0	0	0
1-7 Sep	0	*	0	0
8-15 Sep	0	*	0	0
16-23 Sep	0	*	0	0
24-30 Sep	0	*	0	0
1-7 Oct	*	*	0	0
8-15 Oct	0	*	0	0
16-23 Oct	0	*	0	0
24-31 Oct	1		0	1
1-7 Nov	0			0
8-15 Nov	0			0
16-23 Nov	0			0
24-30 Nov				0
TOTAL	2	2	0	4
* No sampling due to high river flow.				

TABLE 7. INDEX OF ABUNDANCE FOR JUVENILE AMERICAN SHAD COLLECTED BY LIFT NET IN THE FOREBAY OF HOLTWOOD HYDROELECTRIC STATION, 1985-2009.

Year	Total						Wild				Hatchery			
	No. Lifts	No. Fish	Mean	GM	GM	Area under curve	No. Fish	Mean	GM	Area under curve	No. Fish	Mean	GM	Area under curve
			Combined	Combined	Individual			Combined	Combined			Combined	Combined	
			Daily CPUE	Daily CPUE	Lift CPUE*			Daily CPUE (Wild)	Daily CPUE (Wild)			Daily CPUE (Hatchery)	Daily CPUE (Hatchery)	
1985	378	3,626	20.31	7.55		1422	***	***						
1986	404	2,926	10.30	5.71		888	***	***						
1987	428	832	3.17	1.90		178	***	***						
1988	230	929	3.87	1.28		254	***	***						
1989	286	556	0.86	0.43		53	***	***						
1990	290	3,988	13.75	3.67		1059	70	0.24	0.18	16	3,984	13.74	3.66	1042
1991	370	208	0.56	0.39		72	19	0.05	0.05	7	189	0.51	0.36	65
1992	250	39	0.16	0.12		13	14	0.06	0.05	5	25	0.10	0.08	9
1993	250	1,095	4.38	1.20		383	669	2.79	0.86	233	426	1.70	0.72	149
1994	250	206	0.82	0.48		71	35	0.15	0.13	12	171	0.68	0.42	59
1995	115	1,048	9.11	1.26	1.07	801	83	0.72	0.32	53	965	8.39	1.01	742
1997	300	1,372	4.57	0.88	0.61	411	100	0.33	0.23	30	1,272	4.24	0.85	381
1998	300	180	0.60	0.37	0.22	53	9	0.03	0.03	2	171	0.57	0.35	49
1999	300	490	1.63	0.78	0.50	145	19	0.06	0.07	5	471	1.57	0.76	140
2000	300	406	1.35	0.61	0.18	121	4	0.01	0.01	1	402	1.34	0.60	120
2001	299	1,245	4.18	1.37	0.43	273	538	1.81	0.45	112	707	2.38	0.99	161
2002	220	68	0.31	0.15	0.09	20	15	0.07	0.05	3	53	0.24	0.13	16
2003	300	61	0.20	0.13	0.07	17	3	0.01	0.01	1	58	0.23	0.15	17
2004	240	0	0.00	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0
2005	300	200	0.67	0.15	0.10	59	47	0.16	0.11	13	153	0.00	0.00	46
2006	230	8	0.03	0.03	0.01	1.6	0	0.00	0.00	0	8	0.03	0.03	1.6
2007	300	0	0.00	0.00	0.00	0	0	0.00	0.00	0	0	0.00	0.00	0
2008	300	1	0.004	0.004	0.002	0.2	0	0.00	0.00	0	1	0.003	0.003	0.2
2009	300	0	0.000	0.000	0.000	0.0	0	0.00	0.00	0	0	0.000	0.000	0.0

* Required by ASMFC

**Mean flow during outmigration.

***Most of the Holtwood samples processed were from cast net collections.

TABLE 8. HISTORICAL WEEKLY CATCH PER UNIT EFFORT (CPUE) OF JUVENILE AMERICAN SHAD COLLECTED BY AN 8 X 8 FT LIFT NET AT HOLTWOOD POWER STATION INNER FOREBAY*.

Week	Historical Years															
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001
1-7 Aug	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-15 Aug	-	-	-	-	-	-	0.00	-	-	-	0.00	-	-	-	-	-
16-23 Aug	-	-	-	-	-	0.00	0.00	0.00	-	-	0.00	-	-	-	-	-
24-31 Aug	-	-	-	-	-	0.00	0.00	0.00	-	-	0.00	-	-	-	-	-
1-7 Sep	-	-	-	0.00	-	0.00	0.00	0.00	0.00	-	0.00	-	-	-	-	-
8-15 Sep	-	-	1.25	-	-	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00
16-23 Sep	-	-	0.69	-	2.30	0.00	0.00	0.05	0.00	0.00	-	0.00	0.00	6.67	0.00	0.00
24-30 Sep	-	-	0.28	-	-	7.55	0.00	0.00	0.30	0.10	0.00	0.00	0.00	0.30	0.00	0.00
1-7 Oct	-	-	0.89	0.00	1.20	3.87	0.10	0.90	0.20	4.30	0.10	0.00	0.05	4.67	0.00	0.50
8-15 Oct	-	16.67	4.08	0.09	1.20	6.93	0.10	0.03	0.20	3.55	0.00	0.00	0.80	3.65	0.00	0.07
16-23 Oct	0.12	30.29	4.50	0.00	3.22	65.13	0.55	0.45	0.10	0.75	5.05	0.00	2.07	1.87	0.20	0.13
24-31 Oct	1.00	5.40	1.25	9.97	0.50	43.63	0.90	0.50	17.50	0.23	68.90	0.20	2.45	0.50	1.17	0.90
1-7 Nov	41.60	5.29	4.78	19.07	0.00	5.33	1.10	0.00	14.80	0.70	56.05	0.00	1.07	0.00	1.45	1.90
8-15 Nov	28.63	4.09	4.47	2.00	0.00	0.50	2.40	0.00	19.00	0.10	9.30	25.10	0.10	0.00	2.80	7.30
16-23 Nov	10.79	19.52	0.25	0.25	0.00	0.20	0.50	0.00	1.60	0.03	0.00	27.10	0.10	0.00	7.23	6.67
24-30 Nov	36.37	6.31	0.67	0.35	-	0.00	1.18	-	0.10	0.00	0.00	1.46	0.05	0.00	1.85	2.75
1-7 Dec	62.80	14.20	0.00	0.00	-	-	-	-	-	0.00	-	0.00	0.00	0.00	0.00	23.37
8-15 Dec	4.30	0.11	-	-	-	-	1.20	-	-	-	-	-	0.60	0.00	0.00	-
16-23 Dec	0.51	0.00	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-
24-31 Dec	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total shad	3,626	2,926	832	929	556	3,988	208	39	1,095	206	2,100	1,372	180	490	406	1,245
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	300	300
CPUE	9.59	7.24	1.94	4.04	1.94	13.75	0.56	0.16	4.56	0.82	9.13	4.57	0.60	1.63	1.35	4.15

* The lift net program was not conducted in 1996 due to flood damage to the platform.

Table 8. Continued.

Week	Historical Years							Year
	2002	2003	2004	2005	2006	2007	2008	2009
1-7 Aug	-	-	-	-	-	-	-	-
8-15 Aug	-	-	-	-	-	-	-	-
16-23 Aug	-	-	-	-	-	-	-	-
24-31 Aug	-	-	-	-	-	-	-	-
1-7 Sep	-	-	-	-	-	-	-	-
8-15 Sep	-	-	0.00	0.00	0.00	0.00	0.00	0.00
16-23 Sep	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-30 Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1-7 Oct	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00
8-15 Oct	0.03	0.50	0.00	0.00	0.00	0.00	0.00	0.00
16-23 Oct	3.30	0.27	0.00	0.00	0.00	0.00	0.00	0.00
24-31 Oct	0.03	0.00	0.00	6.67	0.20	0.00	0.00	0.00
1-7 Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-15 Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
16-23 Nov	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
24-30 Nov	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00
1-7 Dec	0.00	0.00	0.00	-	-	0.00	0.00	0.00
8-15 Dec	0.00	0.00	-	-	-	-	-	0.00
16-23 Dec	-	-	-	-	-	-	-	-
24-31 Dec	-	-	-	-	-	-	-	-
Total shad	68	61	0	200	8	0	1	0
Total lifts	260	300	240	270	230	300	300	300
CPUE	0.26	0.20	0.00	0.74	0.03	0.00	0.003	0.000

TABLE 9. NUMBER OF FISH COLLECTED DURING INTAKE SCREEN SAMPLING BY UNIT AT PEACH BOTTOM ATOMIC POWER STATION IN FALL, 2 NOVEMBER TO 7 DECEMBER, 2012.

Species	Unit 2	Unit 3	Total
Alewife	427	256	683
American shad	10	19	29
Gizzard shad	16,399	62,129	78,528
Carp	4	28	32
Quillback	1	3	4
White sucker	0	1	1
Comely shiner	21	33	54
Spottail shiner	6	15	21
Spotfin shiner	4	21	25
Bluntnose minnow	1	2	3
Golden shiner	0	3	3
Fallfish	0	4	4
Banded killifish	0	1	1
Shorthead redhorse	1	1	2
Channel catfish	66	63	129
Flathead catfish	15	23	38
White perch	4	3	7
Rock bass	4	13	17
Green sunfish	8	93	101
Pumpkinseed	7	45	52
Bluegill	6,580	21,567	28,147
Smallmouth bass	2	5	7
Largemouth bass	4	30	34
White crappie	0	11	11
Black crappie	0	2	2
Tessellated darter	16	14	30
Yellow perch	2	7	9
Walleye	0	1	1
Logperch	6	23	29
TOTAL	23,588	84,416	108,004

TABLE 10. NUMBER OF JUVENILE AMERICAN SHAD COLLECTED DURING INTAKE SCREEN SAMPLING BY UNIT AT PEACH BOTTOM ATOMIC POWER STATION IN FALL, 2012.

Date	Unit 2	Unit 3	Total
02 Nov	9	17	26
05 Nov	0	2	2
19 Nov	1	0	1
TOTAL	10	19	29

TABLE 11. SPECIES AND NUMBER OF FISH COLLECTED DURING COOLING WATER INTAKE SAMPLING AT CONOWINGO DAM IN FALL, 2012.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	1	0	1
Alewife	9	2	11
Alosa sp. (Decapitated)	2	0	2
Gizzard shad	2,367	708	3,075
Channel catfish	1	0	1
Flathead catfish	1	0	1
Comely shiner	9	0	9
Spotfin shiner	2	0	2
Green sunfish	1	2	3
Bluegill	57	59	116
TOTAL	2,450	771	3,221

TABLE 12. NUMBER OF JUVENILE AMERICAN SHAD COLLECTED DURING COOLING WATER INTAKE STRAINER SAMPLING AT CONOWINGO DAM IN FALL, 2012.

Date	Francis Units (7)	Kaplan Units (4)	Total
01 Nov	1	0	1
<i>TOTAL</i>	<i>1</i>	<i>0</i>	<i>1</i>

TABLE 13. CATCH OF JUVENILE AMERICAN SHAD BY LOCATION FROM THE UPPER CHESAPEAKE BAY DURING THE 2012 MARYLAND DNR JUVENILE FINFISH HAUL SEINE SURVEY.

UPPER BAY PERM	Round 1	Round 2	Round 3
HOWELL PT.	0	0	0
TIMS CR	0	0	0
SASSAFRAS NRMA	0	0	0
PARLOR PT.	0	0	0
ELK NECK PARK	8	0	0
WELCH PT.	0	0	0
HYLAND PT.	0	0	0

HOB (AUX)	Round 1	Round 2	Round 3
CARPENTER PT	0	0	0
PLUM PT	2	0	3
SPOIL ISLAND	0	0	0
TYDINGS ESTATE	0	0	0
TOLCHESTER	0	0	0

TABLE 14. ANALYSIS OF JUVENILE AMERICAN SHAD OTOLITHS COLLECTED IN THE SUSQUEHANNA RIVER, 2012.

		Day	Days	Days	Days	Days	Days				
		3	3,18	3,6,9	3,6,9,15	3,6,9,12, 15	various + sngl feed				
Collection Site	Coll. Date	Jun/ Raystown Br.	W. Br. Susq.	Raystown Br. Jun. R.	N. Br. Susq.	Bald Eagle Cr.	Benner Spring Raceway	Total Hatchery	Total Wild	Total Processed	Total Collected
Columbia	8/7/2012	-	-	-	-	-	-	0	0	0	1
Safe Harbor Dam	10/30/2012	11.4	3.1	1.0	8.3	1.0	0.0	24	2	26	27
	10/31/2012	2	1	0	0	1	0	4	0	4	4
	11/1/2012	1	0	0	0	1	0	2	0	2	2
Peach Bottom Intakes	11/2/2012	7.1	3.5	3.5	1.2	2.4	0.0	15	7	22	26
	11/5/2012	1	0	0	0	1	0	2	0	2	2
	11/19/2012	1	0	0	0	0	0	1	0	1	1
Conowingo Strainers	11/1/2012	0	0	0	0	0	0	0	1	1	1
Grand Total		24.3	7.7	4.4	9.9	6.6	0.0	53.0	10.0	58.0	64.0
Percent		37.9%	12.1%	6.9%	15.5%	10.3%	0.0%	83%	15.6%		

**When the entire sample collected was not processed, the shad successfully processed were weighted to ensure that row totals equalled the total number collected.