RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER

ANNUAL PROGRESS REPORT
2012

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

Maryland Department of Natural Resources
New York Div. of Fish, Wildlife & Marine Resources
Pennsylvania Fish and Boat Commission
Susquehanna River Basin Commission
United States Fish and Wildlife Service
National Marine Fisheries Service

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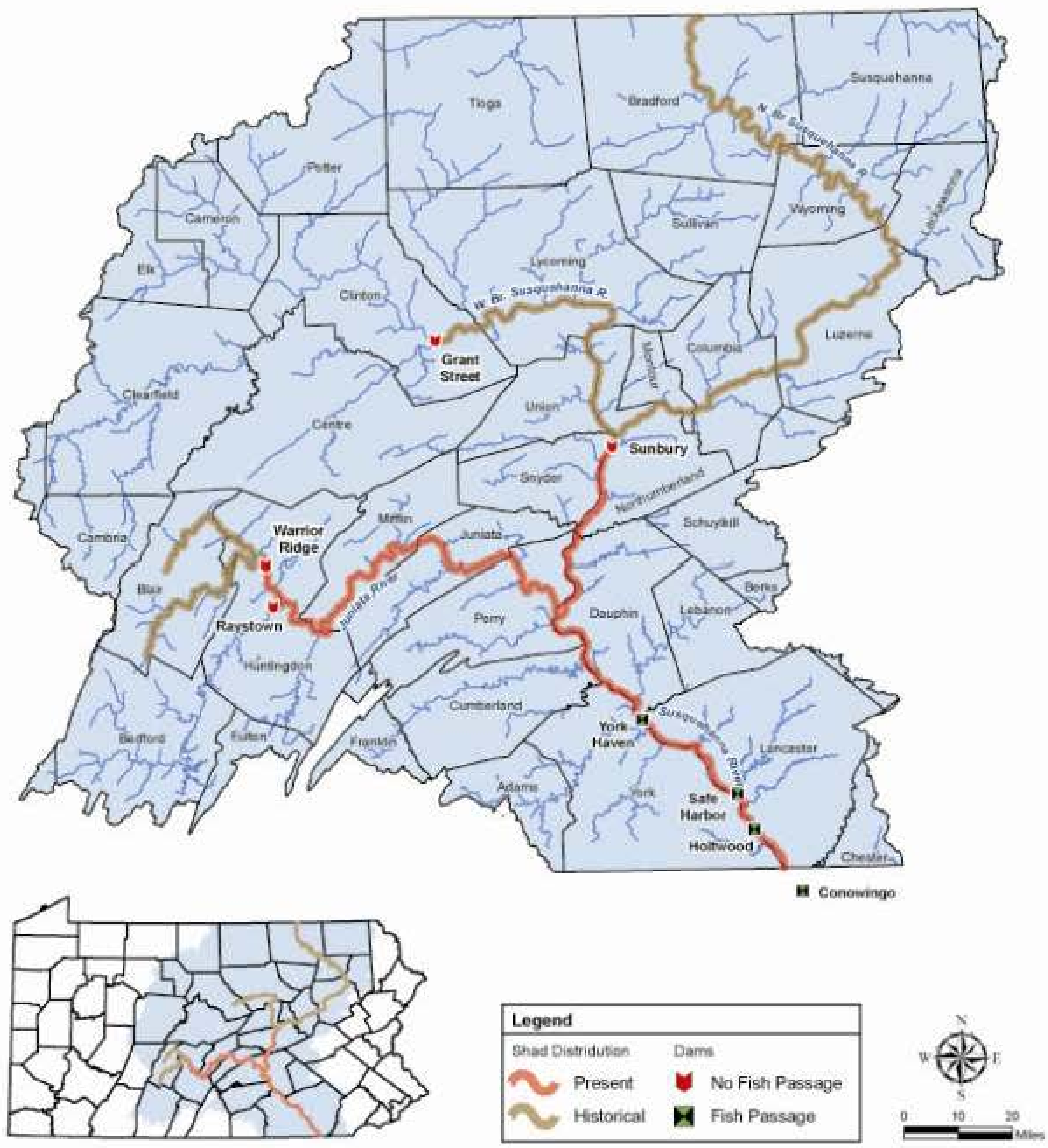
American Shad
Habitat and Distribution
Susquehanna River Basin



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EXECUTIVE SUMMARY

Operation of the Conowingo East Fish Lift (EFL) began April 2, 2012 due to river water temperatures greater than 50.0°F and favorable river flow levels. The EFL operated for 62 days and completed 1,230 lifts in 2012, which is the highest number of lifts conducted at the EFL since the facility became operational in 1991. EFL operations were terminated, with agency concurrence on June 5, 2012. The 2012 fish passage season marks the twenty-second season of overall operation and the sixteenth year of volitional passage operation at the Conowingo EFL. The EFL passed 1,109,911 fish of 33 species and two hybrids; the second highest fish passage total since the start of volitional passage in 1997. Gizzard shad (1,070,672), American shad (22,143), channel catfish (12,224), and quillback (1,523), dominated the catch, and comprised nearly 100% of the total fish collected and passed. Gizzard shad alone accounted for 96% of the total fish collected and passed. A total of 22,143 American shad were passed. The highest daily shad catch occurred on 24 April when 1,710 shad were passed upstream. American shad passage exceeded 1,000 fish on 4 of the 62 days of operation. Shad passage was highest between 1400 hrs and 1759 hrs during which 53% of shad passage occurred. Fishway operations were conducted at water temperatures ranging from 54.0°F to 79.0°F and river flows between 13,700 and 107,300 cfs. Spillage occurred on 2 of the 62 days of operation. River flows fluctuated throughout the passage season but were well within the operating parameters of the EFL excepting the two days when spillage occurred. For most of the season, water clarity was adequate, allowing the viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at the Conowingo EFL in 2012 was 26 (24 orange from 2012; 2 pink from 2011).

The Conowingo Dam West Fish Lift operated for 37 days in 2012 for the purpose of collecting American shad broodfish for egg collection efforts and to collect ASMFC required fishery-independent biological data. The West Fish Lift caught 322,053 fish of 40 taxa. Gizzard shad comprised 95% of the total catch and the next three most numerous species, channel catfish, comely shiner and American shad comprised 3% of the total. Some 1,486 American shad were caught, representing 0.5% of the total catch. A total of seven blueback herring were also caught. WFL operations were funded by the Pennsylvania Fish and Boat Commission and Maryland DNR with a grant to the Alliance for the Chesapeake Bay. The Alliance contracted Normandeau Associates to operate the WFL and conduct the tank-spawning trials.

The Holtwood fish passage facility operated a total of 58 days (highest number of operating days in a single season since the facility became operational in 1997). The tailrace lift was operated on 47 consecutive days, while the spillway lift operated on 40 days. Lift operations were terminated for the season, with agency concurrence, on 5 June. During mid-May (17 and 18 May), fish lift operations were suspended for two days due to high river flows. The tailrace fish lift experienced crowder and hopper sheave mechanical problems (24 and 25 May) that could not be repaired prior to season end. After 25 May, the spillway fish lift operated solely until the season ended on 5 June. The lifts passed 230,365 fish of 26 taxa plus one hybrid. Gizzard shad (211,478), shorthead redhorse (4,679), quillback (4,568) and American shad (4,238), dominated the catch, and comprised nearly 98% of the total fish collected and passed. A total of 3,342 American shad was passed in the tailrace lift while the spillway lift accounted for 896 American shad. The highest daily shad catch occurred on 19 April when 539 shad moved upstream. On a daily basis, 86% of the American shad passed between 0900 and 1759 hrs.Spillage occurred on 42 days of operation. Based on fish passage counts, some 19.1% of American shad passing Conowingo also passed Holtwood. This was below the historical average of 31.0%. A low, stable, river flow appears to be critical for enhancing American shad passage rates. In 2010, we documented 95% of American shad passed at river flows less than 40,000 cfs, with 5% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. In 2012, 76.9% of American shad passed at river flows less than 40,000 cfs, with 22.8% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. Only 0.3% of American shad passed at river flows greater than 60,000 cfs. Future operations of the fishway will build on the past sixteen years of operation experience.

The Safe Harbor fishway began operation on 12 April, with operations ending on 6 June. A total of 161,874 fish of 19 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (136,369) was the dominant species passed and comprised 84% of the catch. The Safe Harbor

Fish Lift passed a total of 3,089 American shad into Lake Clarke, or nearly 73% of the American shad that were passed into Lake Aldred by the Holtwood fishway. More than 90% of the total American shad passed at Safe Harbor occurred prior to 22 May, shortly before Holtwood passed 90% of their American shad season total (23 May).

The York Haven Dam fish ladder was opened on 1 April allowing volitional (unmanned) passage for 24 days. The fishway was manned on a total of 43 days between 25 April and 6 June. Some 97,990 fish of 23 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (87,068) was the dominant fish species passed and comprised almost 89% of the fish passed. Other fishes passed included quillback (4,104), channel catfish (2,858), shorthead redhorse (1,491), carp (669) walleye (602) and smallmouth bass (553). A total of 224 American shad passed upstream through the ladder in 2012. Some 71 shad passed in April and 153 shad passed in May. No shad passed in June. Peak shad passage occurred on 26 April when some 68 shad (30.4% of season total) passed. American shad passed at water temperatures of 50.9°F to 76.1°F, river flows of 25,600 cfs to 94,900 cfs and East Channel flows of 3,100 cfs to 16,000 cfs. Over 41% of the shad (93) passed between 0800 hrs and 1059 hrs, while 78 shad passed from 1100 to 1359 hrs. A total of 53 shad passed between 1400 hrs and the end of manned operation each day (1600 and/or 1700 hrs). The peak hourly passage of shad (18) occurred on 26 April between 1400 hrs and 1459 hrs. As in previous years YHPC agreed to make periodic observations for adult shad in the forebay and open the sluice gate if/when large numbers of adults were observed. No adult shad were observed by Station Personnel that made periodic observations of the forebay area from June through August. The station also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC. Daily monitoring of the York Haven forebay for the presence of juvenile shad began on 10 September when water temperature was 74.0□F. Monitoring continued through 16 November. During this period river flows ranged from 5,850 cfs to 108,000 cfs. The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity. Given fish activity was non-existent there was no need to implement "Downstream Operation".

American shad egg collection on the Potomac River (rkm 150) occurred during 23 days in March and April, 2012. Monofilament gill nets were used to collect 1,187 adult American shad,

supplyng a total of 258 L of American shad eggs (11.2 million) with a 51% fertilization rate, resulting in 5.7 million viable eggs.
7 American shad egg collection on the Delaware River occurred from 13 May through 31 May 2012. Eggs were collected and shipped on 12 of the 13 nights of fishing. A total of 979 adult shad were captured and 116.1 liters of eggs were shipped for a hatchery count of more than 9.0 million eggs. Overall, the viability for Delaware River American shad eggs was 7.8%.

A total of eight tank-spawning tests were conducted at the Conowingo Dam West Fish Lift. Some 481 American shad were injected with sGnRHa from 24 April to 29 May and produced 64.5 liters of eggs. Over 60.7 liters of eggs were shipped to the Van Dyke Hatchery and the remaining 3.8 liters were released into the river below Conowingo Dam. The estimated viability of the eggs shipped to Van Dyke was 24.6%. The total volume of eggs produced per female in 2012 (0.338 liters) was slightly above the average of 0.320 liter observed for the previous ten years. The volume of viable eggs produced per female in the 2012 tests averaged 0.083 liters and was the highest volume since 2001. Injected fish usually produced the first and largest pulse of eggs within 48 hrs followed by little or no egg production past 72 hrs. The overall viability (24.6%) was above the ten year average of 18.4%.

A total of 35 shipments of American shad eggs (24.0 million eggs) were received at the Van Dyke hatchery in 2012. Total egg viability was 30.4% and survival of viable eggs to stocking was 47%, resulting in production of 3.9 million larvae. Larvae were stocked in the Juniata River (1.5 million), Raystown Branch (1.3 million) the West Branch Susquehanna River (172 thousand), Bald Eagle Creek (271 thousand), and the North Branch Susquehanna River in Pennsylvania (150 thousand). Delaware River source American shad larvae were stocked in the Lehigh (301 thousand) and the Schuylkill (200 thousand) rivers. No American shad larvae were stocked in the Delaware River because our stocking goals in the Lehigh and Schuylkill Rivers were not met.All American shad larvae cultured at Van Dyke were marked by 4-hour immersion in oxytetracycline. Marks for American shad were assigned based on release site and/or egg source river. All raceway cultured shad examined for marks had marks as intended except for a few specimens that were not marked**.** Fingerling shad fed OTC laced food did not retain the feed mark.

Normandeau Associates, under contract to PFBC, conducted juvenile American shad haul seine sampling at two sites in the Susquehanna River during the summer and fall in an effort to document in-stream movement, out-migration, abundance, growth, and stock composition/mark analysis. One juvenile American shad was collected by haul seine at Columbia, while none were collected by haul seine at City Island. 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. Additional monitoring occurred at intake screens at Peach Bottom Nuclear Power Station (29 juveniles collected), strainers at Conowingo Dam (one juvenile collected) and strainers at Safe Harbor Dam (35 juveniles collected). Otoliths from all sites combined were 83% hatchery origin and 16% wild, confirming that some natural reproduction of shad occurred in 2012. All groups of uniquely marked larvae were represented in the catch. Potomac River source larvae stocked in the West Branch exhibited the best survival (relative survival set to 1.00, Table A1-1). In general, larvae stocked in the West Branch Susquehanna River have exhibited better survival than other sites since 2005. In four of those eight years, relative survival was 1.00 and mean eight year relative survival from 2005 to 2012 was 0.73. Water quality improvements associated with acid mine drainage abatement projects may be responsible for recent improvement in survival of shad larvae stocked in the West Branch. 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 but may be related to concurrent mortality of yoy smallmouth bass in the Susquehanna River.

A total of 128 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2012. Based on tetracycline marking and otolith microstructure, 76% of the 121 readable otoliths were identified as wild and 24% were identified as hatchery in origin. Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1986-2007 year classes, stocking of approximately 404 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 196 fingerlings was required to return one adult to the lifts. For wild fish, transport of 1.28 adults to upstream areas was required to return one wild fish to the lifts. Actual survival is even higher since not all surviving adults enter the lifts.

A total of 127,000 elvers were collected during 2012 with the majority collected in five pulses. The first pulse occurred at the end of May and then about every two weeks after. The seasonal pattern of migration in 2012 was similar to that observed in previous years with a majority of the eels collected from mid June through mid August. Nine stockings from elvers captured at Conowingo Dam were completed, with an estimated total of 96,000 elvers being stocked in Susquehanna Watershed. Some 66 yellow eels were PIT-tagged this year bringing the total number of PIT-tagged yellow eels in the study to 355. Annual growth rates are being tracked for the 36 PIT tagged eels that have been recaptured after at least one year after tagging. Stocking success at Buffalo and Pine Creek were evaluated by electrofishing surveys in July and August 2012. Sampling above and below the stocking site in Buffalo Creek has shown that at least some of the stocked elvers grew much faster than the yellow eels caught below Conowingo dam.

The Maryland Department of Natural Resources (MDNR) conducted an annual survey targeting adult American shad and hickory shad in the upper Chesapeake Bay (Susquehanna River). American shad were angled from the Conowingo Dam tailrace, measured, sexed, tagged and released. Indices of abundance were derived from hook and line data and from combined lift data. Recreational creel and logbook surveys also provided information on American and hickory shad abundance. MDNR's Susquehanna Restoration and Enhancement Program provided additional hickory shad data from brood stock collection in the Susquehanna River. Although the surplus production model's estimate of abundance in the lower Susquehanna River did not vary significantly over the time series (1984-2012), the estimated number of fish has increased since the early 1980s. Indices of abundance exhibited a decreasing trend for logbook and creel survey data, and varied without trend for hook and line survey data. Male American shad were present in age groups 3-6 and females in age groups 3-8. The trend in the arcsine-transformed percent of American shad repeat spawners is increasing. Hickory shad age structure remained consistent, with a wide range of ages and a high percentage of older fish. Males were present in age groups 3-6 and females in age groups 3-7. Hickory shad CPAH in Deer Creek continued to vary without trend.

SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY - 2012

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EXECUTIVE SUMMARY

Operation of the Conowingo East Fish Lift (EFL) began April 2, 2012 due to river water temperatures greater than 50.0°F and favorable river flow levels. The EFL operated for 62 days in 2012; the third longest season behind 1995 (68 days) and 1997 (64 days). A total of 1,230 lifts were completed in 2012, which is the highest number of lifts conducted at the EFL since the facility became operational in 1991. EFL operations were terminated, with agency concurrence on June 5, 2012. The 2012 fish passage season marks the twenty-second season of overall operation and the sixteenth year of volitional passage operation at the Conowingo EFL.

The EFL passed 1,109,911 fish of 33 species and two hybrids; the second highest fish passage total since the start of volitional passage in 1997. Gizzard shad (1,070,672), American shad (22,143), channel catfish (12,224), and quillback (1,523), dominated the catch, and comprised nearly 100% of the total fish collected and passed. Gizzard shad alone accounted for 96% of the total fish collected and passed.

A total of 22,143 American shad were passed. The highest daily shad catch occurred on 24 April when 1,710 shad were passed upstream. On 4 of the 62 days of operation, American shad passage exceeded 1,000 fish. On a daily basis, overall shad passage was strongest through the fishway between 1400 hrs and 1759 hrs during which 53% of shad passage occurred.

Fishway operations were conducted at water temperatures ranging from 54.0°F to 79.0°F and river flows between 13,700 and 107,300 cfs. Spillage occurred on 2 of the 62 days of operation. River flows fluctuated throughout the passage season but were well within the operating parameters of the EFL excepting the two days when spillage occurred. .

In 2012, fish passage at the EFL was not shut down due to spill. Based on information gained in previous years, the standard operating procedure when spill conditions are in effect is to cease operation of the EFL until spill conditions end. This SOP was not put into effect because of the limited nature of the spill events in 2012.

For most of the season, water clarity was adequate, allowing the viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at the Conowingo EFL in 2012 was 26 (24 orange from 2012; 2 pink from 2011).

Future operations of the EFL will build on the past sixteen years of operation experience.

INTRODUCTION

Exelon Generation Company, LLC, formerly the Susquehanna Electric Company (SECO), has operated a fish passage facility (West lift) at its Conowingo Hydroelectric Station since 1972. Lift operations are part of a cooperative private, state, and federal effort to restore American shad (*Alosa sapidissima*) and other migratory fishes to the Susquehanna River. In accordance with the restoration plan, the operational goal had been to monitor fish populations below Conowingo Dam and transport pre-spawned migratory fishes upriver.

In 1988, the former PECO Energy Company negotiated an agreement with state and federal resource agencies and private organizations to enhance restoration of American shad and other anadromous species to the Susquehanna River. A major element of this agreement was for PECO Energy Company to construct an East Fish Lift Passage Facility (EFL) at Conowingo Dam. Construction of the EFL commenced in April 1990 and it was operational by spring 1991.

With the completion of fishways at Holtwood, Safe Harbor, and York Haven dams, the EFL has been operated to pass fish directly into Conowingo Pond since spring 1997.

Objectives of 2012 operation were: (1) monitor passage of migratory and resident fishes through the fishway; (2) assess fishway and trough effectiveness and make modifications as feasible; and (3) assist in the conduction of studies relating to Conowingo Relicensing issues.

CONOWINGO OPERATION

Project Operation

The Conowingo Hydroelectric Station, built in 1928, is located at river mile 10 on the Susquehanna River (RMC 1992). The powerhouse has a peaking generating capacity of 549.5 MW and a hydraulic capacity of approximately 85,000 cfs. Flows in excess of station draft are spilled through two regulating and 50 crest gates. The powerhouse contains seven vertical Francis (numbered 1 through 7) and four Kaplan (numbered 8 through 11) turbines. The seven Francis units have been equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The four original Kaplan turbines installed in 1964 were replaced over a period of four years (1992 to 1996), with more efficient mixed-flow Kaplan type turbines.

Minimum flow releases from the station during the spring spawning and fishway operating season follow the schedule outlined in the settlement agreement. Minimum flows of 10,000 cubic feet per second (cfs) or natural river flow, whichever is less, as measured at the United States Geological Survey (USGS) gage at Marietta, PA were maintained for the period 1 to 30 April. A minimum flow of 7,500 cfs or natural river flow (as previously noted) was maintained for the period 1 to 31 May. A minimum flow of 5,000 cfs or natural river flow (as previously noted) is maintained when fish lift operations occur in June.

Fishway Operation

The start of operation for the EFL began on April 2, 2012 due to water temperatures greater than 50.0°F and river flows less than 30,000 cfs. A total of 642 American shad were passed on the initial start date. Everyday operation began immediately, and continued through 5 June. On 5 June, operations were terminated with Exelon and Agency approval. The EFL operated for 62 days in 2012; the third longest season behind 1995 (68 days) and 1997 (64 days). A total of 1,230 lifts were completed in 2012, which is the highest number of lifts conducted at the EFL since the facility became operational in 1991. The passage of 1,109,911 fish (all species combined) is the second highest passage total since the onset of volitional passage in 1997.

Daily operation times were planned during optimal fish passage parameters. This year, operational methodologies were influenced by natural river flows, water temperatures, generation and spill conditions, daily/hourly fish passage numbers and testing of a different EFL operation scenario that was part of the radio telemetry study supporting the Conowingo relicensing effort. This EFL operation scenario involved completion of at least 2 lift cycles per hour and 6:00 am starts every other day from 24 April until 28 May. Table 1 provides an overview of all EFL operations since 1991 and Table 2 provides a summary view of the EFL volitional passage operations. Daily EFL operation was conducted by a staff of three people: a lift operator, a supervising biologist, and a biological technician.

The mechanical aspects of East lift operation in 2012 were similar to those described in RMC (1992) and Normandeau Associates, Inc. (1999). Fishing time and/or lift frequency was determined by fish abundance, but the hopper was cycled at least twice an hour throughout the day unless interrupted by mechanical breakdowns. The method of lift operation was also influenced by fish abundance. When a great number of fish were in the fishing channel, the crowder was not operated; instead the crowder screen was raised and then lowered trapping fish over the hopper. This mode of operation, called “fast fish”, involved leaving the crowder in the normal fishing position and raising the hopper frequently to remove fish that accumulated in the holding channel.

As in previous years, records of mechanical problems and failures were recorded. Table 3 provides a summary of mechanical breakdowns and/or high river flow events resulting in interruptions to fish passage that have occurred during EFL operation in various years. During the 2012 season, the air hoses that open and close the hopper door tangled and snapped multiple times. Mechanical issues in 2012 resulted in the loss of approximately 57 hours of operation. Three complete days of operation were lost due to mechanical issues (April 11, 23, and 26), and the remainder of the lost time occurred mostly at the beginning of a day or near the end of a day resulting in the conduction of fewer lifts. It is believed that modifying the hopper air hose arrangement will improve fish lift reliability in future years.

The specific entrance(s) used to attract fishes was dictated by the station discharge and which turbine units were operating. For example, when turbine units 8, 9, 10, and 11 or any combination of large turbines were operating, entrance C was the primary entrance used to attract fishes. Under these conditions the attraction flow through the other entrances is negated or disrupted. Depending on flow, and or generation, entrance A or C was utilized throughout the 2012 season to attract fishes.

Fish Counts

Fish that were lifted and sluiced into the trough were guided by a series of fixed screens. The fixed screens directed the fish to swim up and through a 3 ft wide channel and past a 4 ft by 10 ft counting window located on the west wall of the trough. Fish passing the counting window were identified to species and enumerated by a biologist and/or technician. Passage of fish by the window and out of the trough system was controlled by a set of gates located downstream of the counting window. During periods of peak passage, two people were used to identify and count fish.

At the end of each hour, fish passage data were recorded on data sheets and entered into a Microsoft Excel worksheet on a Personal Computer. Data processing and reporting were PC based and accomplished by program scripts, or macros, created within Microsoft Excel software. After the technician verified the correctness of the raw data, a daily summary of fish passage was produced and distributed in hard copy to plant personnel. Each day's data were backed up to a diskette and stored off site. Daily reports and weekly summaries of fish passage were electronically distributed to plant personnel and other cooperators.

RESULTS

Relative Abundance

The number of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 4. A total of 1,109,911 fish of 33 species and 2 hybrids passed upstream into Conowingo Pond. Gizzard shad (1,070,672), American shad (22,143), channel catfish (12,224), and quillback (1,523), dominated the catch, and comprised nearly 100% of the total fish collected and passed. Gizzard shad alone accounted for 96% of the total fish collected and passed. Peak passage occurred on 7 May when 56,704 fish, (75% gizzard shad), were passed.

American Shad Passage

The East lift collected and passed 22,143 American shad (Table 4). The first 642 American shad passed on the initial day of operation (April 2). Collection and passage of shad varied daily with 37% (8,158) of the shad passed from April 2 to April 21, 39% (8,665) passed from April 22 to May 11, 24% (5,280) passed from May 12 to May 31, and 0.2% passed from June 1to June 5(Figures 1 and 2). On 4 of the 62 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on April 24 when 1,710 American shad were passed.

American shad were collected at water temperatures of 54.0 to 79.0°F and at natural river flows of 13,700 to 107,300 cfs (Table 5, Figure 3). The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 25,375 cfs. The average daily river flow during the operational season was 38,910 cfs.

The hourly passage of American shad at the EFL is given in Table 6. On a daily basis, overall shad passage was strongest through the fishway between 1400 hrs and 1759 hrs during which 53% of shad passage occurred. The highest hourly passage rate occurred from 1600 to 1659 hours.

Gizzard Shad Passage

The East lift collected and passed 1,070,672 Gizzard shad (Table 4). Gizzard shad accounted for 96% of the total fish collected and passed. On 11 of 62 days of operation, Gizzard shad passage exceeded 30,000 fish. Table 2 provides the ratio of American shad to Gizzard shad for the years of volitional passage (1997-2012). In years with a strong American shad run (>50,000) the ratio ranges from 1:2 – 1:14 (American shad: Gizzard shad) and in years without a strong American shad run (<50,000) the ratio ranges from 1:16 – 1:48.

Other Alosids

A small number of river herring, (27 alewife and 25 blueback herring) were passed during the 2012 season. No hickory shad were passed in spring 2012.

Maryland tag-recapture

During the 2012 season, the EFL passed a total of 26 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the Maryland DNR. The total number of floy tags observed at the Conowingo EFL in 2012 was 26; 24 orange from 2012, 2 pink from 2011 (Table 5).

SUMMARY

The EFL operated for 62 days in 2012; the third longest season behind 1995 (68 days) and 1997 (64 days). A total of 1,230 lifts were completed in 2012, which is the highest number of lifts conducted at the EFL since the facility became operational in 1991. The passage of 1,109,911 fish (all species combined) is the second highest passage total since the onset of volitional passage in 1997.

EFL operation was initiated on April 2 with the first 642 American shad passed on that day. The EFL passed 22,143 American shad from April 2 through June 5. The total number of American shad passed during the 2012 season was lower than passage values recorded in 2009 and 2010 (Table 7). It is also the sixth consecutive year in which the EFL passed less than 50,000 American shad.

Modifications made to the fish trough, particularly the valve grating and hopper trough chute since 1999 have diminished the potential for the valve grating to clog with various types of debris and have decreased the number of American shad lift mortalities observed throughout the last several fish passage seasons. Since the valve grating was modified prior to the start of the 2000 season, loss of water flow in the trough has not occurred, particularly during high river flow periods when large amounts of debris may enter the trough through the fish trough exit. An aeration system was also installed prior to the 2000 passage season to diminish low dissolved oxygen levels when the American shad population is heavy in the trough. Prior to fishway operations in 2002, a 30 inch diameter fiberglass elbow was attached to the hopper extension chute, which had been installed in 2001. The modification allows fish to enter the trough center stream, instead of being directed toward the east trough wall. A decrease in lift mortalities has also been observed since the fiberglass elbow was installed. A total of 282 American shad lift mortalities, (1.3% of the total shad passed), was observed in 2012, slightly higher to lift mortalities observed in recent years (0.2% to 1.0%) but less than values observed during trap and transport operations (1.5% to 10.5%).

RECOMMENDATIONS

1) Continue to operate the EFL at Conowingo Dam per annual guidelines developed and approved by the Susquehanna River Technical Committee. Lift operation should adhere to the guidelines; however, flexibility must remain with operating personnel to maximize fishway performance and fish passage.

2) Continue the use of two fish counters during periods of increased fish passage to accurately reflect the number of fish that pass through the EFL.

3) Continue to inspect cables, limit switches, and lift components to enhance season operability, and continue to evaluate effectiveness of fish trough modifications.

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RMC. 1992. Summary of the operations of the Conowingo Dam fish passage facilities in spring 1991. Prepared for Susquehanna Electric Company, Darlington, MD.

TABLES

Table 1. Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2012.

Year	Number of Days Operated	Number of Lifts	Operating Time (hrs)	Catch (millions)	Number of Species	American shad	Blueback herring	Alewife	Hickory shad
1991	60	1168	647.2	0.651	42	13,897	13,149	323	0
1992	49	599	454.1	0.492	35	26,040	261	3	0
1993	42	848	463.5	0.530	29	8,203	4,574	0	0
1994	55	955	574.8	1.062	36	26,715	248	5	1
1995	68	986	706.2	1.796	36	46,062	4,004	170	1
1996	49	599	454.1	0.492	35	26,040	261	3	0
1997	64	652	640.0	0.719	36	90,971	242,815	63	0
1998	50	652	640.0	0.713	33	39,904	700	6	0
1999	52	610	467.0	1.184	31	69,712	130,625	14	0
2000	45	570	367.8	0.494	30	153,546	14,963	2	0
2001	43	559	359.8	0.922	30	193,574	284,921	7,458	0
2002	49	560	440.7	0.657	31	108,001	2,037	74	6
2003	44	645	416.6	0.589	25	125,135	530	21	0
2004	44	590	390.3	0.716	30	109,360	101	89	0
2005	52	541	434.3	0.378	30	68,926	4	0	0
2006	61	619	429.8	0.715	32	56,899	0	0	4
2007	39	479	335.3	0.539	31	25,464	460	429	0
2008	51	483	407.0	0.944	29	19,914	1	4	0
2009	57	618	495.6	0.915	30	29,272	71	160	0
2010	59	685	526.2	0.857	38	37,757	4	1	0
2011	15	259	142.4	0.289	24	20,571	17	2	20
2012	**62**	**1230**	**633.7**	**1.110**	**35**	**22,143**	**25**	**27**	**0**

Table 2. General Summary Information for Conowingo EFL Volitional Passage, 1997 through 2012.

Year	#Days of Ops	#Hrs of Ops	Total # of Lifts	# Fish passed	# Am. shad	# Gizzard shad	# Herring	Avg.#fish/lift	Ratio A.S./Gizz
1997	64	640	652	719,297	90,971	344,332	242,815	1,103	1/4
1998	50	433	460	712,993	39,904	654,575	706	1,550	1/16
1999	52	467	610	1,184,101	69,712	950,500	130,639	1,941	1/14
2000	45	368	570	493,955	153,546	317,753	14,965	866	1/2
2001	43	360	559	921,916	193,574	429,461	292,379	1,649	1/2
2002	49	440	560	656,894	108,001	513,794	2,111	1,173	1/5
2003	44	416	645	589,177	125,135	459,634	551	913	1/4
2004	44	390	590	715,664	109,360	602,677	190	1,212	1/6
2005	52	434	541	377,762	68,926	305,378	4	698	1/4
2006	61	430	619	714,918	56,899	655,990	0	1,154	1/12
2007	39	335	479	539,203	25,464	508,627	889	1,125	1/20
2008	51	409	483	943,838	19,914	919,975	5	1,954	1/46
2009	57	495	618	915,417	29,272	876,412	231	1,481	1/30
2010	59	526	685	857,263	37,757	813,429	5	1,251	1/22
2011	15	142	259	289,453	20,571	257,522	19	1,117	1/13
2012	62	633	1,230	1,109,911	22,143	1,070,672	52	902	1/48

Table 3. Comparison of Shutdown events (mechanical or high river flow) summarizing impacts to fish passage at the Conowingo EFL for various years

	Year								
Categories	2000	2001	2002	2005	2006	2008	2009	2010	2012
Operations									
1st Day of Operation	10-Apr	23-Apr	8-Apr	15-Apr	3-Apr	16-Apr	1-Apr	5-Apr	2-Apr
Water Temperature	48.6°F	52.7°F	51.0°F	52.7°F	52.7°F	57.8°F	49.0°F	58.2°F	57.0°
Every Other Day Operation	4/10-4/18	24-Apr	4/8-4/12	4/15-4/20	4/3-4/7	NA	4/3-4/19	4/5-4/13	NA
Total days operated	45	43	49	52	61	51	57	59	62
Number of Lifts	570	559	560	541	619	483	618	685	1230
Hours of operation	368	360	440	434	429	409	495	526	633
Breakdowns/Repairs									
Event 1	Hopper Hoist Motor failure	Crowder cables snapped	Sheave Wheel bearing seizure	Sheave Wheel bearing	Hopper cables slack and wrapped around screen	Hopper cables slack and rebuilding of the Sheave block	Crowder and Crowder Screen Hoist	Debris in trough and hopper	Air line sheave guide cable snapped
Dates	4/28-5/3	11-May	4/27-4/29	5/15-5/16	4-May	4/27-4/29	4/10-4/13	18-Apr	10-Apr
Hours Lost	51.5	6	22	13	10	22	11	5	11.5
Number of Am. shad caught a week to ten days after repairs completed	112,899 (5/4-5/11)	24,066 (5/12-5/19)	24,613 (4/30-5/8)	11,122 (5/17-5/25)	15,135 (5/5-5/12)	4,522 (4/30-5/8)	606 (4/15-4/26)*	15,004 (4/19-4/25)	4,100 (4/12-4/18)
Number of Gizzard shad caught a week to ten days after repairs completed	101,119 (5/4-5/11)	118,316 (5/12-5/19)	147,558 (4/30-5/8)	48,912 (5/17-5/25)	161,019 (5/5-5/12)	187,626 (4/30-5/8)	195,516 (4/15-4/26)*	139,769 (4/19-4/25)	162,187 (4/12-4/18)
Event 2	NA	Hopper Door Malfunction	NA	NA	NA	NA	Debris clogged hopper pit	NA	Main Hopper cable frayed and guide cable snapped
Dates	NA	27-May	NA	NA	NA	NA	21-May	NA	4/22-4/27
Hours Lost	NA	5.5	NA	NA	NA	NA	6	NA	35.5
Number of Am. shad caught a week to ten days after repairs completed	NA	2,328 (5/28-6/4)	NA	NA	NA	NA	4,781 (5/22-5/29)	NA	5,084 (4/27-5/5)
Number of Gizzard shad caught a week to ten days after repairs completed	NA	12,163 (5/28-6/4)	NA	NA	NA	NA	55,943 (5/22-5/29)	NA	219,459 (4/27-5/5)

Table 3. (continued)

River flow shut downs									
Dates	5/27-5/29	NA	5/15-5/22	NA	NA	NA	NA	NA	NA
River flow	>100,000 cfs	NA		NA	NA	NA	NA	NA	NA
Hours Lost	30	NA	90	NA	NA	NA	NA	NA	NA
Season Downtime b/c of events									
Number of Days	9	0	11	0	1	1	1	0	3
Approximate # of hours	87.5	31.5*	112	13	10	22	17	5	47
American Shad Information									
Am. Shad Season Catch	153,546	193,423	108,001	68,926	56,899	19,914	29,272	37,757	22,134
Day 1st Shad caught	18-Apr	23-Apr	10-Apr	20-Apr	3-Apr	16-Apr	19-Apr	7-Apr	2-Apr
Water Temperature	53.8°F	52.7°	52.0°F	58.9°F	52.7°F	57.8°F	53.3°F	59.4°F	57.0°F
Highest Day/Amount caught	5/5 = 22,565	5/5=26,415	5/8=12,323	5/11=5235	5/3=6,130	5/11=1,943	5/4=4,670	4/20=3,272	4/24=1,710
Bulk of Seaon Passage									
Dates	5/4-5/11	4/29-5/8	5/4-5/13	5/4-5/17	4/30-5/15	4/24-5/11	4/30-5/17	4/19-5/3	4/18-4-27
# of shad	112,899	131,432	57,151	43,427	29,845	10,425	21,780	18,136	6,649
Percentage of run	73%	68%	53%	63%	52%	52%	74%	48%	30%
Dates	5/12-5/25	NA	NA	NA	NA	5/25-5/31	NA	5/7-5/17	NA
# of shad	35,981	NA	NA	NA	NA	4,590	NA	12,312	NA
Percentage of run	23%	NA	NA	NA	NA	23%	NA	33%	NA
Total Run Percentage combined	96%	68%	53%	63%	52%	75%	74%	81%	30%
Comments		20 hours were lost to Radio Telem Tagging in EFL trough					* Every other day passage until 4/19		

Table 4. Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2012.

Date:	*4/2*	*4/3*	*4/4*	*4/5*	*4/6*	*4/7*	*4/8*	*4/9*
Start Fishing Time:	*11:00*	*9:00*	*8:30*	*9:00*	*8:00*	*8:15*	*10:00*	*8:00*
End Fishing Time:	*18:30*	*18:29*	*18:30*	*18:30*	*18:30*	*18:30*	*18:30*	*18:30*
Hours of Operation:	*7.5*	*9.5*	*10.0*	*9.5*	*10.5*	*10.3*	*8.5*	*10.5*
Number of Lifts:	*15*	*16*	*20*	*19*	*20*	*20*	*17*	*17*
Water Temperature (°F):	*57.0*	*56.0*	*56.3*	*56.5*	*56.7*	*56.7*	*57.2*	*58.1*
AMERICAN SHAD	642	80	571	232	152	298	313	176
BLUEBACK HERRING	0	0	0	0	0	0	0	0
ALEWIFE	6	0	0	0	0	0	0	1
GIZZARD SHAD	3,506	9,852	7,353	4,789	15,550	16,604	10,708	6,869
STRIPED BASS	0	0	0	0	0	0	0	2
SEA LAMPREY	1	5	1	0	0	0	1	1
RAINBOW TROUT	0	0	0	1	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	0	0	0	2	0	0	0	0
QUILLBACK	0	0	0	0	0	0	0	0
WHITE SUCKER	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	3	0	0	0	0	0	0	0
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	1	0	0	0	0	0	0	0
CHANNEL CATFISH	9	7	22	26	22	7	7	12
WHITE PERCH	0	0	0	0	0	0	0	0
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	0	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	1	0
SMALLMOUTH BASS	0	3	3	5	0	1	1	3
LARGEMOUTH BASS	0	0	0	0	0	0	0	3
YELLOW PERCH	0	0	0	0	0	0	0	0
WALLEYE	1	3	4	13	5	2	3	3
AMERICAN EEL	0	0	0	0	0	0	0	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0	0	0	0
GOLDEN SHINER	0	0	0	0	0	0	0	0
COMELY SHINER	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	0	0	1	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0
LONGNOSE GAR	0	0	0	0	0	0	0	0
Total	4,169	9,950	7,955	5,068	15,729	16,912	11,034	7,070

Table 4. (continued)

Date:	*4/10*	*4/11*	*4/12*	*4/13*	*4/14*	*4/15*	*4/16*	*4/17*
Start Fishing Time:	*8:50*	*9:30*	*8:30*	*8:20*	*8:00*	*8:00*	*8:15*	*8:15*
End Fishing Time:	*17:30*	*9:31*	*18:30*	*16:30*	*19:00*	*17:00*	*15:30*	*16:20*
Hours of Operation:	*8.7*	*0.0*	*10.0*	*8.2*	*11.0*	*7.5*	*7.3*	*8.1*
Number of Lifts:	*16*	*0*	*20*	*20*	*22*	*12*	*12*	*15*
Water Temperature (°F):	*58.3*	*58.3*	*57.2*	*58.1*	*58.7*	*59.4*	*62.6*	*64.1*
AMERICAN SHAD	107	14	159	435	668	479	344	571
BLUEBACK HERRING	0	0	0	0	0	0	0	0
ALEWIFE	0	0	0	19	0	0	0	0
GIZZARD SHAD	16,173	24	10,260	19,457	38,080	10,951	30,144	38,939
STRIPED BASS	0	0	0	0	0	0	0	0
SEA LAMPREY	2	0	1	6	2	2	2	3
RAINBOW TROUT	0	0	0	0	0	0	0	2
BROWN TROUT	0	0	0	0	0	0	0	0
MUSKELLUNGE	1	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	0	0	0	0	0	2	0	4
QUILLBACK	0	0	0	0	0	0	2	1
WHITE SUCKER	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	0	0	0	2	1	3	0	0
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0
CHANNEL CATFISH	28	0	24	73	7	34	31	24
WHITE PERCH	0	0	0	1	0	0	0	1
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	2	1	3	1	1	4
LARGEMOUTH BASS	1	0	0	1	0	0	0	0
YELLOW PERCH	0	0	0	0	0	1	0	1
WALLEYE	0	0	0	2	1	0	3	0
AMERICAN EEL	0	0	0	0	0	0	0	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0	0	0	0
GOLDEN SHINER	0	0	0	0	0	0	0	0
COMELY SHINER	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0
LONGNOSE GAR	0	0	0	0	0	0	0	0
Total	16,314	38	10,446	19,997	38,762	11,473	30,527	39,550

Table 4. (continued)

Date:	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25
Start Fishing Time:	*13:30*	*9:00*	*8:00*	*8:00*	*8:00*		*6:00*	*8:00*
End Fishing Time:	*19:30*	*9:10*	*18:30*	*18:30*	*10:30*		*19:00*	*11:15*
Hours of Operation:	*6.0*	*10.2*	*10.5*	*10.5*	*2.5*		*13.0*	*3.3*
Number of Lifts:	*12*	*20*	*21*	*19*	*5*		*25*	*6*
Water Temperature (°F):	*63.1*	*61.7*	*62.6*	*63.5*	*64.9*		*62.3*	*63.3*
AMERICAN SHAD	1,444	608	487	378	113		1,710	239
BLUEBACK HERRING	0	0	0	0	0		0	0
ALEWIFE	0	1	0	0	0		0	0
GIZZARD SHAD	14,356	25,644	25,404	14,751	4,971		23,792	28,527
STRIPED BASS	0	0	0	0	0		0	0
SEA LAMPREY	1	3	2	3	1		2	1
RAINBOW TROUT	0	0	0	0	0		1	0
BROWN TROUT	0	0	0	1	0		0	0
MUSKELLUNGE	0	0	0	0	0		0	0
TIGER MUSKIE	0	1	0	0	0		0	0
CARP	3	5	0	7	18		2	2
QUILLBACK	9	12	72	156	16		45	1
WHITE SUCKER	0	1	0	0	0		0	0
SHORTHEAD REDHORSE	0	1	8	6	5		27	2
YELLOW BULLHEAD	0	0	0	0	0		0	0
BROWN BULLHEAD	0	0	7	14	0		11	0
CHANNEL CATFISH	80	18	72	97	44		102	35
WHITE PERCH	0	0	1	0	0		0	0
HYBRID STRIPED BASS	0	0	0	0	0		0	0
ROCK BASS	0	0	0	0	0		0	0
GREEN SUNFISH	0	1	0	0	0		0	0
PUMKINSEED	0	0	0	0	0		0	0
BLUEGILL	0	0	0	0	0		0	0
SMALLMOUTH BASS	1	2	4	2	4		15	14
LARGEMOUTH BASS	0	0	0	0	0		1	2
YELLOW PERCH	0	0	0	1	0		1	0
WALLEYE	1	1	1	0	0		14	36
AMERICAN EEL	0	0	0	0	0		0	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0		4	0
GOLDEN SHINER	0	0	0	0	0		0	0
COMELY SHINER	0	0	0	0	0		0	0
SPOTTAIL SHINER	0	0	0	0	0		0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0		0	0
FLATHEAD CATFISH	0	0	0	0	0		0	0
LONGNOSE GAR	0	0	0	0	0		0	0
Total	15,895	26,298	26,058	15,416	5,172		25,727	28,859

Table 4. (continued)

Date:	*4/26*	*4/27*	*4/28*	*4/29*	*4/30*	*5/1*	*5/2*	*5/3*
Start Fishing Time:		*8:10*	*5:45*	*8:00*	*9:15*	*8:30*	*8:00*	*8:00*
End Fishing Time:		*18:30*	*18:15*	*17:00*	*18:30*	*18:00*	*19:00*	*18:00*
Hours of Operation:		*10.3*	*12.5*	*9.0*	*9.3*	*9.5*	*11.0*	*10.0*
Number of Lifts:		*20*	*24*	*16*	*11*	*19*	*22*	*20*
Water Temperature (°F):		*61.7*	*60.0*	*59.5*	*58.8*	*58.1*	*59.6*	*60.0*
AMERICAN SHAD		1,670	227	154	215	89	521	88
BLUEBACK HERRING		0	0	0	0	0	0	0
ALEWIFE		0	0	0	0	0	0	0
GIZZARD SHAD		35,645	33,252	25,871	21,266	8,064	13,010	30,892
STRIPED BASS		0	0	0	0	0	0	1
SEA LAMPREY		3	4	0	6	2	0	3
RAINBOW TROUT		0	0	0	0	0	0	0
BROWN TROUT		0	0	0	0	1	0	0
MUSKELLUNGE		0	0	0	0	1	0	0
TIGER MUSKIE		0	0	0	0	0	0	0
CARP		1	3	1	2	4	5	0
QUILLBACK		9	15	1	1	7	11	1
WHITE SUCKER		0	0	0	0	0	0	0
SHORTHEAD REDHORSE		9	0	1	1	0	1	1
YELLOW BULLHEAD		1	0	0	0	0	0	0
BROWN BULLHEAD		14	1	0	0	0	0	4
CHANNEL CATFISH		38	60	17	23	29	13	28
WHITE PERCH		0	1	0	0	0	4	3
HYBRID STRIPED BASS		0	0	0	0	0	0	0
ROCK BASS		0	0	0	0	1	0	0
GREEN SUNFISH		0	0	0	0	0	0	0
PUMKINSEED		0	0	0	0	0	0	0
BLUEGILL		0	0	0	0	0	2	1
SMALLMOUTH BASS		14	5	4	7	2	0	6
LARGEMOUTH BASS		0	0	0	0	1	0	0
YELLOW PERCH		0	2	0	0	0	1	1
WALLEYE		14	35	0	5	5	2	9
AMERICAN EEL		0	0	0	0	0	0	0
SPLAKE (Brook x Lake Trout)		0	0	0	0	0	0	0
GOLDEN SHINER		0	0	0	0	0	0	0
COMELY SHINER		0	0	0	0	0	0	0
SPOTTAIL SHINER		0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH		0	0	0	0	0	0	0
FLATHEAD CATFISH		0	0	0	0	0	1	0
LONGNOSE GAR		0	0	0	0	0	0	0
Total		37,418	33,605	26,049	21,526	8,206	13,571	31,038

Table 4. (continued)

Date:	*5/4*	*5/5*	*5/6*	*5/7*	*5/8*	*5/9*	*5/10*	*5/11*
Start Fishing Time:	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*
End Fishing Time:	*18:00*	*19:00*	*18:00*	*19:00*	*19:00*	*19:00*	*19:00*	*18:00*
Hours of Operation:	*12.0*	*11.0*	*12.0*	*11.0*	*13.0*	*11.0*	*13.0*	*10.0*
Number of Lifts:	*24*	*22*	*24*	*22*	*26*	*21*	*26*	*16*
Water Temperature (°F):	*60.0*	*63.2*	*63.5*	*64.4*	*64.4*	*65.3*	*65.7*	*65.3*
AMERICAN SHAD	817	1,303	553	136	358	295	146	31
BLUEBACK HERRING	0	0	0	1	0	0	0	0
ALEWIFE	0	0	0	0	0	0	0	0
GIZZARD SHAD	25,331	26,128	42,813	56,265	38,345	35,030	44,157	14,071
STRIPED BASS	0	0	1	0	0	0	0	0
SEA LAMPREY	0	0	2	4	2	2	3	1
RAINBOW TROUT	0	0	0	0	0	0	2	0
BROWN TROUT	0	0	0	0	0	0	0	0
MUSKELLUNGE	1	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	3	61	22	10	25	3	8	1
QUILLBACK	7	14	42	7	147	155	55	4
WHITE SUCKER	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	2	8	4	5	22	20	6	0
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	4	5	38	76	0	19	5	0
CHANNEL CATFISH	19	128	195	151	97	240	844	110
WHITE PERCH	0	2	0	0	2	3	0	0
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	0	0	0	1	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	1	0	0	0
BLUEGILL	0	0	0	0	1	0	2	2
SMALLMOUTH BASS	2	6	15	20	7	23	4	3
LARGEMOUTH BASS	0	0	1	0	0	0	0	0
YELLOW PERCH	0	0	0	1	0	1	6	0
WALLEYE	6	9	38	27	66	60	42	12
AMERICAN EEL	0	0	0	0	0	0	0	0
SPLAKE (Brook x Lake Trout)	0	1	0	1	0	0	0	0
GOLDEN SHINER	0	0	0	0	0	0	0	0
COMELY SHINER	0	0	0	0	0	0	15	0
SPOTTAIL SHINER	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0
LONGNOSE GAR	0	0	0	0	0	0	0	0
Total	26,192	27,665	43,724	56,704	39,073	35,851	45,296	14,235

Table 4. (continued)

Date:	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*	*5/17*	*5/18*	*5/19*
Start Fishing Time:	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*
End Fishing Time:	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*
Hours of Operation:	*13.0*	*11.0*	*13.0*	*11.0*	*13.0*	*11.0*	*13.0*	*11.0*
Number of Lifts:	*26*	*22*	*25*	*21*	*26*	*22*	*26*	*22*
Water Temperature (°F):	*64.4*	*65.3*	*65.7*	*65*	*65.7*	*65.9*	*66.8*	*66.4*
AMERICAN SHAD	95	141	994	161	119	7	9	5
BLUEBACK HERRING	0	0	0	2	0	0	0	0
ALEWIFE	0	0	0	0	0	0	0	0
GIZZARD SHAD	26,795	29,562	21,580	11,789	17,772	1,660	13,249	9,209
STRIPED BASS	2	1	20	0	2	5	2	5
SEA LAMPREY	0	0	2	1	1	1	1	0
RAINBOW TROUT	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	3	1	0	2	2	11	2	0
QUILLBACK	7	2	3	47	22	5	7	0
WHITE SUCKER	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	7	5	2	9	9	107	12	9
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0
CHANNEL CATFISH	353	44	79	115	211	908	1,384	947
WHITE PERCH	1	0	0	2	3	0	0	1
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	0	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0
BLUEGILL	0	1	0	0	2	2	1	0
SMALLMOUTH BASS	3	3	4	2	3	0	2	0
LARGEMOUTH BASS	0	1	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	1	0	1
WALLEYE	19	3	21	8	30	12	4	1
AMERICAN EEL	0	0	0	0	0	1	0	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0	0	0	0
GOLDEN SHINER	0	0	0	0	0	0	0	0
COMELY SHINER	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	1	0	0	0	0
LONGNOSE GAR	0	0	0	0	0	0	0	0
Total	27,285	29,764	22,705	12,139	18,176	2,720	14,673	10,178

Table 4. (continued)

Date:	*5/20*	*5/21*	*5/22*	*5/23*	*5/24*	*5/25*	*5/26*	*5/27*
Start Fishing Time:	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*	*6:00*	*8:00*
End Fishing Time:	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*
Hours of Operation:	*13.0*	*11.0*	*13.0*	*11.0*	*13.0*	*11.0*	*13.0*	*11.0*
Number of Lifts:	*26*	*22*	*26*	*22*	*26*	*22*	*26*	*22*
Water Temperature (°F):	*67.1*	*68.7*	*68.0*	*69.3*	*71.6*	*72.5*	*72.5*	*73.8*
AMERICAN SHAD	314	417	454	769	503	380	384	327
BLUEBACK HERRING	1	1	0	0	0	0	13	6
ALEWIFE	0	0	0	0	0	0	0	0
GIZZARD SHAD	13,198	13,783	13,906	9,023	9,413	7,274	13,239	5,894
STRIPED BASS	2	1	0	2	9	4	5	3
SEA LAMPREY	0	1	1	0	0	0	0	1
RAINBOW TROUT	0	0	2	1	0	0	0	3
BROWN TROUT	0	4	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	2	3	2	10	19	7	0	9
QUILLBACK	3	189	9	49	68	26	34	54
WHITE SUCKER	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	0	3	3	3	4	4	4	1
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	1	0	0	0	0
CHANNEL CATFISH	206	132	53	80	228	417	187	214
WHITE PERCH	1	0	7	2	0	1	0	0
HYBRID STRIPED BASS	0	0	1	0	0	0	0	0
ROCK BASS	0	0	0	0	0	0	1	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0
BLUEGILL	2	3	1	2	0	0	1	3
SMALLMOUTH BASS	0	8	6	6	2	3	4	1
LARGEMOUTH BASS	1	0	0	0	0	0	0	1
YELLOW PERCH	0	0	0	0	1	0	0	0
WALLEYE	10	7	9	13	29	18	23	10
AMERICAN EEL	0	0	0	1	0	0	1	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0	0	0	0
GOLDEN SHINER	0	0	0	0	0	0	0	0
COMELY SHINER	0	1,025	0	0	0	0	0	0
SPOTTAIL SHINER	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	1	0	0	2	2
FLATHEAD CATFISH	0	0	0	0	0	0	0	0
LONGNOSE GAR	0	0	0	0	0	0	0	0
Total	13,740	15,577	14,454	9,963	10,276	8,134	13,898	6,529

Table 4. (continued)

Date:	*5/28*	*5/29*	*5/30*	*5/31*	*6/1*	*6/2*	*6/3*	*6/4*
Start Fishing Time:	*6:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:30*
End Fishing Time:	*19:00*	*19:00*	*19:00*	*18:00*	*17:30*	*15:30*	*15:30*	*15:30*
Hours of Operation:	*13.0*	*11.0*	*11.0*	*10.0*	*9.5*	*7.5*	*7.5*	*7.0*
Number of Lifts:	*25*	*22*	*22*	*20*	*19*	*15*	*15*	*13*
Water Temperature (°F):	*76.1*	*77.9*	*78.6*	*79.4*	*78.1*	*77.6*	*74.7*	*72.5*
AMERICAN SHAD	100	32	47	22	11	20	2	2
BLUEBACK HERRING	0	0	0	0	0	0	1	0
ALEWIFE	0	0	0	0	0	0	0	0
GIZZARD SHAD	5,869	5,823	5,950	1,162	1,227	487	2,765	1,489
STRIPED BASS	2	6	8	11	18	10	3	1
SEA LAMPREY	2	2	0	0	0	0	0	0
RAINBOW TROUT	2	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0
TIGER MUSKIE	0	0	0	0	0	0	0	0
CARP	18	11	16	11	4	4	0	0
QUILLBACK	132	33	20	5	10	1	5	1
WHITE SUCKER	0	0	0	0	0	0	0	0
S. REDHORSE	2	4	6	0	0	1	1	0
YELLOW BULLHEAD	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	1	0	1	0	0	0
CHANNEL CATFISH	311	518	903	344	573	373	637	167
WHITE PERCH	1	0	2	0	0	0	0	0
HYBRID STRIPED BASS	1	0	1	0	0	0	0	0
ROCK BASS	0	0	1	0	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0
PUMKINSEED	1	0	0	0	0	0	0	0
BLUEGILL	0	2	2	0	3	0	4	0
SMALLMOUTH BASS	10	7	3	1	6	0	0	0
LARGEMOUTH BASS	0	0	0	0	0	0	0	0
YELLOW PERCH	2	0	0	0	0	0	0	0
WALLEYE	18	10	31	6	6	6	5	0
AMERICAN EEL	0	0	0	0	0	0	1	0
SPLAKE (Brook x Lake Trout)	0	0	0	0	0	0	0	0
GOLDEN SHINER	0	0	1	0	0	0	0	0
COMELY SHINER	0	0	0	2	0	0	0	0
SPOTTAIL SHINER	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	4	2	1	0	0	1	0	0
FLATHEAD CATFISH	0	0	0	0	0	1	0	0
LONGNOSE GAR	0	0	0	1	0	0	0	0
Total	6,475	6,450	6,993	1,565	1,859	904	3,424	1,660

Table 4. (continued)

Date:	*6/5*	***Season***
Start Fishing Time:	*8:00*	***Total***
End Fishing Time:	*15:30*	
Hours of Operation:	*7.5*	***633.7***
Number of Lifts:	*15*	***1230.0***
Water Temperature (°F):	*71.3*	
AMERICAN SHAD	5	**22,143**
BLUEBACK HERRING	0	**25**
ALEWIFE	0	**27**
GIZZARD SHAD	1,710	**1,070,672**
STRIPED BASS	3	**129**
SEA LAMPREY	0	**85**
RAINBOW TROUT	0	**14**
BROWN TROUT	0	**6**
MUSKELLUNGE	0	**3**
TIGER MUSKIE	0	**1**
CARP	0	**331**
QUILLBACK	1	**1,523**
WHITE SUCKER	0	**1**
SHORTHEAD REDHORSE	0	**334**
YELLOW BULLHEAD	0	**1**
BROWN BULLHEAD	1	**203**
CHANNEL CATFISH	67	**12,224**
WHITE PERCH	0	**39**
HYBRID STRIPED BASS	0	**3**
ROCK BASS	0	**5**
GREEN SUNFISH	0	**1**
PUMKINSEED	1	**3**
BLUEGILL	1	**39**
SMALLMOUTH BASS	0	**263**
LARGEMOUTH BASS	0	**13**
YELLOW PERCH	0	**21**
WALLEYE	0	**722**
AMERICAN EEL	0	**4**
SPLAKE (Brook x Lake Trout)	0	**6**
GOLDEN SHINER	0	**1**
COMELY SHINER	9	**1,051**
SPOTTAIL SHINER	0	**1**
ATLANTIC NEEDLEFISH	0	**13**
FLATHEAD CATFISH	0	**3**
LONGNOSE GAR	0	**1**
Total	1,798	**1,109,911**

Table 5. Summary of American shad catch, Maryland DNR recaptures, daily average river flow, water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Conowingo Dam East Fish Passage Facility in 2012.

Date	American Shad Catch	MD DNR Recaptures*	Holtwood River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
4/2	642		26,400	54.4	24	8	A/C	310	18.5-23.0	107.2
4/3	80		26,700	54.0	25	11	A/C	310	18.5-23.5	107.3
4/4	571		27,600	54.6	25	11	A/C	310	18.5-23.5	106.5
4/5	232		25,600	55.5	30	7	A/C	310	18.5-22.5	106.7
4/6	152		26,200	56.3	28	9	A/C	310	18.8-20.5	106.7
4/7	298		22,900	56.6	28	10	A/C	310	18.5-23.0	107.9
4/8	313		23,200	56.8	28	5	A/C	310	18.5-21.0	107.2
4/9	176		21,000	56.8	20	9	A/C	310	19.0-20.5	106.7
4/10	107		19,100	56.5	24	5	A/C	310	18.5-21.0	107.0
*4/11**	14		19,000	55.6	24	5		310		108.2
4/12	159		18,400	55.1	24	5	A/C	310	18.5-19.0	107.8
4/13	435		16,100	54.9	25	7	A/C	310	18.4-22.7	107.2
4/14	668		17,100	54.9	26	4	A	310	18.1-19.9	108.2
4/15	479	*1-orange*	16,000	55.4	28	5	A/C	310	18.4-19.0	107.6
4/16	344		16,100	56.5	30	5	A	310	18.0-20.0	107.4
4/17	571		15,500	59.3	34	3	A	310	18.3-19.0	107.3
4/18	1444		14,900	60.1	30	2	A	310	19.7	107.1
4/19	608		14,300	62.3	30	5	A/C	310	18.6	108.2
4/20	487	*1-orange*	16,900	63.1	30	2	A	310	19.0	107.9
4/21	378	*2-orange*	13,700	64.6	30	2	A	310	18.7-19.0	108.0
4/22	113		14,800	64.4	30	2	A	310	18.5	106.5
*4/23***				62.5						
4/24	1710	*1-orange*	18,000	61.6	30	6	A/C	310	18.6-21.0	106.9
4/25	239	*1-orange*	23,400	61.2	35	5	C	310	18.5-20.5	106.8
*4/26***				59.0						
4/27	1670	*2-orange*	43,500	56.1	35	10	A/C	310	19.0-23.4	106.7
4/28	227		41,200	55.9	30-18	9	A/C	310	18.5-23.5	106.7
4/29	154	*1-orange*	39,200	55.8	34	11	A/C	310	18.5-22.5	107.7
4/30	215		37,300		30	11	A/C	310	19.5-23.5	108.0
5/1	89		33,600	56.5	30	11	A/C	310	19.0-23.2	107.4
5/2	521	*1-orange*	31,400	58.0	26	10	A/C	310	19.0-23.2	107.1
5/3	88		30,700	60.9	30	10	C	310	21.0-22.8	106.8
5/4	817	*1-orange*	29,400	63.3	30	10	A/C	310	18.5-23.0	106.8
5/5	1303	*2-orange*	41,300	65.8	30	7	A/C	310	19.9-22.6	107.3
5/6	553		46,400	67.6	30	11	A/C	310	18.5-23.5	108.2
5/7	136	*1-orange*	50,200	65.5	30	11	C	310	22.8-23.5	106.3
5/8	358	*2-orange*	46,300	64.3	30	11	A/C	310	22.5-23.5	106.5

Table 5. (continued)

Date	American Shad Catch	MD DNR Recaptures*	Holtwood River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
5/9	295		45,600	64.3	30	10	C	310	22.5-23.3	106.2
5/10	146		56,700	63.6	26	11	C	310	23.5	107.1
5/11	31		65,200	62.9	22	11	C	310	23.8	106.8
5/12	95		64,500	63.5	17	11	C	310	22.0-23.5	106.2
5/13	141		56,800	64.8	22	11	C	310	23.0	106.8
5/14	994	*3-orange*	49,100	65.4	23	11	C	310	21.5-23.5	107.5
5/15	161		51,500	65.7	29-23	11	C	310	23.5	107.2
5/16	119		89,000	66.1	25	11	C	310	23.6	106.5
5/17	7		107,300	65.5	23	11	C	310	24.3	107.8
5/18	9		90,200	66.0	22	11	C	310	23.5	107.6
5/19	5		70,800	67.0	20	11	C	310	24.1	107.5
5/20	314	*1-pink*	57,100	68.5	20	11	C	310	22.0	106.8
5/21	417		47,500	69.1	25	11	C	310	23.0	108.2
5/22	454	*1-orange*	41,700	69.2	28	11	A/C	310	21.2	106.5
5/23	769	*3-orange; 1-pink*	39,800	69.9	28	11	A/C	310	21.2	108.4
5/24	503		40,400	71.4	29	11	A/C	310	23.0	107.7
5/25	380		39,100	72.7	29	11	A/C	310	21.0	107.3
5/26	384		34,800	74.4	26	8	A/C	310	21.5	107.5
5/27	327	*1-orange*	31,800	76.4	28	10	A/C	310	21.0	107.6
5/28	100		39,400	78.2	35	11	A/C	310	20.9	108.7
5/29	32		46,900	79.0	30	11	C	310	23.3	108.2
5/30	47		44,300	78.3	28	11	C	310	22.7	106.7
5/31	22		46,900	78.3	29	11	C	310	22.0	107.1
6/1	11		46,500	77.0	20	11	A/C	310	20.7	107.5
6/2	20		53,600	74.4	20-14	11	C	310	22.3	108.8
6/3	2		64,400	71.4	10-14	11	C	310	22.7	107.9
6/4	2		56,300	69.8	12	9	C	310	22.5	105.8
6/5	5		50,700	68.4	12-15	8	C	310	22.5	106.8

*Viewing only, No operation
**No operation or viewing

Table 6. Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2012.

Date:	*4/2*	*4/3*	*4/4*	*4/5*	*4/6*	*4/7*	*4/8*	*4/9*	*4/10*	*4/11*	*4/12*	*4/13*
Observation Time-Start:	*11:00*	*9:00*	*8:30*	*8:30*	*8:20*	*8:20*	*10:00*	*8:30*	*8:20*	*9:30*	*8:30*	*8:30*
Observation Time-End:	*18:45*	*18:48*	*18:45*	*18:45*	*18:45*	*18:45*	*18:48*	*18:45*	*18:15*	*14:30*	*18:45*	*16:45*
Military Time (hrs)												
0600 to 0659												
0700 to 0759												
0800 to 0859			1	4	1	0		10	3		2	1
0900 to 0959		12	2	6	3	0		6	2	7	2	7
1000 to 1059		10	0	3	0	2	3	0	1		1	2
1100 to 1159	0	8	1	0	3	3	3	11	1	3	3	42
1200 to 1259	2	24	49	8	72	12	5	11	4	3	3	137
1300 to 1359	98	1	186	49	30	31	55	22	0	1	11	112
1400 to 1459	143	6	174	58	15	114	41	20	11		29	59
1500 to 1559	162	8	94	46	5	100	48	36	16		43	40
1600 to 1659	131	3	51	31	9	23	62	39	35		46	18
1700 to 1759	68	6	11	21	7	9	64	15	31		12	12
1800 to 1859	38	2	2	6	7	4	32	6	3		7	5
1900 to 1959												
Total	642	80	571	232	152	298	313	176	107	14	159	435

Table 6. (continued)

Date:	*4/14*	*4/15*	*4/16*	*4/17*	*4/18*	*4/19*	*4/20*	*4/21*	*4/22*	*4/23*	*4/24*	*4/25*
Observation Time-Start:	*8:15*	*8:15*	*8:30*	*8:30*	*11:30*	*8:25*	*8:20*	*8:20*	*8:15*		*6:30*	*8:15*
Observation Time-End:	*19:25*	*17:00*	*16:00*	*16:30*	*19:45*	*19:30*	*19:00*	*18:50*	*11:55*		*19:35*	*12:00*
Military Time (hrs)												
0600 to 0659											1	
0700 to 0759	1	34	1	18							3	
0800 to 0859	0	10	15	19		13	22	19	74		4	4
0900 to 0959	3	16	3	2		55	13	22	27		5	209
1000 to 1059	3	16	2	3		28	13	5	9		10	11
1100 to 1159	1	51	8	0		9	12	5	3		117	15
1200 to 1259	5	107	17	3		9	4	5			135	
1300 to 1359	6	96	182	75	23	15	5	7			57	
1400 to 1459	48	130	116	171	240	64	11	12			169	
1500 to 1559	145	19		280	387	150	46	51			368	
1600 to 1659	208				292	125	81	71			417	
1700 to 1759	190				233	80	170	71			208	
1800 to 1859	58				181	32	110	110			110	
1900 to 1959					88	28					106	
Total	668	479	344	571	1,444	608	487	378	113	0	1,710	239

Table 6. (continued)

Date:	*4/26*	*4/27*	*4/28*	*4/29*	*4/30*	*5/1*	*5/2*	*5/3*	*5/4*	*5/5*	*5/6*	*5/7*
Observation Time-Start:		*8:30*	*6:10*	*8:15*	*8:30*	*8:15*	*8:00*	*8:15*	*6:00*	*8:00*	*6:00*	*8:00*
Observation Time-End:		*18:45*	*18:30*	*17:15*	*19:00*	*18:26*	*19:30*	*18:15*	*18:15*	*19:30*	*18:15*	*19:25*
Military Time (hrs)												
0600 to 0659			21						1		5	
0700 to 0759			13						29		61	
0800 to 0859		3	12	13		11	11	19	66	58	77	18
0900 to 0959		5	5	30	6	27	7	27	15	28	86	14
1000 to 1059		5	1	11	10	4	5	4	27	5	45	3
1100 to 1159		8	5	3	5	1	1	3	8	2	66	1
1200 to 1259		18	2	2	10	2	0	2	26	7	33	13
1300 to 1359		121	3	1	2	3	1	3	40	22	38	21
1400 to 1459		250	11	9	6	2	14	2	125	190	39	4
1500 to 1559		369	20	41	3	6	34	10	196	231	24	5
1600 to 1659		633	47	30	3	9	126	9	202	233	20	21
1700 to 1759		214	71	14	81	13	129	9	57	237	44	18
1800 to 1859		44	16		89	11	139	0	25	217	15	13
1900 to 1959							54			73		5
Total	0	1,670	227	154	215	89	521	88	817	1,303	553	136

Table 6. (continued)

Date:	*5/8*	*5/9*	*5/10*	*5/11*	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*	*5/17*	*5/18*	*5/19*
Observation Time-Start:	*6:00*	*8:00*	*6:00*	*8:00*	*6:25*	*8:00*	*6:15*	*8:15*	*6:10*	*8:10*	*6:15*	*8:15*
Observation Time-End:	*19:20*	*19:15*	*19:20*	*18:30*	*19:25*	*19:15*	*19:25*	*19:15*	*19:20*	*19:15*	*19:15*	*19:15*
Military Time (hrs)												
0600 to 0659	2		13				11		12		0	
0700 to 0759	9		16		1		13		4		1	
0800 to 0859	2	29	9	2	1	3	161	2	7	3	1	0
0900 to 0959	10	61	8	2	3	8	279	16	14		0	2
1000 to 1059	12	29	7	3	7	8	108	35	6		0	2
1100 to 1159	12	37	2	6	2	4	115	38	15		1	0
1200 to 1259	19	41	4	3	6	5	66	18	13	2	0	0
1300 to 1359	33	34	11	0	8	15	56	9	14	1	2	0
1400 to 1459	46	22	19	7	14	27	44	10	5		0	0
1500 to 1559	68	9	8	6	2	18	30	7	2		1	1
1600 to 1659	49	3	17	1	1	27	41	14	3	1	1	0
1700 to 1759	46	1	16	1	3	16	17	3	9		2	0
1800 to 1859	29	23	14	0	22	8	28	8	13		0	0
1900 to 1959	21	6	2		25	2	25	1	2		0	0
Total	358	295	146	31	95	141	994	161	119	7	9	5

Table 6. (continued)

Date:	*5/20*	*5/21*	*5/22*	*5/23*	*5/24*	*5/25*	*5/26*	*5/27*	*5/28*	*5/29*	*5/30*	*5/31*
Observation Time-Start:	*6:00*	*8:00*	*6:15*	*8:15*	*6:00*	*8:15*	*6:20*	*8:00*	*6:00*	*8:15*	*8:00*	*8:00*
Observation Time-End:	*19:15*	*19:25*	*19:15*	*19:30*	*19:15*	*19:20*	*19:20*	*19:15*	*19:15*	*19:20*	*19:15*	*18:10*
Military Time (hrs)												
0600 to 0659	0		68		13		8		1			
0700 to 0759	7		122		13		63		18			
0800 to 0859	2	23	99	93	38	41	73	24	30	2	3	2
0900 to 0959	8	22	34	187	60	120	44	131	11	3	0	10
1000 to 1059	7	58	11	86	104	91	52	64	7	8	3	3
1100 to 1159	5	52	26	84	75	41	40	27	9	8	10	0
1200 to 1259	6	39	12	29	73	21	26	21	2	1	10	2
1300 to 1359	13	21	22	32	37	26	14	25	4	3	1	2
1400 to 1459	31	16	22	34	21	15	9	7	9	1	2	1
1500 to 1559	45	31	16	32	20	4	12	5	5	0	0	1
1600 to 1659	65	57	7	73	7	3	10	2	4	0	1	0
1700 to 1759	75	31	6	49	14	5	9	11	0	0	5	1
1800 to 1859	37	52	8	43	18	6	20	9		4	9	0
1900 to 1959	13	15	1	27	10	7	4	1		2	3	
Total	314	417	454	769	503	380	384	327	100	32	47	22

Table 6. (continued)

Date:	*6/1*	*6/2*	*6/3*	*6/4*	*6/5*	*Season Total*
Observation Time-Start:	*8:30*	*8:00*	*8:00*	*8:30*	*8:00*	
Observation Time-End:	*18:00*	*16:00*	*16:00*	*16:00*	*16:00*	
Military Time (hrs)						
0600 to 0659						**156**
0700 to 0759						**427**
0800 to 0859	0	0	0	0	0	**1,140**
0900 to 0959	3	2	0	0	1	**1,691**
1000 to 1059	1	5	2	0	0	**961**
1100 to 1159	1	6	0	1	0	**1,019**
1200 to 1259	1	3	0	1	0	**1,154**
1300 to 1359	1	2	0	0	1	**1,704**
1400 to 1459	1	1	0	0	2	**2,649**
1500 to 1559	0	1	0	0	1	**3,308**
1600 to 1659	1					**3,363**
1700 to 1759	2					**2,417**
1800 to 1859						**1,633**
1900 to 1959						**521**
Total	11	20	2	2	5	**22,143**

Table 7. Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2012.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		Number	% of C.E.L.	Number	% of Holt.	Number	% of S.H.
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,687	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%
2004	109,360	3,428	3.1%	2,109	61.5%	219	10.4%
2005	68,926	34,189	49.6%	25,425	74.4%	1,772	7.0%
2006	56,899	35,968	63.2%	24,929	69.3%	1,913	7.7%
2007	25,464	10,338	40.6%	7,215	69.8%	192	2.7%
2008	19,914	2,795	14.0%	1,252	44.8%	21	1.7%
2009	29,272	10,896	37.2%	7,994	73.4%	402	5.0%
2010	37,757	16,472	43.6%	12,706	77.1%	907	7.1%
2011	20,571	21	0.1%	8	38.1%	0	0.0%
2012	**22,143**	**4,238**	**19.1%**	**3,089**	**72.9%**	**224**	**7.3%**

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS – 2012

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INTRODUCTION

The shore-based trapping device at Conowingo Dam known as the West Fish Lift (WFL) has operated every spring since 1972 for the purpose of collecting and counting American shad, river herring, other migratory species and resident fishes in the tailrace. Since 1985, most shad collected here have been sorted from the daily catch, placed into circular transport tanks, and stocked into suitable spawning waters upstream of the mainstem hydroelectric dams. During the spring runs of 1991 through 1996 the newer East Fish Lift at Conowingo Dam also served this purpose. With fish passage available at Holtwood and Safe Harbor dams since 1997, the Conowingo East Fish Lift was operated to pass all fish into the project head pond.
Upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam but Exelon has agreed to keep the West Fish Lift operational to provide brood fish for egg collection efforts and biological samples for ASMFC required fishery independent monitoring. Project details are coordinated with the resource agencies through the Susquehanna River Technical Committee (SRTC). Funding for contractor expenses for WFL operation, as well as shad tank spawning trials in 2012 was derived from annual contributions by the PA Fish and Boat Commission and Maryland DNR. In the past, these contributed funds had been administered by the USFWS Susquehanna Coordinator. With the re-assignment of the USFWS Coordinator, PFBC made arrangements for The Alliance for the Chesapeake Bay to administer the funds and the Alliance contracted with Normandeau Associates to operate the WFL.

The objectives of Conowingo West Fish Lift operations in 2012 included: collection and enumeration of shad, river herring, and other migratory and resident fishes; and obtaining adult shad for an on-site tank spawning and shad egg collection program conducted at Conowingo Dam. Shad taken here are also monitored for DNR tags and sex ratios, and scale and head samples are taken for age and otolith analysis. American shad collected from the WFL were also used for special studies in 2012. The Conowingo adult shad turbine survival study required 323 fish, the Conowingo EFL upstream fish passage effectiveness study required 35 adult shad, the York Haven downstream fish passage study required 64 shad, and 148 shad were utilized for the PPL Holtwood PIT-tag study.

METHODS

West Fish Lift operational procedures adopted by the SRTC included limiting the period of operation to the peak six weeks of the run (late April through the first week in June) and limiting daily lift operations to 8 hours (1100-1900 hrs.). Within these parameters the West Fish Lift was operated as in past years, maintaining appropriate entrance velocities and curbing use of adjacent units 1 and 2 whenever river flow dropped below 60,000 cfs. Normandeau Associates, Inc. (NAI) was contracted to operate both Conowingo fish lifts and to conduct American shad tank spawning trials with egg deliveries to Van Dyke hatchery.

Average daily river flow at Conowingo suffered 4 minor peaks and one major peak between April 1 and June 6 (Figure 1). Water temperature during the same period increased more or less gradually from 55 to 79° F. Lift operations began on April 23 and occurred on 37 days through June 1. Total fishing effort over this period amounted to 404 lifts and a fishing time of 244 hours.

American shad collected in the lift were counted and either placed into holding or spawning tanks. Shad in excess of those needed for on-site spawning, or for biological data were returned alive to the tailrace. Other species were identified, enumerated and returned to the tailrace. No live shad brood fish were provided to Maryland DNR for tank spawning in 2012. Every 50th shad in the West Fish Lift collection was sacrificed for otoliths and a scale sample was taken. Lengths and weights were measured, and sex ratios of shad in daily catches were recorded.

RESULTS

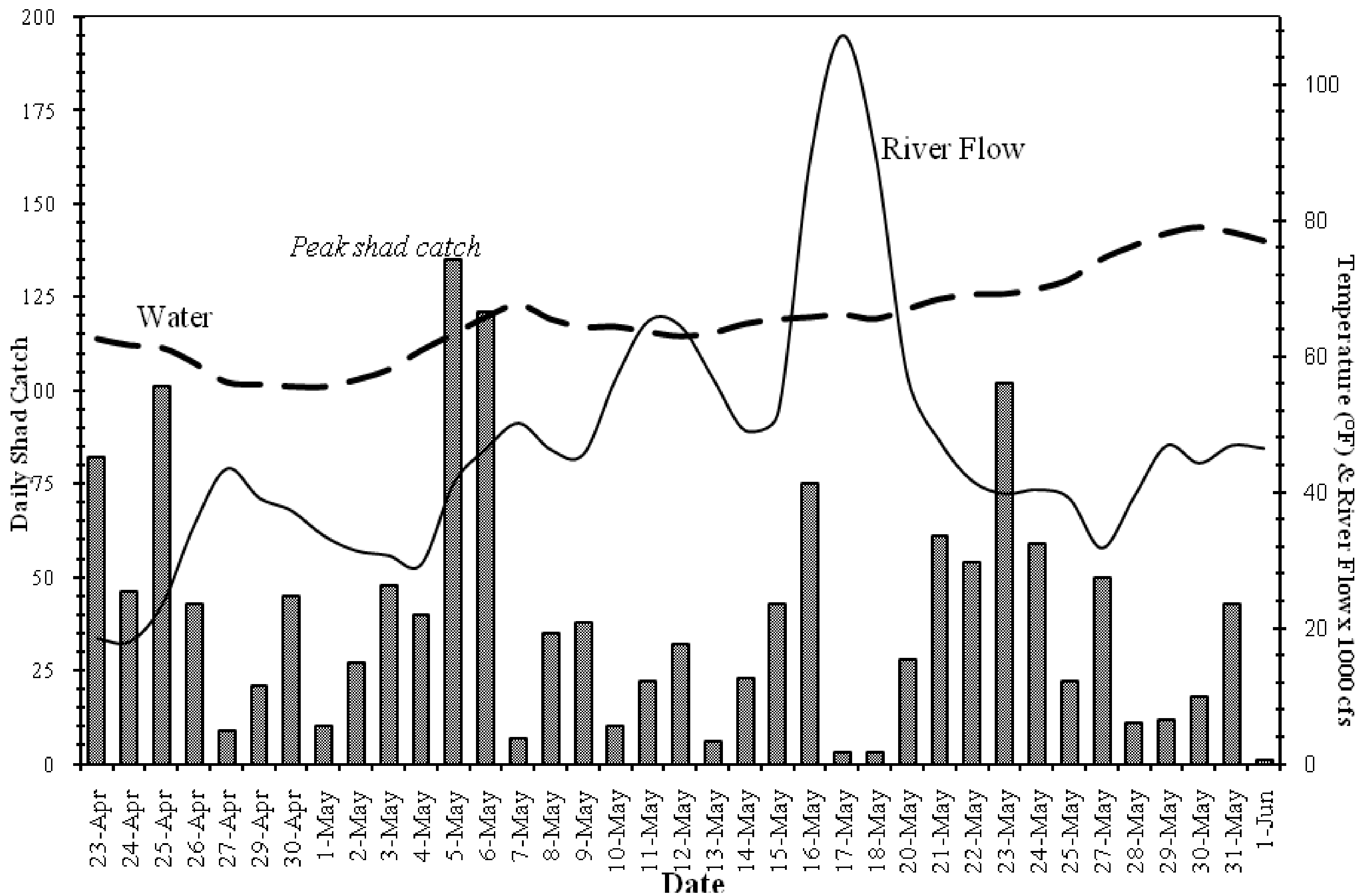
The West Fish Lift caught 322,053 fish of 40 taxa (Table 1). Gizzard shad comprised 95% of the total catch and the next three most numerous species, channel catfish, comely shiner and American shad comprised 3% of the total. Some 1,486 American shad were caught, representing 0.5% of the total catch (Table 2). Some seven blueback herring were also caught. Catch of American shad averaged 40 per operating day with a peak day catch of 135 shad on May 5. Normandeau Associates used 481 American shad at the lift site for tank spawning. Of the 121 shad sacrificed for hatchery vs. wild analysis by PFBC, 24% were shown to be of hatchery origin. Males averaged 440 mm in total length and 757 g while females averaged 511 mm and 1,319 g. Overall male to female sex ratio of shad in the West Fish Lift in 2012 was 1.0 to 1.3 (Table 3).

DISCUSSION

An early spring and low river flows in 2012 resulted in an early start for West Fish Lift operation on April 1. Peak catch occurred on May 5 with a catch of 135 American shad. West Fish Lift catch per effort of 6.1 shad per fishing hour was well below the long term average of 30 shad per fishing hour (Table 4). Operations and fish catch at the West Fish Lift during 1985-2011 are summarized in Table 5.

FIGURES

FIGURE 1. A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 2012. The West Lift was not operated on 28 April, 19 May, and 26 May.



TABLES

TABLE 1. Catch of fishes at the Conowingo Dam West Fish Lift, 2012.

Number of Days	**37**
Number of Lifts	**404**
Fishing Time (hours : minutes)	**243:57**
Number of Taxa	**37**
AMERICAN SHAD	1,486
HICKORY SHAD	0
BLUEBACK HERRING	7
ALEWIFE	0
GIZZARD SHAD	306,895
STRIPED BASS	508
HYBRID STRIPED BASS	22
CARP	898
White Perch	1,555
American Eel	138
Brook Trout	5
Brown Trout	4
Goldfish	1
Golden Shiner	1
Comely Shiner	3,174
Spotfin Shiner	43
Spottail Shiner	7
Swallowtail Shiner	1
Mimic Shiner	1
Quillback	85
White Sucker	6
Shorthead Redhorse	322
Brown Bullhead	98
Yellow Bullhead	1
Channel Catfish	4,940
Flathead Catfish	209
Rock Bass	68
Redbreast Sunfish	6
Green Sunfish	2
Pumpkinseed	32
Bluegill	167
Smallmouth Bass	280
Largemouth Bass	26
White Crappie	4
Black Crappie	1
Yellow Perch	44
Walleye	614
Tesselated Darter	3
Atlantic Needlefish	366
Sea Lamprey	33
Total	**322,053**

TABLE 2. Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 23 April - 1 June, 2012.

Date:	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	Total
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	for the Week
Number of Lifts:	0	14	7	13	5	10	0	49
Time of First Lift:		9:05	8:30	8:40	12:15	8:40		
Time of Last lift:		15:30	13:50	15:50	15:00	15:15		
Operating time (hours):	0:00	6:25	5:20	7:10	2:45	6:35	0:00	28:15:00
Average Water Temperature (°F):		64.0	62.6	62.5	63.1	62.3		
American shad		82	46	101	43	9		281
Blueback herring		0	0	0	0	0		0
Alewife		0	0	0	0	0		0
Gizzard shad		11,175	4,750	12,300	4,500	16,650		49,375
Hickory shad		0	0	0	0	0		0
Striped bass		0	0	0	0	1		1
Carp		199	30	2	2	12		245
Other species		170	152	134	122	229		807
Total		11,626	4,978	12,537	4,667	16,901		50,709

Date:	29-Apr	30-Apr	1-May	2-May	3-May	4-May	5-May	Total
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	for the Week
Number of Lifts:	11	10	10	10	12	12	13	78
Time of First Lift:	8:45	9:30	10:00	8:45	8:35	8:30	8:30	
Time of Last lift:	15:30	15:30	15:30	15:30	15:15	15:30	15:30	
Operating time (hours):	6:45	6:00	5:30	6:45	6:40	7:00	7:00	45:40:00
Average Water Temperature (°F):	59.0	58.6	57.7	57.8	58.8	59.5	61.4	
American shad	21	45	10	27	48	40	135	326
Blueback herring	0	0	0	0	0	1	0	1
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	8,435	5,250	5,525	4,800	13,975	11,500	13,850	63,335
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	0	0	2	3	0	0	18	23
Carp	15	0	0	1	2	0	2	20
Other species	85	41	41	100	78	190	802	1,337
Total	8,556	5,336	5,578	4,931	14,103	11,731	14,807	65,042

Table 2. (continued).

Date:	6-May	7-May	8-May	9-May	10-May	11-May	12-May	Total
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	for the Week
Number of Lifts:	6	10	9	13	16	13	19	86
Time of First Lift:	11:20	8:45	8:30	8:15	8:30	8:15	8:28	
Time of Last lift:	15:15	15:30	15:30	15:30	15:30	15:30	15:45	
Operating time (hours):	3:55	6:45	7:00	7:15	7:00	7:15	7:17	46:27:00
Average Water Temperature (°F):	63.2	64.9	66.0	67.9	66.4	65.2	65.3	
American shad	121	7	35	38	10	22	32	265
Blueback herring	1	0	0	0	0	0	0	1
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	2,750	14,800	7,250	10,700	20,850	10,650	25,000	92,000
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	2	1	6	48	33	12	18	120
Carp	1	88	6	15	26	14	19	169
Other species	241	186	892	670	620	308	138	3,055
Total	3,116	15,082	8,189	11,471	21,539	11,006	25,207	95,610

Date:	13-May	14-May	15-May	16-May	17-May	18-May	19-May	Total
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	for the Week
Number of Lifts:	15	16	11	17	11	14		84
Time of First Lift:	8:20	8:20	6:10	8:15	8:30	8:30		
Time of Last lift:	15:30	15:15	13:30	15:30	15:30	15:30		
Operating time (hours):	7:10	6:55	7:20	7:15	7:00	7:00	0:00	42:40:00
Average Water Temperature (°F):	65.4	65.8	65.8	67.2	67.6	67.6		
American shad	6	23	43	75	3	3		153
Blueback herring	0	0	0	1	0	0		1
Alewife	0	0	0	0	0	0		0
Gizzard shad	17,450	12,800	4,225	13,600	5,100	14,750		67,925
Hickory shad	0	0	0	0	0	0		0
Striped bass	12	13	57	40	5	5		132
Carp	45	14	2	44	220	77		402
Other species	133	198	370	181	358	406		1,646
Total	17,646	13,048	4,697	13,941	5,686	15,241		70,259

Table 2. (continued)

Date:	20-May	21-May	22-May	23-May	24-May	25-May	26-May	**Total**
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	**for the Week**
Number of Lifts:	10	11	15	9	8	10		63
Time of First Lift:	8:40	8:30	8:20	8:20	8:30	8:15		
Time of Last lift:	15:30	15:30	15:30	15:30	15:30	15:30		
Operating time (hours):	6:50	7:00	7:10	7:10	7:00	7:15	0:00	42:25:00
Average Water Temperature (°F):	68.1	68.6	69.9	69.8	71.2	71.4		
American shad	28	61	54	102	59	22		326
Blueback herring	0	4	0	0	0	0		4
Alewife	0	0	0	0	0	0		0
Gizzard shad	7,950	4,450	7,970	1,427	2,880	2,706		27,383
Hickory shad	0	0	0	0	0	0		0
Striped bass	3	13	18	22	15	2		73
Carp	7	10	15	3	3	1		39
Other species	170	313	191	292	388	211		1,565
Total	8,158	4,851	8,248	1,846	3,345	2,942		29,390

Date:	27-May	28-May	29-May	30-May	31-May	1-Jun	**Total**	**Total**
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	**for the Week**	**for the Year**
Number of Lifts:	7	6	8	9	7	7	44	**404**
Time of First Lift:	9:00	10:10	8:30	8:05	8:30	9:15		
Time of Last lift:	15:30	15:30	15:30	15:30	15:30	14:30		
Operating time (hours):	6:30	5:20	7:00	7:25	7:00	5:15	38:30:00	**243:57:00**
Average Water Temperature (°F):	74.4	75.9	78.0	79.1	79.9	78.8		
American shad	50	11	12	18	43	1	135	**1,486**
Blueback herring	0	0	0	0	0	0	0	**7**
Alewife	0	0	0	0	0	0	0	**0**
Gizzard shad	565	445	2,485	2,352	622	408	6,877	**306,895**
Hickory shad	0	0	0	0	0	0	0	**0**
Striped bass	16	18	25	19	40	41	159	**508**
Carp	1	0	7	5	8	2	23	**898**
Other species	792	475	447	890	844	401	3,849	**12,259**
Total	1,424	949	2,976	3,284	1,557	853	11,043	**322,053**

TABLE 3. American shad sex ratio information, Conowingo West Fish Lift, 2012. No operation on 28 April, 19 May, and 26 May.

Date	Sample size	Males	Females	Male:Female Ratio
23-Apr	**82**	55	27	1: 0.5
24-Apr	**46**	28	18	1: 0.6
25-Apr	**101**	64	36	1: 0.6
26-Apr	**43**	25	18	1: 0.7
27-Apr	**9**	5	4	1: 0.8
29-Apr	**21**	11	10	1: 0.9
30-Apr	**45**	25	20	1: 0.8
1-May	**10**	6	4	1: 0.7
2-May	**27**	16	11	1: 0.7
3-May	**48**	31	17	1: 0.5
4-May	**40**	25	15	1: 0.6
5-May	**135**	87	48	1: 0.6
6-May	**121**	67	23	1: 0.3
7-May	**7**	5	2	1: 0.4
8-May	**35**	20	15	1: 0.8
9-May	**38**	31	7	1: 0.2
10-May	**10**	3	7	1: 2.3
11-May	**22**	16	6	1: 0.4
12-May	**32**	18	14	1: 0.8
13-May	**6**	4	2	1: 0.0
14-May	**23**	15	8	1: 0.5
15-May	**43**	27	16	1: 0.6
16-May	**75**	40	35	1: 0.9
17-May	**3**	1	2	1: 2.0
18-May	**3**	1	2	1: 2.0
20-May	**28**	12	16	1: 1.3
21-May	**61**	29	32	1: 1.1
22-May	**54**	19	35	1: 1.8
23-May	**102**	28	74	1: 2.6
24-May	**59**	23	36	1: 1.6
25-May	**22**	7	15	1: 1.6
27-May	**50**	13	37	1: 2.8
28-May	**11**	2	9	1: 4.5
29-May	**12**	7	5	1: 0.7
30-May	**18**	3	15	1: 5.0
31-May	**43**	7	36	1: 5.1
1-Jun	**1**	0	1	1: 0.0
Totals	**1,486**	**776**	**678**	**1: 0.9**

Table 4. Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods,* 1985-2012.

Year	Number Days	Number Lifts	Fishing Hours	Total Catch	Catch Per Day	Catch Per Lift	Catch Per Hour
1985	37	839	328.6	1,518	41	2	4.6
1986	53	737	431.5	5,136	97	7	11.9
1987	49	1,295	506.5	7,659	156	6	15.1
1988	54	1,166	471.7	5,137	95	4	10.9
1989	46	1,034	447.2	8,216	179	8	18.4
1990	62	1,247	541.0	15,958	257	13	29.5
1991	59	1,123	478.5	13,273	225	12	27.7
1992	61	1,517	566.0	10,323	169	7	18.2
1993	41	971	398.0	5,328	130	5	13.4
1994	44	918	414.0	5,595	127	6	13.5
1995	64	1,216	632.2	15,588	244	13	24.7
1996	27	441	245.2	11,458	424	26	46.7
1997	44	611	295.1	12,974	295	21	44.0
1998	26	476	238.6	6,577	253	14	27.6
1999	43	709	312.6	9,658	225	14	30.9
2000	34	424	206.5	9,785	288	23	47.4
2001	41	425	195.1	10,940	267	26	56.1
2002	31	417	147.1	9,347	302	22	63.5
2003	31	637	171.8	9,802	316	27	57.0
2004	14	151	74.3	3,426	245	23	46.1
2005	30	295	165.9	3,896	130	13	23.5
2006	37	394	214.9	3,970	107	10	18.5
2007	29	288	135.3	4,272	147	15	31.6
2008	34	481	174.4	2,627	77	5	15.1
2009	28	282	144.1	6,534	233	23	45.3
2010	27	238	138.2	5,605	208	24	40.6
2011	15	144	85.6	3,074	205	21	35.9
2012	**37**	**404**	**243.9**	**1,486**	**40**	**4**	**6.1**

*Only applies to 1985-1995 data. Excludes early and late season catch and effort when less than 10 shad/day were taken.

Table 5. Operations and fish catch at Conowingo West Fish Lift, 1985 - 2012.

Year	Number of Days	Total Fish (Millions)	Number of Taxa	American Shad	Hickory Shad	Alewife	Blueback Herring
1985	55	2.318	41	1,546	9	377	6,763
1986	59	1.831	43	5,195	45	2,822	6,327
1987	60	2.593	43	7,667	35	357	5,861
1988	60	1.602	49	5,169	64	712	14,570
1989	53	1.066	45	8,311	28	1,902	3,611
1990	72	1.188	44	15,964	77	425	9,658
1991	63	0.533	45	13,330	120	2,649	15,616
1992	64	1.560	46	10,335	376	3,344	27,533
1993	45	0.713	37	5,343	0	572	4,052
1994	47	0.564	46	5,615	1	70	2,603
1995	68	0.995	44	15,588	36	5,405	93,859
1996	28	1.233	39	11,473	0	1	871
1997	44	0.346	39	12,974	118	11	133,257
1998	41	0.575	38	6,577	6	31	5,511
1999	43	0.722	34	9,658	32	1,795	8,546
2000	34	0.458	37	9,785	1	9,189	14,326
2001	41	0.310	38	10,940	36	7,824	16,320
2002	31	0.419	35	9,347	0	141	428
2003	31	0.147	30	9,802	1	16	183
2004	14	0.039	30	3,426	0	0	1
2005	30	0.094	36	3,896	0	0	0
2006	37	0.163	38	3,970	0	2	6
2007	29	0.159	36	4,272	0	7	153
2008	34	0.733	37	2,627	0	2	7
2009	28	0.226	39	6,534	4	20	165
2010	27	0.158	36	5,605	1	1	81
2011	15	0.100	32	3,074	0	0	0
2012	**37**	**0.322**	**37**	**1,486**	**0**	**0**	**7**

SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY - 2012

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EXECUTIVE SUMMARY

Fish lift operations began at the Conowingo East fish lift (EFL) on 2 April, 2012. The passage of over one-thousand American shad at the Conowingo EFL on 6 April triggered the start of fish lift operations at Holtwood on 7 April. This marks to earliest operation start date at the Holtwood fish passage facility. The Holtwood fish passage facility operated a total of 58 days (highest number of operating days in a single season since the facility became operational in 1997). The tailrace lift was operated on 47 consecutive days, while the spillway lift operated on 40 days. Lift operations were terminated for the season, with agency concurrence, on 5 June. During mid-May (17 and 18 May), fish lift operations were suspended for two days due to high river flows. The tailrace fish lift experienced crowder and hopper sheave mechanical problems (24 and 25 May) that could not be repaired prior to season end. After 25 May, the spillway fish lift operated solely until the season ended on 5 June. The 2012 fish passage season marks the sixteenth year of operation at Holtwood.

The lifts passed 230,365 fish of 26 taxa plus one hybrid. Gizzard shad (211,478), shorthead redhorse (4,679), quillback (4,568) and American shad (4,238), dominated the catch, and comprised nearly 98% of the total fish collected and passed. Walleye (2,354) and channel catfish (1,734) were also regularly observed in the daily catch. American shad represented the sole *Alosa* species collected and passed at Holtwood in 2012.

A total of 3,342 American shad (79% of total shad catch) was passed in the tailrace lift while the spillway lift accounted for 896 American shad (21% of total shad catch). The highest daily shad catch occurred on 19 April when 539 shad moved upstream during 10.8 hours of operation. On a daily basis, American shad passed through the fishway between 0700 hrs and 1959 hrs with 86% (3,651 of 4,238 shad) passed between 0900 and 1759 hrs.

Fishway operations were conducted at water temperatures ranging from 54.8°F to 79.0°F and river flows between 89,000 and 13,700 cfs (Figure 1). Spillage occurred on 42 days of operation. River water temperatures and river flows were within the observed historic range.

For most of the season, water clarity was moderately clear, making it possible to identify American shad with attached Maryland DNR floy tags if they passed by the viewing window. The number of floy tags observed at Holtwood in 2012 was 5 (4 orange, 1 pink).

The 2012 American shad passage rate at Holtwood versus Conowingo (19.1% of fish passing Conowingo passed Holtwood) was below the historical average of 31.0% (1997-2011).

A low, stable, river flow appears to be critical for enhancing American shad passage rates. In 2010, we documented 95% of American shad passed at river flows less than 40,000 cfs, with 5% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. In 2012, 76.9% of American shad passed at river flows less than 40,000 cfs, with 22.8% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. Only 0.3% of American shad passed at river flows greater than 60,000 cfs. Future operations of the fishway will build on the past sixteen years of operation experience.

INTRODUCTION

On 1 June 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (Holtwood) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by the spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream passage facility consisting of a tailrace and spillway lift successfully operated during spring 1997 through spring 2012. This year marked the sixteenth operational season.

Objectives of 2012 upstream fishway operation were (1) monitor and maximize passage of migratory and resident fishes through the fishway; and (2) minimize interruptions to fish passage operations due to equipment breakdowns or malfunctions.

HOLTWOOD OPERATION

Project Operation

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units having a combined generating capacity of 107 MW, and a reservoir (Lake Aldred) of 2,400 acres surface area. Each unit is capable of passing approximately 3,000 cfs. Spills occur at the project when river flow or project inflow exceeds the station hydraulic capacity of approximately 31,500 cfs.

Hydraulic conditions in the spillway at the project are controlled by numerous factors that change hourly, daily and throughout the fishway operating season. The primary factors are river flows, operation of the power station, installation and integrity of the flash boards, and operation of the Safe Harbor Hydroelectric Station.

In spring 2012, all rubber dams were inoperable (not inflated) due to irreparable damage that occurred in previous years and current redevelopment activities. Wooden flashboards have been installed in place of these rubber dam sections. In spring of 2012, the flashboards closest to the Fish Lift facility were damaged and repairs could not be conducted until after cessation of fish lift operations due to consistent river flow and spill status. Operations began at the Holtwood Fish Lift facility on 7 April, after the passage of one-thousand shad at Conowingo Dam on 6 April. Since river flows were greater than station capacity, spill occurred on 42 of 58 days of fish lift operation, (Table 2). In 2012, station capacity was limited to a maximum of nine units due to maintenance on Unit 2 and various redevelopment activities. Passage operations ended on 5 June, with agency concurrence, due to river flows higher than station capacity, poor water clarity, increasing water temperatures, and the lack of American shad in the daily catch.

Fishway Design and Operation

Fishway Design

The Holtwood fishway is sized to pass a design population of 2.7 million American shad and 10 million river herring. The design incorporates numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998).

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough through which the fish swim into Lake Aldred. Attraction flow, in, though, and from the lifts, is supplied via a piping system and five diffusers that are gravity fed from two trough intakes. Generally, water conveyance and attraction flow is controlled by regulating the three entrance gates and seven motor-operated valves. Fish that enter the tailrace and/or spillway entrances are attracted by water flow into the mechanically operated crowder chambers. Once inside, fish are crowded into the hoppers (6,700 gal capacity). Fish are then lifted in the hoppers and sluiced into the trough. Fish swim upstream through the trough past a counting facility and into the forebay through a 14 ft wide fish lift exit gate.

Design guidelines for fishway operation include five entrance combinations. These are: (1) entrances A, B, and C; (2) entrances A and B; (3) entrances A and C; (4) entrance A only; and (5) entrance C only. Completion of the attraction water system after the 1997 season resulted in the drafting of operating protocols and guidelines that are flexible and utilize experience gained during previous years of fish lift operation. In 2012, the following gate combinations were utilized: Entrances A and C (29 days); Entrance A only (18 days), and Entrance C only (11days). . Entrance gate B was not used in 2012 due to rock and debris in the gate's channel guides. This problem will be addressed and Gate B should be operational in 2013. The spillway lift, (Entrance Gate C), has historically been used less frequently when river flows are greater than 40,000 cfs or flashboard sections are damaged or missing. However, with the completion of the Unit 1 draft tube extension that will supply attraction water to the Piney channel during fish lift operations, it is anticipated that Gate C will be used routinely to provide fish passage from the spillway area.

Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch, and managed to maximize that catch. Constant oversight by PPL and Normandeau staff ensured that maintenance activities and mechanical or electrical problems were dealt with immediately to minimize fish lift operational interruptions. Normal pre-season equipment preparations began in March 2012, as well as additional preparations (i.e. clearing mud out of diffusers and both hopper pits that was deposited during the fall flooding), and all equipment functioned properly at that time.

This year, Holtwood operations began one day after the passage of one-thousand American shad at Conowingo Dam. Fish lift operations began on 7 April. This year we recorded 58 days of operation. The tailrace lift was operated 47 days during this year's fish passage operation and encountered one major mechanical problem. On 24 May, the tailrace crowder cables snapped, so operations were modified to accommodate the cable problem. On 25 May, as the tailrace hopper was being raised during the third lift of the day, a grinding noise was noticed. The lift was completed and the problem reported. A crew was dispatched to investigate the problem. The crew attempted to lubricate the hopper and discovered that the downstream sheave bearing would not accept grease. It was determined that a bearing within the hopper sheave had frozen. Further investigations were conducted and the tailrace lift was shut down after it was determined that a new bearing would have to be ordered. The tailrace lift did not operate for the rest of the 2012 fish passage season. The spillway lift was operated on 40 days this season and encountered no major mechanical problems.

The 2012 American shad passage rate at Holtwood versus Conowingo (19.1% of fish passing Conowingo passed Holtwood) was below the historical average of 31.0% (1997-2011) (Table 6). Operational hours varied throughout the season in an attempt to maximize the catch of American shad.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. A three person staff consisting of a lift operator, a supervising biologist, and biological technician manned the facility daily. A detailed description of the fishway's major components and their operation are found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

Fish Counts

Fish passing the counting window are identified to species and counted by a biologist or biological technician. The counting area is located immediately downstream of the main attraction water supply area in the trough. As fish swim upstream and approach the counting area, they are directed by a series of fixed screens to swim up and through a 3 ft wide, 12 ft long channel on the west side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are identified and counted. Passage from the fishway is controlled by two different gates. During the day, fish passage rates are controlled by the technician who opens/closes a set of gates downstream of the viewing window. At night fish are denied passage from the fishway by closing this gate. When necessary, flow is maintained through the exit channel to insure that adequate water quality exists for fish held overnight.

Fish passage data is handled by a single system that records and processes the data. The data (species and numbers passed) is recorded on a worksheet by the biologist or biological technician as fish pass the viewing window. At the end of each hour, fish passage data is entered into a Microsoft Excel spreadsheet and saved. Data processing and reporting is PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheet software.

At day's end, the data is checked and verified by the biologist or biological technician. After data verification is completed, a daily summary of fish passage is produced and distributed to plant personnel. Each day's data is backed up to a diskette and stored off-site. Daily reports and weekly summaries of fish passage numbers are electronically distributed to members of the Holtwood FPTAC and other cooperators.

RESULTS

Relative Abundance

The diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2012 operational period is presented in Table 1. A total of 230,365 fish of 26 taxa and one hybrid passed upstream into Lake Aldred. Gizzard shad (211,478), Shorthead redhorse (4,679), Quillback (4,568) and American shad (4,238), dominated the catch, and comprised nearly 98% of the total fish collected and passed. American shad represented the sole *Alosa* species collected and passed at Holtwood in 2012. The high passage day for all species combined occurred on 6 May, when 15,289 fish were passed, comprised mostly of gizzard shad (13,783), and shorthead redhorse (525).

For most of the season, water clarity ranged from 20 to 30 inches of visibility (Table 2), which made it possible for viewing technicians to identify American shad with attached

Maryland DNR floy tags. The number of floy tags observed at Holtwood in 2012 was 5 (4 orange; 1 pink).

American Shad Passage

A total of 4,238 American shad were passed at Holtwood during 2012; 3,342 American shad passed in the tailrace lift while the spillway lift accounted for 896 American shad (Table 3). The highest daily shad catch occurred on 19 April when 539 shad moved upstream during 10.8 hours of operation. Fishway operations were conducted at water temperatures ranging from 54.8°F to 79.0°F and river flows between 89,000 and 13,700 cfs (as measured at Holtwood Dam), (Table 2 and Figure 1). Spillage occurred on 42 days of operation. River water temperatures and river flows were within the observed historic range.

The capture of shad at the fishway occurred over a relatively wide range of station operation and discharge conditions (Table 2). Shad were attracted to the tailrace lift at water elevations ranging from 115 ft. to 121 ft. Tailrace elevations correspond to unit operation, which varies from 0 to 10 units. In 2012, Unit 2 remained offline due to repairs and general maintenance. During spring 2012, tailrace fishway operation generally coincided with an eight turbine operation/generation scenario. Spillway lift operation usually occurs during periods of no or minimal spillage, but damaged flashboards and mechanical difficulties on the tailrace lift led to use of the spillway lift during spill events. Prior to fish lift operations in 2012, redevelopment activities included reshaping the Piney Island channel, installation of a weir in the Piney channel, and completion of the Unit 1 draft tube extension. Unit 1 was returned to operation in mid-May and operated during the remaining part of the season. Observations made by the biologists on site suggest an increase of resident fish collected and passed by the spillway lift, even during times of spill. The redesigned Piney channel and weir and operation of Unit 1 may be a positive factor for improving anadromous and resident fish passage in future years at Holtwood.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164.5 ft to 174 ft (Table 2). We experienced some higher forebay levels this year due to the installation of higher flashboards (6 ft high) along the eastern section of the spillway. These boards were installed to protect a portion of the work and equipment related to the

Redevelopment in the Piney channel. Forebay elevations during passage operations ranged from 166 ft to 170 ft for approximately 46% of the 2012 season.

The hourly passage numbers of American shad at Holtwood are provided in Table 4. On a daily basis, American shad passed through the fishway between 0700 hrs and 1959 hrs with 86% (3,651 of 4,238 shad) passed between 0900 and 1759 hrs. American shad passage was low each day of operation (<600 per day), and no strong patterns relating to passage time were determined.

Each year, we attempt to qualitatively assess the relative number of shad using the tailrace and spillway lifts by viewing each hopper of fish and estimating the number of shad in each lift as they are sluiced into the trough. The spillway lift was operated on forty days in an effort to pass any shad attracted into the spillway area adjacent to the fishlift. We summarized this information by lift, and applied results to the daily shad passage count. We determined the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 3,342 and 896 shad were captured in the tailrace and spillway lifts over the total operating period in 2012, respectively (Table 3).

Passage Evaluation

In spring 2012, our fishway evaluation efforts focused on maximizing the passage of American shad at both the tailrace and spillway lifts with minimal interruptions to passage operations due to equipment breakdowns or malfunctions.

We present a summary of American shad passage at three river flow ranges in Table 5. As stated in previous reports, low, stable river flows are more conducive to fish passage at Holtwood. In 2012, spill events occurred during 42 of 58 days of fishway operation. In 2010, we documented 95% of American shad passed at river flows less than 40,000 cfs, with 5% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. In 2012, 76.9% of American shad passed at river flows less than 40,000cfs, with 22.8% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. Only 0.3% of American shad passed at river flows greater than 60,000cfs (Table 5 and Figure 2). During fish lift operations in 2012, river flows ranged from 89,000 and 13,700 cfs. The 2012 American shad passage rate at Holtwood versus Conowingo (19.1% of American shad passed at Conowingo were passed by

Holtwood), was below the historical average of 31.0% observed at Holtwood from 1997 to 2011 (Table 6).

We hope to optimize future fishway operations by utilizing knowledge gained through these sixteen years of operation. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis. Fish survival in the fishways was excellent; we observed 0 shad mortalities during the 2012 American shad passage season.

RECOMMENDATIONS

4) Review the current maintenance program to identify additional equipment maintenance inspection and testing activities to reduce in-season disruptions to operation. Unusual conditions, (e.g. severe flood events) require a more thorough review of the impacts to the equipment.

5) Operate the fishway at Holtwood Dam under annual operational guidelines developed and approved by the HFPTAC. Fishway operation should adhere to these guidelines; however, personnel must retain the ability to make “on-the-spot” modifications to maximize fishway performance.

6) Continue, as a routine part of fishway operation, a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel as necessary, nightly inspections of picket screens, and daily checks of hopper doors. Routine maintenance activities minimize disruption of fishway operation.

7) Implement protocols/guidelines to spill trash through gates 7 and 9. This should be done on an as needed basis prior to or after daily scheduled fishway operations.

LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Holtwood Fish Passage Facility in 1997. Report prepared for PPL, Inc., Allentown, PA.

Normandeau Associates, Inc. 1999. Summary of the operation at the Holtwood Fish Passage Facility in 1998. Report prepared for PPL, Inc., Allentown, PA.

FIGURES

Figure 1. A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Holtwood Fish Passage Facility, spring 2012. No operation due to high flow event (May 17-18).

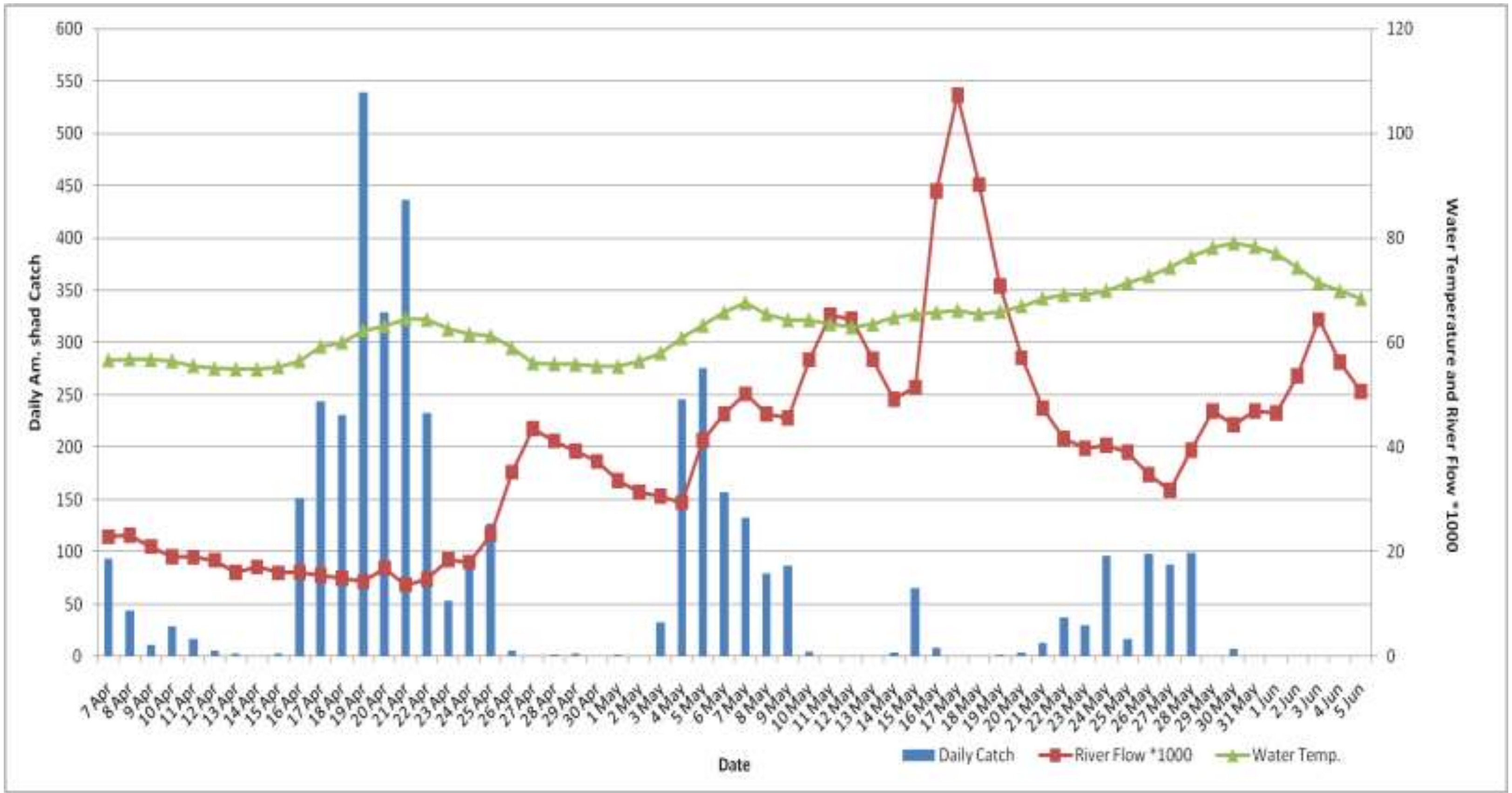
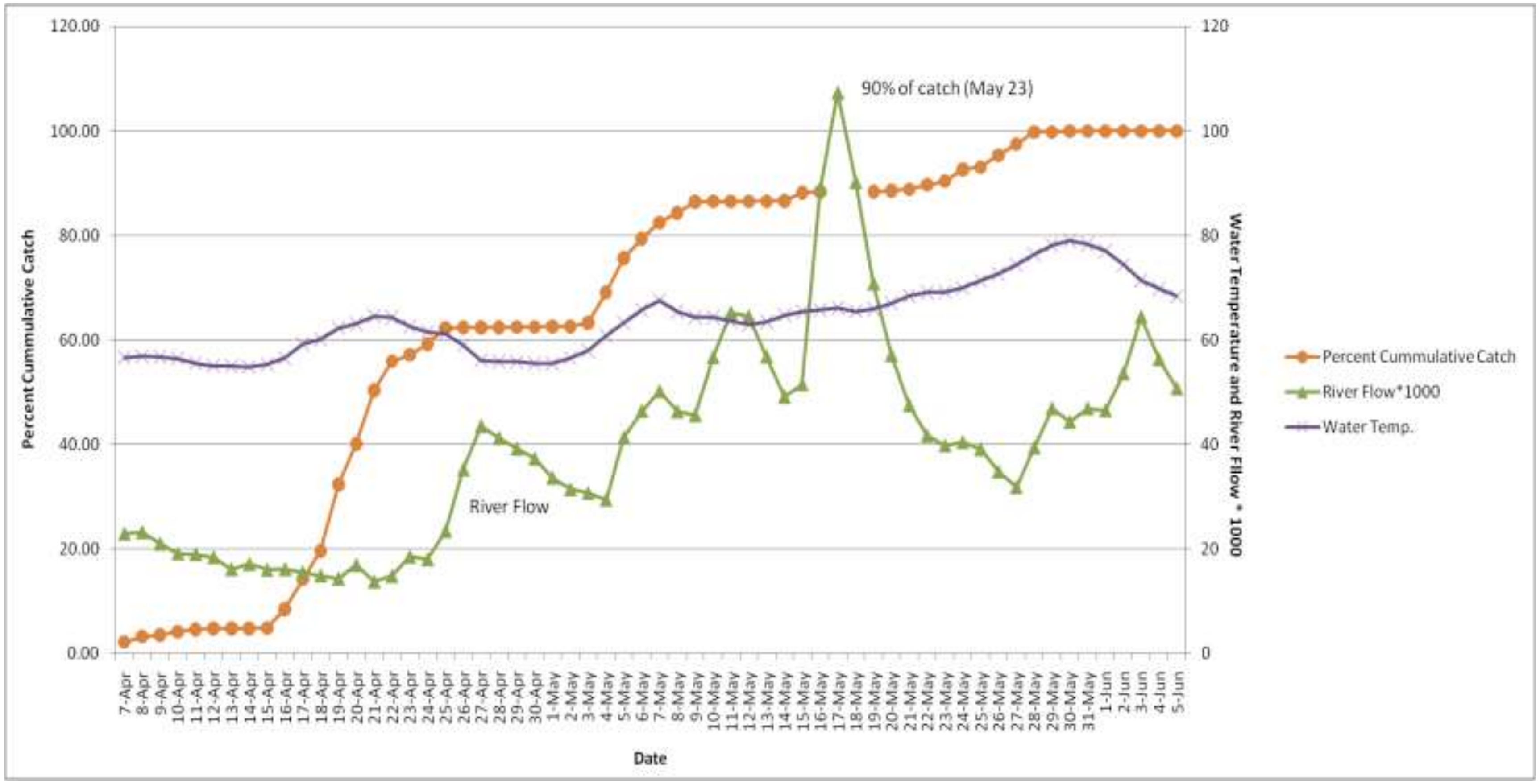


Figure 2. A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad.



TABLES

Table 1. Summary of the daily number of fish passed by the Holtwood fish passage facility in 2012.

Date:	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*
Hours of Operation - Tailrace:	*9.8*	*6.7*	*2.7*	*5.0*	*10.6*	*9.8*	*10.2*	*10.0*	*9.1*	*10.4*
Number of Lifts - Tailrace:	*12*	*13*	*5*	*8*	*17*	*17*	*17*	*15*	*15*	*18*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*56.3*	*56.8*	*56.3*	*56.8*	*55.4*	*54.7*	*54.4*	*54.5*	*54.8*	*56.0*
American shad	93	44	11	29	17	6	3	1	3	151
Gizzard shad	447	571	628	840	838	1,073	334	58	1,122	871
Carp	1	0	0	0	0	1	0	1	15	0
Quillback	1	1	0	1	1	0	0	0	0	0
Shorthead redhorse	50	76	2	12	9	8	0	10	3	24
Channel catfish	3	23	0	1	0	0	0	0	1	0
White sucker	0	0	0	0	0	0	0	0	5	0
Bluegill	0	1	0	0	0	0	0	0	0	0
Smallmouth bass	37	13	4	3	12	2	0	6	3	3
Largemouth bass	0	0	0	0	0	0	0	0	0	3
Black crappie	0	0	0	0	0	0	0	0	0	1
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	36	47	9	9	15	15	0	11	3	3
Total	***668***	***776***	***654***	***895***	***892***	***1,105***	***337***	***87***	***1,155***	***1,056***

Table 1. (continued).

Date:	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*
Hours of Operation - Tailrace:	*11.0*	*10.3*	*10.8*	*10.4*	*10.7*	*10.5*	*10.5*	*10.4*	*10.9*	*10.3*
Number of Lifts - Tailrace:	*20*	*19*	*18*	*18*	*17*	*18*	*17*	*17*	*17*	*12*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*8.5*	*10.2*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*8*	*11*
Water Temperature (°F):	*58.8*	*59.3*	*60.8*	*61.7*	*64.3*	*64.6*	*62.8*	*61.4*	*60.4*	*60.2*
American shad	244	231	539	329	436	233	53	87	127	6
Gizzard shad	1,991	9,589	10,022	4,772	3,648	3,810	3,538	1,646	2,966	845
Sea lamprey	0	1	0	0	0	1	0	0	1	0
Rainbow trout	1	0	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0	1	0
Muskellunge	0	0	0	0	1	0	0	0	0	0
Carp	4	0	2	0	0	0	1	0	3	2
Quillback	69	7	15	56	151	152	70	96	68	14
Shorthead redhorse	379	59	38	121	305	112	28	93	15	24
Channel catfish	4	5	1	0	4	11	7	32	33	57
Northern Hog sucker	0	0	0	0	0	0	0	1	0	0
Rock bass	0	0	0	0	1	0	0	1	0	0
Smallmouth bass	20	6	4	17	22	12	1	1	10	2
Largemouth bass	5	3	0	2	6	0	0	1	5	1
Black crappie	0	0	0	1	0	0	0	0	1	0
White crappie	0	1	0	1	0	0	0	1	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	25	24	34	47	66	55	34	11	42	75
Striped Bass	1	0	0	0	0	0	0	0	0	0
Total	***2,743***	***9,926***	***10,655***	***5,346***	***4,640***	***4,386***	***3,732***	***1,970***	***3,272***	***1,026***

Table 1. (continued).

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*
Hours of Operation - Tailrace:	*10.5*	*10.1*	*9.9*	*10.3*	*9.7*	*9.4*	*8.1*	*10.5*	*10.0*	*9.8*
Number of Lifts - Tailrace:	*12*	*11*	*13*	*12*	*12*	*12*	*12*	*17*	*16*	*16*
Hours of Operation - Spillway:	*10.3*	*10.2*	*9.8*	*10.1*	*9.7*	*9.9*	*10.2*	*10.6*	*9.9*	*9.3*
Number of Lifts - Spillway:	*9*	*8*	*10*	*9*	*11*	*10*	*16*	*16*	*14*	*12*
Water Temperature (°F):	*56.1*	*56.1*	*55.8*	*55.5*	*54.8*	*56.2*	*57.2*	*60.5*	*62.6*	*65.1*
American shad	0	2	3	1	2	0	33	246	276	157
Gizzard shad	191	151	192	197	206	240	2,576	12,131	13,523	13,783
Sea lamprey	0	0	0	0	0	0	0	0	0	1
Brown trout	0	1	1	1	1	0	0	0	0	3
Muskellunge	0	1	0	0	0	0	1	0	0	0
Carp	0	5	6	2	2	6	2	4	9	30
Quillback	5	10	80	25	4	75	1,327	788	243	475
Shorthead redhorse	74	49	104	56	29	98	645	352	174	525
Channel catfish	29	21	29	6	8	21	0	0	7	96
Rock bass	0	0	0	0	0	0	0	0	0	1
Pumpkinseed	0	0	0	0	0	0	0	0	0	1
Bluegill	0	0	0	0	0	0	0	1	1	0
Smallmouth bass	7	3	8	1	4	4	21	24	37	46
Largemouth bass	2	0	1	0	0	0	3	5	7	0
Walleye	28	21	22	20	38	43	12	59	58	170
Hybrid Striped Bass	0	0	0	0	0	0	0	0	1	1
Comely Shiner	0	0	0	0	0	58	0	0	0	0
Total	***336***	***264***	***446***	***309***	***294***	***545***	***4,620***	***13,610***	***14,336***	***15,289***

Table 1. (continued).

Date:	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Hours of Operation - Tailrace:	*11.6*	*9.7*	*9.9*	*8.0*	*8.0*	*8.0*	*8.1*	*8.2*	*9.1*	*3.3*
Number of Lifts - Tailrace:	*16*	*15*	*16*	*10*	*11*	*11*	*12*	*12*	*14*	*5*
Hours of Operation - Spillway:	*9.0*	*9.0*	*9.7*	*8.1*	*8.1*	*8.1*	*8.2*	*8.1*	*9.2*	*3.4*
Number of Lifts - Spillway:	*10*	*10*	*14*	*8*	*9*	*9*	*9*	*10*	*13*	*5*
Water Temperature (°F):	*68.1*	*65.9*	*64.2*	*64.2*	*63.2*	*62.4*	*62.5*	*64.4*	*65.4*	*65.3*
American shad	133	79	87	5	0	1	1	4	65	8
Gizzard shad	10,265	9,632	14,713	5,852	5,577	7,940	3,875	4,374	14,751	889
Sea lamprey	0	0	0	0	0	0	0	1	0	0
Rainbow trout	1	0	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	2	0	0	0	0
Muskellunge	0	0	1	0	0	0	0	0	0	0
Carp	5	10	10	5	1	2	1	6	4	1
Quillback	236	99	35	5	9	2	4	29	16	0
Shorthead redhorse	184	180	93	22	29	19	23	28	23	1
Channel catfish	11	11	35	0	10	21	37	13	9	20
Flathead catfish	2	0	0	0	0	0	0	0	0	0
Brown Bullhead	0	0	2	0	0	0	0	0	0	0
Rock bass	1	0	2	0	0	1	0	0	0	0
Bluegill	0	1	3	0	0	2	1	0	0	0
Smallmouth bass	39	30	8	3	3	4	1	4	4	0
Largemouth bass	2	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	3	0	0	0	0	0	0	1
Walleye	46	143	94	61	34	27	46	67	113	4
Striped Bass	0	0	1	0	0	0	0	0	0	0
Comely Shiner	0	0	184	0	0	0	0	0	0	0
Total	***10,925***	***10,185***	***15,271***	***5,953***	***5,663***	***8,021***	***3,989***	***4,526***	***14,985***	***924***

Table 1. (continued).

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*
Hours of Operation - Tailrace:	*	*	*8.0*	*8.0*	*7.9*	*8.7*	*8.6*	*9.0*	*5.7*	*0.0*
Number of Lifts - Tailrace:			*13*	*12*	*12*	*14*	*14*	*11*	*4*	*0*
Hours of Operation - Spillway:			*7.7*	*8.1*	*7.8*	*8.2*	*8.7*	*8.9*	*9.0*	*9.6*
Number of Lifts - Spillway:			*8*	*9*	*9*	*9*	*9*	*13*	*14*	*19*
Water Temperature (°F):			*65.9*	*66.0*	*68.3*	*69.1*	*69.1*	*69.9*	*71.2*	*72.5*
American shad			2	4	13	37	30	96	17	98
Gizzard shad			4,071	2,516	4,017	6,420	5,313	5,868	3,423	3,790
Rainbow trout			0	1	0	0	0	3	0	1
Brown trout			0	0	0	2	3	0	2	0
Muskellunge			0	1	1	0	1	0	0	0
Carp			0	1	1	7	3	3	7	21
Quillback			0	0	2	17	23	43	40	105
Shorthead redhorse			0	6	3	72	53	54	71	178
Channel catfish			7	16	18	22	41	39	146	209
Flathead catfish			3	1	0	1	1	1	0	0
Rock bass			1	0	0	0	1	0	0	0
Pumpkinseed			0	0	0	0	0	0	0	0
Bluegill			1	1	0	1	6	0	0	0
Smallmouth bass			0	0	1	3	3	6	1	4
Largemouth bass			0	0	0	0	1	0	0	1
Walleye			2	5	9	41	33	97	90	142
Comely Shiner			0	0	0	0	0	0	0	95
Total	***0***	***0***	***4,087***	***2,552***	***4,065***	***6,623***	***5,512***	***6,210***	***3,797***	***4,644***

Table 1. (continued).

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	***322.6***
Number of Lifts - Tailrace:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***469.0***
Hours of Operation - Spillway:	*8.9*	*8.0*	*8.0*	*8.0*	*8.3*	*8.0*	*5.8*	*5.0*	*4.9*	*5.3*	***337.8***
Number of Lifts - Spillway:	*15*	*14*	*12*	*14*	*10*	*11*	*9*	*7*	*7*	*7*	***427.0***
Water Temperature (°F):	*74.0*	*75.5*	*77.7*	*79.4*	*78.5*	*77.6*	*75.5*	*71.3*	*69.9*	*68.5*	
American shad	88	99	0	7	1	0	0	0	0	0	**4,238**
Gizzard shad	2,102	1,803	82	1,205	83	78	10	9	9	12	**211,478**
Sea lamprey	0	0	0	0	0	0	0	0	0	0	**10**
Rainbow trout	0	0	0	0	0	0	0	0	0	0	**16**
Brown trout	2	2	0	0	0	0	0	0	0	0	**12**
Muskellunge	2	0	0	1	0	0	0	0	0	0	**142**
Carp	0	20	0	6	0	0	0	0	0	0	**3,345**
Quillback	37	55	0	77	0	0	0	0	0	0	**3,845**
Shorthead redhorse	85	62	2	16	1	0	0	0	0	0	**2,740**
Channel catfish	125	195	53	208	14	31	36	4	2	2	**1,002**
Flathead catfish	0	0	0	1	0	0	3	0	0	0	**11**
Brown Bullhead	0	0	0	0	0	0	0	0	0	0	**2**
White sucker	0	0	0	0	0	0	0	0	0	0	**0**
Northern Hog sucker	0	0	0	0	0	0	0	0	0	0	**43**
Rock bass	0	0	0	0	0	0	0	0	0	0	**8,196**
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	**426**
Bluegill	0	0	0	0	0	0	0	0	0	0	**157**

Table 1. (continued).

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	***322.6***
Number of Lifts - Tailrace:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***469.0***
Hours of Operation - Spillway:	*8.9*	*8.0*	*8.0*	*8.0*	*8.3*	*8.0*	*5.8*	*5.0*	*4.9*	*5.3*	***337.8***
Number of Lifts - Spillway:	*15*	*14*	*12*	*14*	*10*	*11*	*9*	*7*	*7*	*7*	***427.0***
Water Temperature (°F):	*74.0*	*75.5*	*77.7*	*79.4*	*78.5*	*77.6*	*75.5*	*71.3*	*69.9*	*68.5*	
Smallmouth bass	7	2	0	0	1	0	0	0	0	0	**88,597**
Largemouth bass	0	0	0	0	0	0	0	0	0	0	**2**
Black crappie	0	0	0	0	0	0	0	0	0	0	**184**
White crappie	1	0	0	0	0	0	0	0	0	0	**80,443**
Yellow perch	0	0	0	0	0	0	0	0	0	0	**0**
Walleye	129	98	8	31	2	0	0	0	0	0	**268**
Striped Bass	0	0	0	0	0	0	0	0	0	0	**0**
Hybrid Striped Bass	0	0	0	0	0	0	0	0	0	0	**0**
Comely Shiner	0	90	0	25	0	0	0	11	0	0	**126**
Spotfin Shiner	20	0	0	0	0	5	0	0	0	0	**25**
Total	***2,598***	***2,426***	***145***	***1,577***	***102***	***114***	***49***	***24***	***11***	***14***	**7,060**

Table 2. Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in 2012.

Date	River Flow (cfs)	Ave.Water Temp. (°F)	Secchi (in)	Number of Units	Weir Gate Operation			Elevation (ft)		
					A	B	C*	Tailrace	Spillway	Forebay
7 Apr	22,900	56.64	30	8	X			115	115	169
8 Apr	23,200	56.84	28	8	X			121	Spill	170
9 Apr	21,000	56.76	28	8	X			117	Spill	169
10 Apr	19,100	56.48	28	8	X			116.5	Spill	170
11 Apr	19,000	55.59	28	8	X			117	115	167
12 Apr	18,400	55.05	28	8	X			117	115	167
13 Apr	16,100	54.93	28	8	X			117.5	115	165
14 Apr	17,100	54.86	24	8	X			121	115	165
15 Apr	16,000	55.37	24	8	X			118	115	164.5
16 Apr	16,100	56.52	24	8	X			113	Spill	167
17 Apr	15,500	59.25	24	6	X			116	115	166
18 Apr	14,900	60.08	24	4	X			116	115	166.5
19 Apr	14,300	62.31	26	8	X			116	115	166.4
20 Apr	16,900	63.14	26	8	X			117	115	167
21 Apr	13,700	64.55	26	8	X			113	115	166
22 Apr	14,800	64.40	26	8	X			106	115	167
23 Apr	18,500	62.54	26	8	X			118.5	115	167
24 Apr	18,000	61.60	26	8	X			118.5	115	167.5
25 Apr	23,400	61.23	26	8	X		X	119	115	169
26 Apr	35,200	58.97	18	8	X		X	119.3	Spill	169.4
27 Apr	43,500	56.12	22	8	X		X	121	Spill	171.5
28 Apr	41,200	55.91	22	8	X		X	120	Spill	172

Table 2. (continued)

Date	River Flow (cfs)	Ave.Water Temp. (°F)	Secchi (in)	Number of Units	Weir Gate Operation A	Weir Gate Operation B	Weir Gate Operation C*	Elevation (ft) Tailrace	Elevation (ft) Spillway	Elevation (ft) Forebay
29 Apr	39,200	55.81	22	8	X		X	120	Spill	172
30 Apr	37,300	55.50	18	7	X		X	120.5	Spill	172
1 May	33,600	55.46	18	8	X		X	121	Spill	171
2 May	31,400	56.49	20	8	X		X	121	Spill	171.5
3 May	30,700	58.02	30	9	X		X	120	Spill	169
4 May	29,400	60.85	31	9	X		X	119	Spill	169
5 May	41,300	63.27	32	9	X		X	119.3	Spill	168
6 May	46,400	65.76	33	9	X		X	121	Spill	172
7 May	50,200	67.60	32	9	X		X	120	Spill	173
8 May	46,300	65.45	30	9	X		X	121	Spill	171
9 May	45,600	64.30	30-24	9	X		X	119.5	Spill	171
10 May	56,700	64.33	26	9	X		X	121	Spill	173
11 May	65,200	63.57	20	9	X		X	121	Spill	173
12 May	64,500	62.94	20	9	X		X	121	Spill	173
13 May	56,800	63.46	20	9	X		X	121	Spill	172
14 May	49,100	64.78	22	9	X		X	121.3	Spill	172
15 May	51,500	65.44	22	9	X		X	119.5	Spill	171.5
16 May	89,000	65.74	20	8	X		X	120	Spill	174
17 May	107,300	66.14	--	--	--	--	--	--	--	--
18 May	90,200	65.49	--	--	--	--	--	--	--	--
19 May	70,800	65.95	18	8	X		X	120	Spill	172.3
20 May	57,100	66.96	18	8	X		X	120	Spill	172

Table 2. (continued)

Date	River Flow (cfs)	Ave.Water Temp. (°F)	Secchi (in)	Number of Units	Weir Gate Operation A	B	C*	Elevation (ft) Tailrace	Spillway	Forebay
21 May	47,500	68.45	22	8	X		X	120	Spill	172
22 May	41,700	69.11	24	8	X		X	119	Spill	170
23 May	39,800	69.2	24	8	X		X	119.5	Spill	170
24 May	40,400	69.93	24	6	X		X	116.5	Spill	170
25 May	39,100	71.36	20	6	X		X	117	Spill	171
26 May	34,800	72.71	21-18	8			X	117	Spill	168
27 May	31,800	74.36	21-18	8			X	119	Leakage	168
28 May	39,400	76.36	21-18	8			X	119	Spill	169
29 May	46,900	78.16	20	8			X	119.4	Spill	171
30 May	44,300	79.03	18-10	8			X	118	Spill	168.3
31 May	46,900	78.33	18-12	6			X	116.4	Spill	171
1 Jun	46,500	77.04	16	8			X	116	Spill	171
2 Jun	53,600	74.36	10-4	8			X	118	Spill	172
3 Jun	64,400	71.42	2	8			X	120.9	Spill	172
4 Jun	56,300	69.8	2	8			X	119.5	Spill	172
5 Jun	50,700	68.4	5	8			X	119.3	Spill	170.5

Table 3. Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station, 2012.

	Shad	Number Collected			Percent Collected	
Date	Catch	Tailrace	Spillway		Tailrace	Spillway
7-Apr	93	93	--		100%	--
8-Apr	44	44	--		100%	--
9-Apr	11	11	--		100%	--
10-Apr	29	29	--		100%	--
11-Apr	17	17	--		100%	--
12-Apr	6	6	--		100%	--
13-Apr	3	3	--		100%	--
14-Apr	1	1	--		100%	--
15-Apr	3	3	--		100%	--
16-Apr	151	151	--		100%	--
17-Apr	244	244	--		100%	--
18-Apr	231	231	--		100%	--
19-Apr	539	539	--		100%	--
20-Apr	329	329	--		100%	--
21-Apr	436	436	--		100%	--
22-Apr	233	233	--		100%	--
23-Apr	53	53	--		100%	--
24-Apr	87	87	--		100%	--
25-Apr	127	127	0		100%	0%
26-Apr	6	6	0		100%	0%
27-Apr	0	0	0		0%	0%
28-Apr	2	1	1		50%	50%
29-Apr	3	3	0		100%	0%
30-Apr	1	1	0		100%	0%
1-May	2	1	1		50%	50%
2-May	0	0	0		0%	0%
3-May	33	10	23		30%	70%
4-May	246	74	172		30%	70%
5-May	276	152	124		55%	45%
6-May	157	125	32		80%	20
7-May	133	113	20		85%	15%
8-May	79	49	30		62%	38%
9-May	87	27	60		30%	70%
10-May	5	3	2		60%	40%
11-May	0	0	0		0%	0%
12-May	1	1	0		100%	0%
13-May	1	1	0		100%	0%
14-May	4	4	0		100%	0%

Table 3. (continued).

Date	Shad Catch	Number Collected Tailrace	Number Collected Spillway		Percent Collected Tailrace	Percent Collected Spillway
15-May	65	13	52		20%	80%
16-May	8	8	0		100%	0%
17-May	*	--	--		--	--
18-May	*	--	--		--	--
19-May	2	2	0		100%	0%
20-May	4	2	2		50%	50%
21-May	13	13	0		100%	0%
22-May	37	37	0		100%	0%
23-May	30	28	2		94%	6%
24-May	96	29	67		30%	70%
25-May	17	2	15		12%	88%
26-May	98	**	98		--	100%
27-May	88	--	88		--	100%
28-May	99	--	99		--	100%
29-May	0	--	0		--	0%
30-May	7	--	7		--	100%
31-May	1	--	1		--	100%
1-Jun	0	--	0		--	0%
2-Jun	0	--	0		--	0%
3-Jun	0	--	0		--	0%
4-Jun	0	--	0		--	0%
5-Jun	0	--	0		--	0%
Total	***4,238***	***3,342***	***896***		***79%***	***21%***

* Shut Down due to High Flow Event

** Tailrace Lift shut down for rest of season due to tailrace crowder and hopper sheave mechanical problems

Table 4. Hourly summary of American shad passage at the Holtwood fish passage facility in 2012.

Date:	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*
Observation Time (Start):	*8:50*	*12:25*	*8:43*	*14:20*	*8:10*	*8:50*	*8:30*
Observation Time (End):	*18:35*	*19:00*	*12:00*	*19:00*	*19:00*	*18:59*	*18:50*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	6	--	2	--	1	1	--
0900 to 0959	5	--	5	--	1	--	--
1000 to 1059	--	--	3	--	2	1	--
1100 to 1159	12	--	1	--	2	--	--
1200 to 1259	14	13	0	--	0	--	2
1300 to 1359	9	11	0	--	1	--	--
1400 to 1459	2	4	0	6	2	1	--
1500 to 1559	12	8	--	8	6	--	1
1600 to 1659	16	--	--	7	1	1	--
1700 to 1759	13	2	--	3	0	--	--
1800 to 1859	4	6	--	5	1	2	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**93**	**44**	**11**	**29**	**17**	**6**	**3**

Date:	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*
Observation Time (Start):	*8:15*	*8:25*	*8:20*	*8:10*	*8:15*	*8:10*	*8:20*
Observation Time (End):		*17:40*	*19:00*	*19:10*	*18:45*	*19:20*	*19:00*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	--	--	--	1	14	17	23
0900 to 0959	--	--	--	8	55	23	45
1000 to 1059	--	--	15	7	15	46	26
1100 to 1159	--	--	25	20	6	25	17
1200 to 1259	--	--	57	5	10	31	7
1300 to 1359	--	--	32	6	14	63	19
1400 to 1459	--	--	5	21	24	57	29
1500 to 1559	1	3	5	45	42	62	27
1600 to 1659	--	--	4	44	25	89	49
1700 to 1759	--	--	8	58	20	75	37
1800 to 1859	--	--	--	25	6	43	50
1900 to 1959	--	--	--	4	--	8	--
2000 to 2059	--	--	--	--	--	--	--
Total	**1**	**3**	**151**	**244**	**231**	**539**	**329**

Table 4. (continued).

Date:	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Observation Time (Start):	*8:00*	*8:00*	*8:00*	*8:20*	*8:00*	*8:10*	*8:10*
Observation Time (End):	*9:00*	*18:45*	*18:45*	*18:45*	*18:50*	*18:25*	*18:35*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	9	49	3	2	4	4	--
0900 to 0959	37	45	5	3	1	0	--
1000 to 1059	38	12	3	3	2	1	--
1100 to 1159	5	43	5	5	0	0	--
1200 to 1259	4	14	6	8	9	0	--
1300 to 1359	60	13	10	6	9	0	--
1400 to 1459	78	14	14	17	9	1	--
1500 to 1559	55	15	4	14	39	0	--
1600 to 1659	71	13	2	11	25	0	--
1700 to 1759	28	9	1	14	18	0	--
1800 to 1859	42	6	0	4	11	0	--
1900 to 1959	9	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**436**	**233**	**53**	**87**	**127**	**6**	**0**

Date:	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*
Observation Time (Start):	*9:00*	*8:10*	*8:10*	*8:30*	*8:05*	*8:05*	*8:10*
Observation Time (End):	*18:25*	*18:15*	*18:25*	*18:15*	*18:10*	*18:15*	*18:55*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	--	--	--	--	--	--	2
0900 to 0959	--	1	--	--	--	--	19
1000 to 1059	1	--	--	--	--	3	13
1100 to 1159	--	--	--	--	--	--	23
1200 to 1259	--	--	--	--	--	--	36
1300 to 1359	--	1	1	1	--	2	34
1400 to 1459	--	1	--	--	--	1	24
1500 to 1559	--	--	--	--	--	12	36
1600 to 1659	--	--	--	1	--	7	22
1700 to 1759	--	--	--	--	--	6	25
1800 to 1859	1	--	--	--	--	2	12
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**2**	**3**	**1**	**2**	**0**	**33**	**246**

Table 4. (continued)

Date:	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*
Observation Time (Start):	*8:15*	*8:15*	*8:10*	*8:05*	*8:10*	*8:02*	*8:10*
Observation Time (End):	*18:15*	*18:15*	*18:20*	*17:50*	*18:00*	*16:45*	*16:20*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	11	4	10	20	3	--	--
0900 to 0959	23	11	26	22	19	1	--
1000 to 1059	32	14	17	6	20	--	--
1100 to 1159	42	25	18	1	21	--	--
1200 to 1259	38	15	5	8	4	--	--
1300 to 1359	38	18	2	9	8	1	--
1400 to 1459	24	13	0	10	3	2	--
1500 to 1559	29	10	6	2	6	1	--
1600 to 1659	22	21	23	1	1	--	--
1700 to 1759	13	18	19	--	2	--	--
1800 to 1859	4	8	7	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**276**	**157**	**133**	**79**	**87**	**5**	**0**

Date:	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*
Observation Time (Start):	*8:00*	*8:00*	*8:00*	*8:50*	*8:20*		
Observation Time (End):	*16:20*	*16:30*	*16:30*	*17:20*	*12:00*		
Military Time (hrs)							
0700 to 0759	--	--	--	--	--		
0800 to 0859	--	1	--	11	--		
0900 to 0959	--	--	--	35	2		
1000 to 1059	--	--	1	12	--		
1100 to 1159	--	--	3	3	6		
1200 to 1259	--	--	--	2	--		
1300 to 1359	--	--	--	--	--		
1400 to 1459	--	--	--	--	--		
1500 to 1559	1	--	--	2	--		
1600 to 1659	--	--	--	--	--		
1700 to 1759	--	--	--	--	--		
1800 to 1859	--	--	--	--	--		
1900 to 1959	--	--	--	--	--		
2000 to 2059	--	--	--	--	--		
Total	**1**	**1**	**4**	**65**	**8**	**0**	**0**

Table 4. (continued).

Date:	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*
Observation Time (Start):	*8:20*	*8:15*	*8:20*	*7:50*	*8:00*	*7:55*	*7:30*
Observation Time (End):	*16:25*	*16:15*	*16:20*	*16:30*	*16:45*	*16:50*	*16:15*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	2
0800 to 0859	--	--	--	2	--	26	4
0900 to 0959	--	--	1	4	10	17	4
1000 to 1059	--	--	5	5	4	21	3
1100 to 1159	--	1	1	5	2	15	4
1200 to 1259	--	--	--	9	2	14	--
1300 to 1359	--	1	2	5	5	2	--
1400 to 1459	1	2	3	2	4	1	--
1500 to 1559	--	--	--	2	2	--	--
1600 to 1659	1	--	1	3	1	--	--
1700 to 1759	--	--	--	--	--	--	--
1800 to 1859	--	--	--	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**2**	**4**	**13**	**37**	**30**	**96**	**17**

Date:	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*
Observation Time (Start):	*7:10*	*7:10*	*7:20*	*7:20*	*7:10*	*8:00*	*7:25*
Observation Time (End):	*16:43*	*16:15*	*15:30*	*15:30*	*15:20*	*15:30*	*15:30*
Military Time (hrs)							
0700 to 0759	5	5	11	--	1	--	--
0800 to 0859	16	10	42	--	4	1	--
0900 to 0959	9	12	14	--	1	--	--
1000 to 1059	6	18	4	--	1	--	--
1100 to 1159	8	5	16	--	--	--	--
1200 to 1259	5	8	7	--	--	--	--
1300 to 1359	7	14	2	--	--	--	--
1400 to 1459	22	4	3	--	--	--	--
1500 to 1559	16	12	--	--	--	--	--
1600 to 1659	4	--	--	--	--	--	--
1700 to 1759	--	--	--	--	--	--	--
1800 to 1859	--	--	--	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**98**	**88**	**99**	**0**	**7**	**1**	**0**

Table 4. (continued)

Date:	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	***Season Total***
Observation Time (Start):	*7:15*	*7:10*	*7:15*	*7:05*	
Observation Time (End):	*13:15*	*12:20*	*12:15*	*12:40*	
Military Time (hrs)					
0700 to 0759	--	--	--	--	24
0800 to 0859	--	--	--	--	303
0900 to 0959	--	--	--	--	464
1000 to 1059	--	--	--	--	360
1100 to 1159	--	--	--	--	365
1200 to 1259	--	--	--	--	333
1300 to 1359	--	--	--	--	406
1400 to 1459	--	--	--	--	404
1500 to 1559	--	--	--	--	484
1600 to 1659	--	--	--	--	466
1700 to 1759	--	--	--	--	369
1800 to 1859	--	--	--	--	239
1900 to 1959	--	--	--	--	21
2000 to 2059	--	--	--	--	0
Total	**0**	**0**	**0**	**0**	4,238

Table 5. Holtwood fishway summary table evaluating American shad passage at three river flow ranges.

	1997	1998*	1999	2000*	2001	2002*	2003*
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun
Season duration (days)	58	47	40	40	43	55	36
Number of days of operation	55	41	40	36	42	35	34
Am. shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135
Am. shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254
River flow ≤40,000 cfs							
Number of days	48	22	34	19	40	19	15
Percent of season	87%	54%	85%	53%	95%	54%	44%
No. of Am. shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229
Daily ave. of Am. shad passed	546	341	1,002	1,037	2,733	543	1,348
Percent of total passage	93%	91%	98%	67%	99%	59%	80%
River flow 40,001 to 60,000 cfs							
Number of days	7	2	6	12	2	14	18
Percent of season	13%	5%	15%	33%	5%	40%	53%
No. of Am. shad passed	1,862	230	633	9,536	634	7,029	5,019
Daily ave. of Am. shad passed	266	115	106	795	317	502	279
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.8%
River flow >60,000 cfs							
Number of days	0	17	0	5	0	2	1
Percent of season	0%	41%	0%	14%	0%	6%	3%
No. of Am. shad passed	0	493	0	173	0	171	6
Daily ave. of Am. shad passed	0	29	0	35	0	86	6
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%

* Denotes seasons of high river flow or frequent spillage.

Table 5. (continued).

	2004*	2005	2006	2007	2008*	2009*	2010	2011*	2012*
Migration season start date	26 Apr	27 Apr	11 Apr	01 May	21 Apr	03 May	21 Apr	20 May	07 Apr
Migration season end date	03 Jun	10 Jun	06 Jun	04 Jun	09 Jun	07 Jun	09 Jun	05 Jun	05 Jun
Season duration (days)	39	45	57	35	50	36	50	17	60
Number of days of operation	39	36	57	35	49	36	48	10	58
Am. shad season total (Conowingo)	109,360	68,926	56,899	25,464	19,914	29,272	37,757	20,571	22,143
Am. shad season total (Holtwood)	3,428	34,189	35,968	10,338	2,795	10,896	16,472	21	4,238
River flow <u><</u>40,000 cfs									
Number of days	2	33	48	27	20	20	40	0	31
Percent of season	5%	92%	84%	77%	40%	56%	83%	0%	53%
No. of Am. shad passed	2	34,060	35,302	9,549	2,242	8,939	15,606	0	3260
Daily ave. of Am. shad passed	1	1,032	735	354	112	447	372	0	105
Percent of total passage	0%	99.6%	98.1%	92.3%	80.2%	82%	95%	0%	76.9%
River flow 40,001 to 60,000 cfs									
Number of days	20	3	5	8	22	14	8	2	18
Percent of season	51.3%	8%	9%	23%	44%	39%	17%	12%	30.0%
No. of Am. shad passed	1,943	129	566	789	533	1,846	866	0	967
Daily ave. of Am. shad passed	97	43	113	99	24	132	108	0	54
Percent of Total Passage	56.7%	0.4%	1.6%	7.6%	19.0%	17.0%	5%	0.0%	22.8%
River flow >60,000 cfs									
Number of days	17	0	4	0	8	2	0	15	4
Percent of season	43.6%	0%	7%	0%	16%	5%	0%	88%	6.7%
No. of Am. shad passed	1,483	0	100	0	20	111	0	21	11
Daily ave. of Am. shad passed	87	0	25	0	2	55	0	2	3
Percent of total passage	43.3%	0.0%	0.3%	0.0%	0.7%	1.0%	0%	100%	0.3%

* Denotes seasons of high river flow or frequent spillage.

Table 6. Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2012.

Conowingo East		Holtwood		Safe Harbor		York Haven	
Year	Am. shad catch	**Number**	**% of C.E.L.**	**Number**	**% of Holt.**	**Number**	**% of S.H.**
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,687	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%
2004	109,360	3,428	3.1%	2,109	61.5%	219	10.4%
2005	68,926	34,189	49.6%	25,425	74.4%	1,772	7.0%
2006	56,899	35,968	63.2%	24,929	69.3%	1,913	7.7%
2007	25,464	10,338	40.6%	7,215	69.8%	192	2.7%
2008	19,914	2,795	14.0%	1,252	44.8%	21	1.7%
2009	29,272	10,896	37.2%	7,994	73.4%	402	5.0%
2010	37,757	16,472	43.6%	12,706	77.1%	907	7.1%
2011	20,571	21	0.1%	8	38.1%	0	0.0%
2012	**22,143**	**4,238**	**19.1%**	**3,089**	**72.9%**	**224**	**7.3%**

SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY – 2012

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INTRODUCTION

On June 1, 1993 representatives of Safe Harbor Water Power Corporation (SHWPC), two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed Safe Harbor, Holtwood, and York Haven Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. A major element of this agreement was for SHWPC, the operator of the Safe Harbor Hydroelectric Project (Safe Harbor), to construct and place in operation an upstream fishway by April 1, 1997. The fishway that provides fish access into Lake Clarke was placed into service in April of 1997.

Objectives for 2012 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATION

Project Operation

Safe Harbor is situated on the Susquehanna River (river mile 31) in Lancaster and York counties, Pennsylvania. The project consists of a concrete gravity dam 4,869 ft long and 75 ft high, a powerhouse 1,011 ft long with 12 generating units with a combined generating capacity of 417.5 MW, and a reservoir of 7,360 surface acres. The net operating head is about 55 ft.

Safe Harbor is the third upstream dam on the Susquehanna River. The station was built in 1931 and originally consisted of seven generating units. Five units were added and operational in 1986, which increased the hydraulic capacity to 110,000 cfs. Each unit is capable of passing approximately 8,500 cfs. Natural river flows in excess of 110,000 cfs are spilled over three regulating and 28 crest gates. The five new mixed-flow turbines have seven fixed-runner blades, a diameter of 240 in, and runner speed of 76.6 rpm. The runner blades are somewhat spiraled and do not have bands at the top or bottom. Two of these new turbines are equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The seven old units are five-blade Kaplan type turbines. These units have horizontal, adjustable, propeller-shaped blades.

FISHWAY DESIGN AND OPERATION

Fishway Design

The fishway was sized to pass a design population of 2.5 million American shad and 5 million river herring. The design incorporated numerous criteria established by the USFWS and the resource agencies. Physical design parameters for the fishway are given in the 1997 summary report (Normandeau Associates, Inc. 1998).

The Safe Harbor lift has three entrances (gates A, B, and C). The lift has a fish handling system, which includes a mechanically operated crowder, picket screen, hopper, and hopper trough gate. Fishes captured in the lift are sluiced into the trough and pass into Lake Clarke. Attraction flow, in, through, and from the lift is supplied through a piping system controlled by motor operated valves, attraction water gates, attraction water pools, and two diffusers that are gravity fed from two intakes. Generally, water conveyance and attraction flow is controlled by regulating two motor operated valves and three attraction water gates, which control flow from and into the attraction water pools and regulating the three entrance gates. Fish that enter the fishway entrances are attracted by water flow into the mechanically operated crowder chamber by regulating gate F. Once inside, fish are crowded over the hopper (4,725 gal. capacity), lifted, and sluiced into the trough. Fish swim upstream past a counting facility, which includes a separate public viewing room and into the forebay approximately 150 ft upstream of the dam. The trough extends 40 ft into the forebay in order to sluice the fish past the skimmer wall.

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; (3) entrance A and C, and (4) entrance A, B, and C individually. Operation during the 2012 season utilized a combination of entrances A, B, and C or A and C (Table 2).

Fishway Operation

Safe Harbor fishway operation commences soon after passage of approximately 500 American shad via the Holtwood fishway. In 2012, operations commenced on 12 April, six days after Holtwood passed 194 American shad into Lake Aldred.

The Safe Harbor fishway began operation on 12 April, with operations ending on 6 June. Lift operations ended due to the dwindling fish catch and rising water temperatures; indications that the migration run was ending.

Throughout the 2012 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

Daily operation of the Safe Harbor fishway was dependent on the American shad catch and managed in a flexible fashion. To minimize interruptions to fishway operation, SHWPC performed maintenance activities that included periodic cleaning of the exit channel, daily inspections, cleaning of picket screens, and other routine maintenance activities. Mechanical and/or electrical problems were addressed as needed.

Fish Counts

Fish lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide channel on the east side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to exiting the fishway. Fish passage was controlled by the biological technician, who opened/closed a gate located downstream of the viewing window from a controller mounted inside the counting room. Each night, after operations ended for the day, fish were denied passage from the fishway by closing the gate downstream of the window.

A 1,500 watt halogen lamp mounted above the viewing window and three adjustable 500 watt underwater lights (two at mid-depth on either side of the window and one on the bottom) gave the biologist and/or technician a degree of control over lighting conditions at the window. Overhead and underwater light intensity was adjusted daily, based on the constantly changing ambient light conditions. In addition, a screen capable of reducing the channel width at the counting window from 36 in down to 18 in (and a range of intermediate widths) was adjusted as viewing conditions and fish passage dictated. For the entire season, the adjustable screen was set at 18 in.

At the end of each hour, fish passage data were recorded on a worksheet and entered into a Microsoft Excel spreadsheet on a personal computer. Data processing and reporting were PC based and accomplished by program scripts, or macros, created within Microsoft Excel software. After the technician verified the correctness of the raw data, a daily summary of fish passage was produced and e-mailed to plant personnel. Each day's data were backed up to a diskette and stored off site. Daily reports and weekly summaries of fish passage were electronically distributed to members of the SHFPTAC and other cooperators.

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed in 2012 by the Safe Harbor fishway is presented in Table 1. A total of 161,874 fish of 19 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (136,369) was the dominant species passed and comprised 84% of the catch. Some 3,089 American shad were passed upstream through the fishway and comprised nearly 2% of the catch. Other predominant fishes passed included quillback (12,582), channel catfish (4,972), carp (1,475), shorthead redhorse (1,321) and walleye (1,296). Peak passage occurred on 5 May, when 9,495 fish, (78% gizzard shad), were passed.

American Shad Passage

The Safe Harbor fishway passed 3,089 American shad in 2012 during 56 days of operation (Table 1). This year's passage of American shad (3,089) is the fourth lowest in sixteen years of operation (Table 4). Safe Harbor managed to pass 72.9% of the American shad passed at Holtwood Dam and nearly 14% of the American shad passed by Conowingo Dam, (Table 4). Peak shad passage occurred on 5 May, when 288 American shad were captured and passed during 10 hours of operation.

American shad were passed at water temperatures of 54.9°F to 79.0°F and river flows of 13,700 to 107,300 cfs (Table 2 and Figures 1 and 2). Water temperature was relatively stable (remained below 70.0°) from April 12 to May 24. After May 24, the water temperature steadily climbed to the end of the season except for the last three days of operation.

The number of American shad observed passing through the trough by hour is shown in Table 3. With the season's shad catch broken down based on hours of observation, passage rates were consistent from 0900 hrs to 1659 hrs. Passage sharply declined after 1700 hrs. The peak passage hour for American shad during the entire season was observed between 1600 hrs to 1659 hrs, with a total of 369 American shad passed. The highest hourly passage (71) occurred between 1600 hrs and 1659 hrs on 5 May.

During the 2012 season, the Safe Harbor fishway passed no MD DNR tagged American shad that had been passed by downstream fish lift facilities.

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2012.

SUMMARY

The 2012 Safe Harbor fishway operating season was conducted with minimal disruptions to operations due to mechanical problems.

A total of 3,089 American shad were passed into Lake Clarke, or nearly 73% of the American shad that were passed into Lake Aldred by the Holtwood fishway (Table 4). More than 90% of the total American shad passed at Safe Harbor occurred prior to 22 May, shortly before Holtwood passed 90% of their American shad season total (23 May). Future operations of the fishway will build on the past sixteen years of experience.

RECOMMENDATIONS

1) Operate the fishway at Safe Harbor Dam per annual guideline developed and approved by the SHFPTAC. Fishway operation should adhere to the guideline; however, flexibility must remain with operating personnel to maximize fishway operation and performance.

LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Safe Harbor Fish Passage Facility in 1997. Prepared for Safe Harbor Water Power Corporation, Conestoga, PA.

Normandeau Associates, Inc. 1999. Summary of operation at the Safe Harbor Fish Passage Facility in 1998. Prepared for Safe Harbor Water Power Corporation, Conestoga, PA.

FIGURES

Figure 1. A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the daily American shad catch at the Safe Harbor Fish Passage Facility, spring 2012.

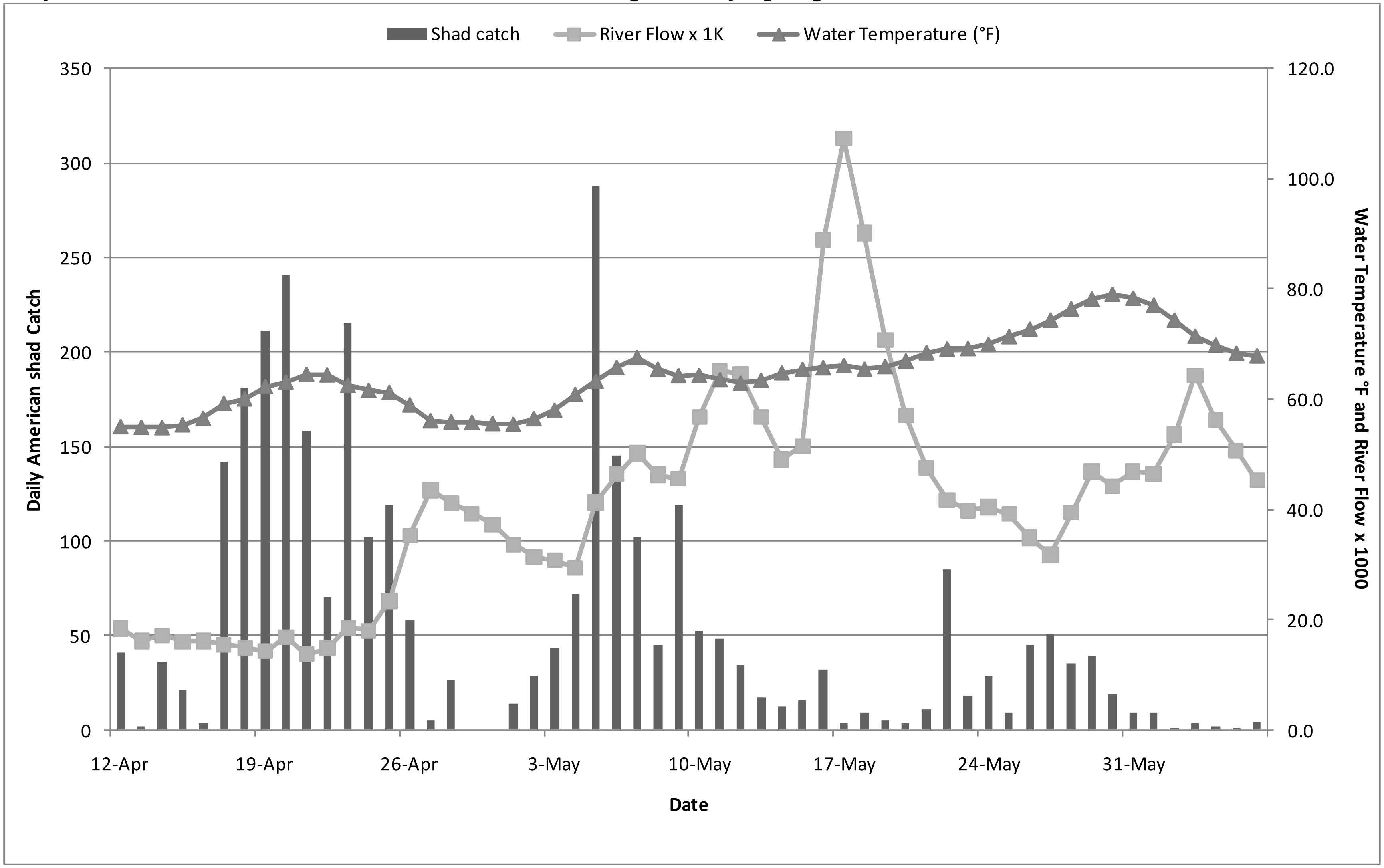
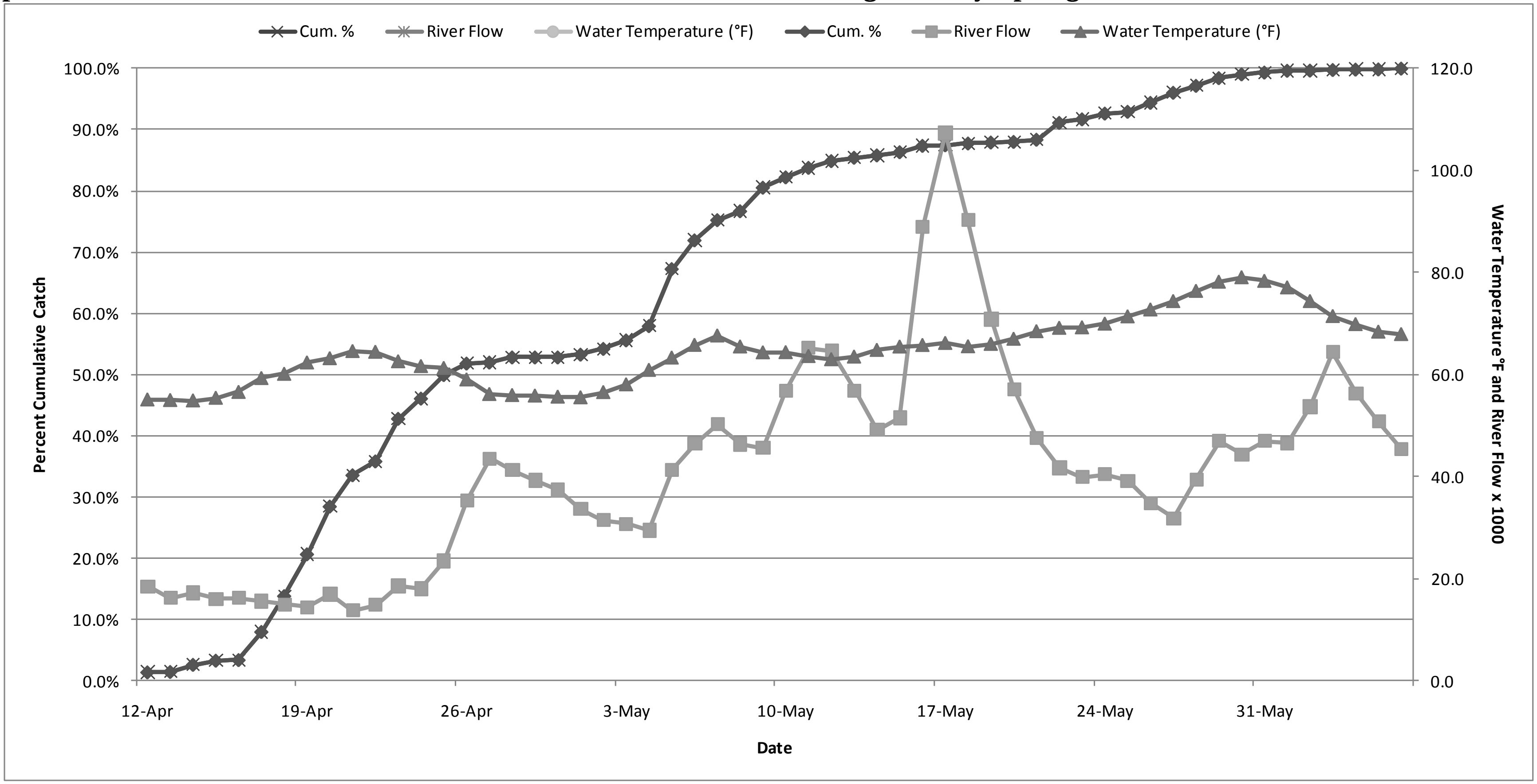


Figure 2. A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the percent cumulative American shad catch at the Safe Harbor Fish Passage Facility, spring 2012.



TABLES

Table 1. Number and disposition of fish passed by the Safe Harbor fishway in 2012.

Date:	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr
Viewing Start Time:	8:25	7:00	7:40	7:00	8:30	7:00	7:25	10:10	9:45	9:40	9:00
Viewing End Time:	16:50	16:40	16:50	16:40	17:20	17:40	17:50	18:00	17:30	18:07	17:30
Hours of Operation:	8.4	9.7	9.2	9.7	8.8	10.7	10.4	7.8	7.8	8.5	8.5
Number of Lifts:	9	5	10	8	8	12	14	11	10	11	9
Water Temperature (°F):	53.1	53.2	53.2	55.4	58	59.5	61	63	64.4	64.9	64.5
AMERICAN SHAD	41	2	36	21	3	142	181	211	241	158	70
GIZZARD SHAD	1187	113	236	29	60	521	873	4935	5187	3802	970
STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	0	0	0	0	0	0	0	0	0	1	0
BROWN TROUT	0	0	0	0	0	1	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0	1
CARP	0	10	43	12	29	140	351	270	45	42	37
QUILLBACK	43	3	18	36	129	1809	723	905	431	706	326
S. REDHORSE	2	1	0	0	1	42	18	5	20	19	15
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	1	1	0	2	12	14	104	62	32	35	105
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	0	0	0	0	0	3	1	0
BLUEGILL	0	0	0	0	0	0	0	0	0	2	0
SMALLMOUTH BASS	14	1	20	17	23	136	98	68	73	16	3
LARGEMOUTH BASS	0	0	0	0	0	1	1	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	1	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	1	0	0	0	0
WALLEYE	2	1	0	0	1	23	23	8	12	14	7
FLAT HEAD CATFISH	0	0	0	0	0	0	0	0	0	0	0
Daily Total	**1,290**	**132**	**353**	**117**	**258**	**2,829**	**2,373**	**6,465**	**6,044**	**4,796**	**1,534**

Table 1 (continued)

Date:	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May	2-May	3-May
Viewing Start Time:	9:30	9:30	9:30	9:45	9:30	9:30	9:30	9:30	11:40	9:30	9:40
Viewing End Time:	18:00	17:45	17:55	17:35	16:30	17:30	17:30	17:30	17:45	17:30	17:45
Hours of Operation:	8.5	8.3	8.4	7.8	7.0	8.0	8.0	8.0	6.1	8.0	8.1
Number of Lifts:	11	11	11	11	8	8	8	6	7	10	11
Water Temperature (°F):	58.5	57	59.2	55.4	56.5	56.3	55.4	54.7	55.9	57.2	58.6
AMERICAN SHAD	215	102	119	58	5	26	0	0	14	29	43
GIZZARD SHAD	3849	4375	2174	290	427	419	23	69	1892	347	760
STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	1	0	0	0	0	0	0	0	0	0	0
CARP	3	4	1	2	0	4	0	1	0	11	24
QUILLBACK	266	50	15	4	68	23	0	0	95	1155	565
S. REDHORSE	6	2	2	3	13	6	0	1	44	235	103
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	128	13	18	19	71	5	1	0	3	21	21
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	1	0	0	0	0	0	0	2
BLUEGILL	0	0	1	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	4	5	2	2	4	3	0	0	5	6	23
LARGEMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0	2
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	1	0
WALLEYE	19	4	10	20	1	3	1	2	9	43	52
FLAT HEAD CATFISH	0	0	0	0	0	0	0	0	0	0	0
Daily Total	**4,492**	**4,555**	**2,342**	**399**	**589**	**489**	**25**	**73**	**2,062**	**1,848**	**1,595**

Table 1. (continued)

Date:	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May
Viewing Start Time:	11:20	8:20	9:00	9:30	9:30	9:00	9:30	9:25	9:30	9:00	9:00
Viewing End Time:	17:40	18:15	17:45	17:30	17:30	17:35	17:30	17:30	17:30	16:48	17:30
Hours of Operation:	6.3	9.9	8.8	8.0	8.0	8.6	8.0	8.1	8.0	7.8	8.5
Number of Lifts:	9	14	13	12	14	13	13	11	12	12	10
Water Temperature (°F):	61.5	64.5	68	67	64	63.3	63.3	63.5	62.5	63	65.7
AMERICAN SHAD	72	288	145	102	45	119	52	48	34	17	12
GIZZARD SHAD	1880	7418	2960	3518	7507	8066	8906	6871	6011	2703	1083
STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	1	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0	1
MUSKELLUNGE	0	0	1	0	0	0	0	0	1	0	0
CARP	24	136	55	15	10	3	0	0	0	3	2
QUILLBACK	834	1147	1045	580	41	14	11	6	3	4	68
S. REDHORSE	199	147	100	80	21	11	2	1	7	2	25
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	93	223	310	395	64	39	30	44	12	23	193
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	2	6	3	1	0	0	0	1	1	0	0
BLUEGILL	0	2	0	0	0	1	0	0	0	0	1
SMALLMOUTH BASS	30	23	35	21	3	2	2	6	2	1	2
LARGEMOUTH BASS	3	0	0	0	0	1	0	0	0	0	0
WHITE CRAPPIE	1	2	0	1	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	1	0	0	0	0	0	0	0
WALLEYE	81	103	55	138	17	13	16	7	15	11	45
FLAT HEAD CATFISH	0	0	0	0	0	0	1	0	0	0	0
Daily Total	**3,220**	**9,495**	**4,709**	**4,852**	**7,708**	**8,269**	**9,020**	**6,984**	**6,086**	**2,764**	**1,432**

Table 1. (continued)

Date:	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May
Viewing Start Time:	9:00	8:30	8:30	10:00	8:48	8:30	8:45	9:00	8:45	9:00	8:30
Viewing End Time:	16:47	17:30	17:30	17:17	17:25	17:30	17:32	17:45	17:20	17:30	8:31
Hours of Operation:	7.8	9.0	9.0	7.3	8.6	9.0	8.8	8.8	8.6	8.5	0.0
Number of Lifts:	10	10	10	9	11	11	14	11	11	9	1
Water Temperature (°F):	65.5	65.5	64.9	64	66	68.2	70	69	70	71	71
AMERICAN SHAD	16	32	3	9	5	3	11	85	18	29	9
GIZZARD SHAD	761	8646	5771	1016	1002	1651	396	1430	1143	3125	19
STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	1	0	0	0	0	1	0	0	0	0	0
BROWN TROUT	0	1	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	1	0	0	0	0	0	0
CARP	3	23	17	3	2	3	10	34	1	7	0
QUILLBACK	25	12	3	0	0	3	129	130	7	2	0
S. REDHORSE	2	9	5	1	0	2	8	26	16	7	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	104	190	117	24	91	167	325	300	61	90	0
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	0	0	0	0	0	1	0	0	1	1	0
BLUEGILL	1	0	0	0	0	0	0	1	0	2	0
SMALLMOUTH BASS	1	3	0	1	1	0	0	2	1	0	0
LARGEMOUTH BASS	0	0	0	0	1	0	0	2	0	1	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0	0
WALLEYE	18	8	4	2	5	3	51	100	47	52	0
FLAT HEAD CATFISH	0	0	0	0	0	0	0	0	0	0	0
Daily Total	**932**	**8,924**	**5,920**	**1,056**	**1,108**	**1,834**	**930**	**2,110**	**1,295**	**3,316**	**28**

Table 1. (continued)

Date:	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun
Viewing Start Time:	14:25	8:30	9:00	9:30	9:00	9:00	9:00	9:00	9:00	9:30	9:10
Viewing End Time:	18:35	17:30	17:05	17:30	17:50	17:30	17:30	16:10	16:12	16:10	16:15
Hours of Operation:	4.2	9.0	8.1	8.0	8.8	8.5	8.5	7.2	7.2	6.7	7.1
Number of Lifts:	7	10	10	9	9	9	9	6	8	8	7
Water Temperature (°F):	76	75.6	77	77	77	78	77.5	75	71.6	70.2	68.5
AMERICAN SHAD	45	51	35	39	19	9	9	1	3	2	1
GIZZARD SHAD	8497	4197	2740	1190	1461	715	488	1330	351	225	493
STRIPED BASS	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0	0
CARP	10	52	8	8	7	2	4	3	1	0	0
QUILLBACK	157	395	157	155	136	105	30	4	5	1	2
S. REDHORSE	20	51	18	18	3	1	1	0	0	0	0
BROWN BULLHEAD	0	0	0	0	0	0	0	1	0	0	0
CHANNEL CATFISH	80	138	167	200	311	80	233	50	67	24	36
HYBRID STRIPED BASS	0	0	0	0	0	0	0	0	0	1	1
ROCK BASS	1	1	0	0	0	0	0	0	0	0	0
BLUEGILL	3	2	5	6	3	0	0	0	0	0	1
SMALLMOUTH BASS	4	0	1	2	2	1	1	0	0	0	0
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0	1
WHITE CRAPPIE	0	0	1	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0	0
WALLEYE	42	52	60	19	28	7	25	3	0	0	6
FLAT HEAD CATFISH	0	0	0	0	0	0	1	0	0	1	0
Daily Total	**8,859**	**4,939**	**3,192**	**1,637**	**1,970**	**920**	**792**	**1,392**	**427**	**254**	**541**

Table 1. (continued)

Date:	6-Jun	Season Total
Viewing Start Time:	9:00	**21.4**
Viewing End Time:	16:15	
Hours of Operation:	7.3	**451.3**
Number of Lifts:	8	**549.0**
Water Temperature (°F):	68	
AMERICAN SHAD	4	**3,089**
GIZZARD SHAD	261	**136,369**
STRIPED BASS	1	**1**
SEA LAMPREY	0	**4**
BROWN TROUT	0	**3**
MUSKELLUNGE	0	**5**
CARP	0	**1,475**
QUILLBACK	1	**12,582**
S. REDHORSE	0	**1,321**
BROWN BULLHEAD	0	**1**
CHANNEL CATFISH	23	**4,972**
HYBRID STRIPED BASS	0	**2**
ROCK BASS	0	**26**
BLUEGILL	0	**31**
SMALLMOUTH BASS	0	**670**
LARGEMOUTH BASS	0	**12**
WHITE CRAPPIE	1	**9**
BLACK CRAPPIE	0	**3**
WALLEYE	8	**1,296**
FLAT HEAD CATFISH	0	**3**
Daily Total	**299**	**161,874**

Table 2. Summary of daily average river flow and water temperature as measured at Holtwood Dam, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Safe Harbor fish passage facility in 2012.

Date	River Flow[1] (mcfs)	Water Temp (°F)	Secchi (in)	Maximum # of Units Operating	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
12-Apr	18,400	55.0	24	5	A/C	500	169.3	226.9
13-Apr	16,100	54.9	24	6	A/C	500	170.1	226.9
14-Apr	17,100	54.9	28	4	A/C	500	168.7	226.3
15-Apr	16,000	55.4	24	NA	A/C	500	168.2	226.5
16-Apr	16,100	56.5	24	3	A/B/C	500	169.5	226.4
17-Apr	15,500	59.2	24	1	A/B/C	500	167.2	226.1
18-Apr	14,900	60.1	22	2	A/C	500	167.5	226.1
19-Apr	14,300	62.3	24	4	A/C	500	169.1	225.8
20-Apr	16,900	63.1	22	1	A/C	500	168.3	226.2
21-Apr	13,700	64.5	20	4	A/C	500	168.5	226.8
22-Apr	14,800	64.4	18	3	A/C	500	168.6	227.0
23-Apr	18,500	62.5	18	5	A/C	500	170.0	226.2
24-Apr	18,000	61.6	16	6	A/C	500	170.4	226.2
25-Apr	23,400	61.2	16	6	A/C	500	170.5	226.2
26-Apr	35,200	59.0	16	9	A/C	500	172.2	266.3
27-Apr	43,500	56.1	16	10	A/C	500	173.3	226.3
28-Apr	41,200	55.9	18	10	A/C	500	172.4	226.8
29-Apr	39,200	55.8	18	8	A/C	500	171.9	227.2
30-Apr	37,300	55.6	18	8	A/C	500	172.9	226.5
1-May	33,600	55.5	24	7	A/C	500	172.3	226.9
2-May	31,400	56.5	24	7	A/C	500	172.5	226.3
3-May	30,700	58.0	30	7	A/C	500	170.5	227.3
4-May	29,400	60.9	30	9	A/C	500	171.9	225.9
5-May	41,300	63.3	30	5	A/C	500	171.6	226.8
6-May	46,400	65.8	32	7	A/C	500	172.5	226.9
7-May	50,200	67.6	30	9	A/C	500	173.6	226.5
8-May	46,300	65.4	30	7	A/C	500	173.2	226.5
9-May	45,600	64.3	20	8	A/C	500	173.5	226.6
10-May	56,700	64.3	18	10	A/C	500	174.7	226.3
11-May	65,200	63.6	16	11	A/C	500	175.3	225.8
12-May	64,500	62.9	20	9	A/C	500	174.8	226.9
13-May	56,800	63.5	24	8	A/C	500	173.8	227.0
14-May	49,100	64.8	30	9	A/C	500	173.7	226.6
15-May	51,500	65.4	24	8	A/C	500	173.4	226.7

Table 2. (continued)

Date	River Flow[1] (mcfs)	Water Temp (°F)	Secchi (in)	Maximum # of Units Operating	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
16-May	89,000	65.7	24	11	A/C	500	176.4	225.2
17-May	107,300	66.1	12	12	A/C	500	176.5	225.5
18-May	90,200	65.5	12	11	A/C	500	176.2	226.8
19-May	70,800	66.0	16	8	A/C	500	174.4	226.1
20-May	57,100	67.0	16	9	A/C	500	173.7	226.9
21-May	47,500	68.4	18	11	A/C	500	174.1	226.2
22-May	41,700	69.1	24	7	A/C	500	171.5	227.1
23-May	39,800	69.2	24	8	A/C	500	173.3	226.1
24-May	40,400	69.9	24	7	A/C	500	173.5	226.1
25-May	39,100	71.4	24	8	A/C	500	173.4	226.3
26-May	34,800	72.7	24	5	A/C	500	172.4	226.5
27-May	31,800	74.4	24	7	A/C	500	172.4	226.9
28-May	39,400	76.4	24	6	A/C	500	171.5	227
29-May	46,900	78.2	24	7	A/C	500	174.1	226.1
30-May	44,300	79.0	20	8	A/C	500	173.3	226.3
31-May	46,900	78.3	18	8	A/C	500	173.1	226.3
1-Jun	46,500	77.0	18	9	A/C	500	173.1	226.6
2-Jun	53,600	74.4	10	9	A/C	500	174.1	226.9
3-Jun	64,400	71.4	10	9	A/C	500	173.8	226.5
4-Jun	56,300	69.8	6	8	A/C	500	173.8	226.1
5-Jun	50,700	68.4	10	8	A/C	500	173.5	227
6-Jun	45,300	67.9	16	7	A/C	500	172.8	226.8

1 River flow and temperature measured at Holtwood Dam.

Table 3. Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2012.

Date:	*12-Apr*	*13-Apr*	*14-Apr*	*15-Apr*	*16-Apr*	*17-Apr*	*18-Apr*	*19-Apr*	*20-Apr*	*21-Apr*	*22-Apr*	*23-Apr*
Observation Time-Start:	*8:25*	*7:00*	*7:40*	*7:00*	*8:30*	*7:00*	*7:25*	*10:10*	*9:45*	*9:40*	*9:00*	*9:30*
Observation Time-End:	*16:50*	*16:40*	*16:50*	*16:40*	*17:20*	*17:40*	*17:50*	*18:00*	*17:30*	*18:07*	*17:30*	*18:00*
Military Time (hrs)												
0700 to 0759			0			3	7					
0800 to 0859			0	2	1	4	7					
0900 to 0959			2	1		0	14		11	0	3	11
1000 to 1059	5	1	5			2	30	28	16	12	7	26
1100 to 1159	8	1	0	5		12	29	37	40	21	7	22
1200 to 1259	3		2	4		17	18	26	31	22	8	36
1300 to 1359	6		7	1		12	20	22	34	14	9	25
1400 to 1459	1		6	1		12	16	35	33	16	4	31
1500 to 1559	9		5	5		27	11	24	34	20	9	42
1600 to 1659	9		9	2		37	9	25	27	18	15	17
1700 to 1759					2	16	20	14	15	32	8	5
1800 to 1859										3		
1900 to 1959												
Total	**41**	**2**	**36**	**21**	**3**	**142**	**181**	**211**	**241**	**158**	**70**	**215**
Date:	*24-Apr*	*25-Apr*	*26-Apr*	*27-Apr*	*28-Apr*	*29-Apr*	*30-Apr*	*1-May*	*2-May*	*3-May*	*4-May*	*5-May*
Observation Time-Start:	*9:30*	*9:30*	*9:45*	*9:30*	*9:30*	*9:30*	*9:30*	*11:40*	*9:30*	*9:40*	*11:20*	*8:20*
Observation Time-End:	*17:45*	*17:55*	*17:35*	*16:30*	*17:30*	*17:30*	*17:30*	*17:45*	*17:30*	*17:45*	*17:40*	*18:15*
Military Time (hrs)												
0700 to 0759											7	
0800 to 0859												12
0900 to 0959	8	9	2			0	0		0	6		35
1000 to 1059	9	22	17	1	3	0	0		2	5		31
1100 to 1159	7	14	9		5	0	0	1	2	1	4	11
1200 to 1259	9	12	5		2	0	0	2	8		6	34
1300 to 1359	11	21	10	1	2	0	0	1	5	6	6	28
1400 to 1459	15	10	3		6	0			3	4	12	12
1500 to 1559	15	7	6	1	2	0	0	1	2	7	6	24
1600 to 1659	15	9	5		3	0	0	6	6	8	11	71
1700 to 1759	13	15	1	2	3	0	0	3	1	6	20	14
1800 to 1859												16
1900 to 1959												
Total	**102**	**119**	**58**	**5**	**26**	**0**	**0**	**14**	**29**	**43**	**72**	**288**

Table 3. (continued)

Date:	*6-May*	*7-May*	*8-May*	*9-May*	*10-May*	*11-May*	*12-May*	*13-May*	*14-May*	*15-May*	*16-May*	*17-May*
Observation Time-Start:	*9:00*	*9:30*	*9:30*	*9:00*	*9:30*	*9:25*	*9:30*	*9:00*	*9:00*	*9:00*	*8:30*	*8:30*
Observation Time-End:	*17:45*	*17:30*	*17:30*	*17:35*	*17:30*	*17:30*	*17:30*	*16:48*	*17:30*	*16:47*	*17:30*	*17:30*
Military Time (hrs)												
0700 to 0759												
0800 to 0859											3	0
0900 to 0959	28	26	3	13	10	9	7	3	1	1	3	1
1000 to 1059	24	25	10	17	3	2		1	2	3	4	0
1100 to 1159	13	4	4	10	4	1	6	3	1	2	5	0
1200 to 1259	7	10	7	12	8	6	5	0	3	2	10	0
1300 to 1359	12	7	2	21	7	13	6	2	2	1	4	2
1400 to 1459	32	7		6	11	9	9	3	2	3	2	0
1500 to 1559	8	12	6	21	8	4	1	4	1	3	0	
1600 to 1659	6	6	8	15	1	4		1	0	1	0	0
1700 to 1759	15	5	5	4		0			0		1	0
1800 to 1859												
1900 to 1959												
Total	**145**	**102**	**45**	**119**	**52**	**48**	**34**	**17**	**12**	**16**	**32**	**3**
Date:	*18-May*	*19-May*	*20-May*	*21-May*	*22-May*	*23-May*	*24-May*	*25-May*	*26-May*	*27-May*	*28-May*	*29-May*
Observation Time-Start:	*10:00*	*8:48*	*8:30*	*8:45*	*9:00*	*8:45*	*9:00*	*8:30*	*14:25*	*8:30*	*9:00*	*9:30*
Observation Time-End:	*17:17*	*17:25*	*17:30*	*17:32*	*17:45*	*17:20*	*17:30*	*18:31*	*18:35*	*17:30*	*17:05*	*17:30*
Military Time (hrs)												
0700 to 0759												
0800 to 0859	6	1	1	0		0		9		12		
0900 to 0959	0	1	0	1	4	0	5			13	4	12
1000 to 1059	0	0	0	5	6	0	4			9	2	7
1100 to 1159	0	1	0	1	2	6				3	9	4
1200 to 1259	1	0	0	0	19	2				4	3	4
1300 to 1359	0	1	1	1	13	2	8			0	7	7
1400 to 1459	1	0	0	2	21	2	9		2	6	0	1
1500 to 1559	1	1	0	0	14	0	2		1	1	9	2
1600 to 1659	0	0	1	0	2	4	1		11	1	1	2
1700 to 1759	0	0	0	1	4	2			26	2	0	
1800 to 1859									5			
1900 to 1959												
Total	**9**	**5**	**3**	**11**	**85**	**18**	**29**	**9**	**45**	**51**	**35**	**39**

Table 3. (continued)

Date:	*30-May*	*31-May*	*1-Jun*	*2-Jun*	*3-Jun*	*4-Jun*	*5-Jun*	*6-Jun*		
Observation Time-Start:	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:30*	*9:10*	*9:00*		***Season***
Observation Time-End:	*17:50*	*17:30*	*17:30*	*16:10*	*16:12*	*16:10*	*16:15*	*16:15*		***Total***
Military Time (hrs)										
0700 to 0759										**17**
0800 to 0859										**58**
0900 to 0959	1	3	0		0	1	0			**252**
1000 to 1059	3	3	1	1	1		1	1		**357**
1100 to 1159	3	1	0		2		0			**321**
1200 to 1259	1		3		0		0			**352**
1300 to 1359	0		2		0	1	0	2		**365**
1400 to 1459	2	1	3		0		0	1		**355**
1500 to 1559	3	1	0		0		0			**360**
1600 to 1659	2		0		0		0			**369**
1700 to 1759	4		0							**259**
1800 to 1859										**24**
1900 to 1959										**0**
Total	**19**	**9**	**9**	**1**	**3**	**2**	**1**	**4**		**3,089**

Table 4. Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2012.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		Number	% of C.E.L.	Number	% of Holt.	Number	% of S.H.
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,687	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%
2004	109,360	3,428	3.1%	2,109	61.5%	219	10.4%
2005	68,926	34,189	49.6%	25,425	74.4%	1,772	7.0%
2006	56,899	35,968	63.2%	24,929	69.3%	1,913	7.7%
2007	25,464	10,338	40.6%	7,215	69.8%	192	2.7%
2008	19,914	2,795	14.0%	1,252	44.8%	21	1.7%
2009	29,272	10,896	37.2%	7,994	73.4%	402	5.0%
2010	37,757	16,472	43.63%	12,706	77.14%	907	7.14%
2011	20,571	21	0.1%	8	38.1%	0	0.0%
2012	**22,143**	**4,238**	**19.1%**	**3,089**	**72.9%**	**224**	**7.3%**

SUMMARYOF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT – 2012

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EXECUTIVE SUMMARY

The fish ladder was opened on 1 April allowing volitional (unmanned) passage for 24 days prior to initiating manned Fishway operation. In 2012, the Fishway was manned on a total of 43 days between 25 April and 6 June. Some 97,990 fish of 23 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (87,068) was the dominant fish species passed and comprised almost 89% of the fish passed. Other predominant fishes passed included quillback (4,104), channel catfish (2,858), shorthead redhorse (1,491), carp (669) walleye (602) and smallmouth bass (553). Passage varied daily and ranged from 103 fish on 25 April to 8,002 fish on 12 May when 8.2% of the season total was passed.

A total of 224 American shad passed upstream through the ladder in 2012. Some 71 shad passed in April and 153 shad passed in May. No shad passed in June. Peak shad passage occurred on 26 April when some 68 shad (30.4% of season total) passed.

American shad were collected and passed at water temperatures of 50.9°F to 76.1°F, River flows of 25,600 cfs to 94,900 cfs and East Channel flows of 3,100 cfs to 16,000 cfs. Passage during April occurred at Rivers flows that varied from 32,100 cfs to 38,800 cfs. Water temperature during this period ranged from 50.9°F to 57.2°F and East Channel flows varied 2,133 cfs to 5,240 cfs. Passage during May occurred at Rivers flows that increased from 26,300 cfs to 94,900 cfs before declining to 28,600 on 26 May. Water temperature during this period ranged from 59.9°F to 76.1°F and East Channel flows varied from 3,100 cfs to 16,000 cfs.

Over 41% of the shad (93) passed between 0800 hrs and 1059 hrs; hourly passage varied from no shad to 9 shad. Some 78 shad passed from 1100 to 1359 hrs. A total of 53 shad passed between 1400 hrs and the end of manned operation each day (1600 and/or 1700 hrs). The peak hourly passage of shad (18) occurred on 26 April between 1400 hrs and 1459 hrs.

As in previous years YHPC agreed to make periodic observations for adult shad in the forebay and open the sluice gate if/when large numbers of adults were observed. No adult shad were observed by Station Personnel that made periodic observations of the forebay area from June through August.

The station also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC. Daily monitoring of the York Haven forebay for the presence of juvenile shad began on 10 September when water temperature was 74.0°F. Monitoring continued through 16 November. During this period River flows ranged from 5,850 cfs to 108,000 cfs. The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity. Given fish activity was non-existent there was no need to implement "Downstream Operation".

INTRODUCTION

In 1993, York Haven Power Company (YHPC), the licensees of the Safe Harbor and Holtwood Projects, the U.S. Department of the Interior represented by the Fish and Wildlife Service ("USFWS"), the Susquehanna River Basin Commission ("SRBC"), the states of Maryland and Pennsylvania and their involved agencies – Maryland Department of Natural Resources ("MDNR"), Pennsylvania Fish and Boat Commission ("PFBC") and Pennsylvania Department of Environmental Resources ("PADEP"), and two other parties signed the Susquehanna River Fish Passage Settlement Agreement.

This agreement established for each project a Fish Passage Technical Advisory Committee ("FPTAC") comprised of representatives of the affected licensee, USFWS, PFBC and MDNR. Each FPTAC is responsible for reviewing and monitoring the design, construction, maintenance and operation of the fish passage facilities at the respective project, preparing an annual report, and recommending studies and/or modifications to improve upstream and downstream passage.

Although the FPTAC did not schedule a specific meeting to discuss Fishway operation to discuss Fishway operation, committee members had the opportunity to discuss Fishway operation with Station personnel during project relicensing meetings. As in previous years, objectives of 2012 operation were to monitor passage of migratory and resident fishes through the Fishway and continue to assess operation.

YORK HAVEN FISHWAY OPERATIONS

The installation and operation of the Fishway are part of a cooperative private, state and federal effort to restore American shad (*Alosa sapidissima*) and other migratory fish to the

Susquehanna River. In 1997, YHPC and the resource agencies reached a new settlement agreement to revise the type and location of the York Haven fish passage facility. The Fishway is located in Dauphin County, PA at the Three Mile Island end of the East Channel Dam at the York Haven Hydroelectric Project (FERC No. 1888). The Fishway was placed in service by YHPC in April 2000.

Fishway operation coincides with a springtime minimum flow release. As part of the 1997 agreement, YHP agreed to maintain a spill of up to 4,000 cfs over the Main Dam and a minimum release of approximately 2,000 cfs in the East Channel through the Fishway during spring operation. River flow in excess of spring minimum flow requirements and station capacity is spilled over the Main and East Channel Dams and through the Fishway. A nominal 2,100 cfs East Channel minimum flow is released through the fishway 24 hrs a day during the entire Fishway operating season. When River flows are less than 23,000 cfs, a nominal minimum spill of 4,000 cfs is maintained over the Main Dam during daily Fishway operation.

Project Operation

The hydroelectric station located in York Haven, PA built in 1904, is situated on the River (river mile 55) in Dauphin and York counties, Pennsylvania (Figure 1). It is the fourth upstream hydroelectric facility on the River. The Project is a 20 unit run-of-river facility capable of producing approximately 19 MW and has an estimated hydraulic capacity of 17,000 cfs. It includes two dams that impound approximately 5 miles of the River forming Lake Frederic. The Main Dam is approximately 5,000-ft long, with a maximum height of 17-ft. The East Channel Dam is approximately 925-ft long with a maximum height of 9-ft. When River flow exceeds station hydraulic capacity (55% of the year), water is spilled over the two dams.

Fishway Design and Operation

Fishway Design

Fishway design incorporated numerous criteria established by the USFWS and the other resource agencies. The Fishway has an operating limit of 150,000 cfs River flow (East Channel flow limit of approximately 22,000 cfs). The Fishway includes two sections; a “weir cut” and a vertical notch fish ladder. Figure 2 provides the general arrangement of the Fishway. A detailed description of the Fishway and its major components is located in 2000 and 2001 summary reports (Kleinschmidt 2000 & 2002).

Fishway Operation

Fishway preparations began in early March and volitional passage (unmanned) began on 1 April. Only the entrance and exit gate were open during a 24 day unmanned period of Fishway operation between 1 and 24 April.

Manned Fishway operation, commenced on Wednesday 25 April, 4 days after the Safe Harbor Fish Lift had passed 1,036 American shad. In 2012, the Fishway was manned on a total of 43 days between 25 April and 6 June. Normally, fish were counted and allowed to pass upstream between 0800 hrs and 1600 hrs. However, per the Fishway Operation Plan, counting was extended to 1700 hrs on 26 April as five shad had passed between 1600 hrs and 1700 hrs. Since no shad were observed passing the ladder between 30 May and 6 June, an 8 day period, manned Fishway operation ended at 1600 hrs on 6 June.

Between 25 April and 6 June both fixed wheel gates and the diffuser gate were opened. These gates remained opened throughout the spawning migration. The entrance gate was the only gate that was adjusted throughout the season. This gate was adjusted manually maintaining a 0.5-ft to 0.8-ft differential between the surface water elevation downstream of the entrance and the water elevation in the diffuser area of the fish ladder. This setting resulted in an average velocity of 4 ft/sec to 6 ft/sec at the entrance to the ladder. The 7-ft wide stop gate, located between the weir and the fish ladder entrance, remained closed during the entire period of operation.

Excluding the first and last day of manned operation, the Fishway was typically staffed by one person. This person, a biologist or technician, adjusted the position of the entrance gate, counted and recorded the number of fish that passed through the ladder hourly, removed debris from the exit of the ladder, made visual observations of fish activity and movement in and through the ladder, and made observations once each day below the Main Dam. These individuals also recorded water elevations several times each day on staff gauges located throughout the Fishway.

After manned Fishway operation ended on 6 June, the South fixed wheel gate was closed. On 7 June, the fish ladder and North fixed wheel gate were set to deliver a minimum flow of 400 cfs into the East Channel. Except for a short in early October (4 to 9 October) when the Fishway was closed to inspect the ladder's diffuser chamber, the Fishway remained open through 28 November and was set to deliver a minimum stream flow of at least 400 cfs to the East Channel.

Fish Counts

Fish that passed through the ladder were identified to species and enumerated as they passed the counting window by a biologist and/or technician. A description of the procedures used to count fish is described in prior annual operating reports (Kleinschmidt 2000 and 2002). Fish passage by the viewing window was controlled by opening or closing an aluminum grating gate with an electric hoist that was controlled from inside the viewing room. The stop gate was opened each morning at 0800 hrs and closed nightly at 1600 hrs or 1700 hrs when the Fishway was manned. Occasionally, it was closed for brief periods of time as needed each day to enable personnel manning the Fishway to remove debris from screens and the fishway exit other conduct other activities. In addition, in an effort to improve viewing, the adjustable crowder screen was adjusted as needed to allow all fish that passed to be observed. Gate settings on the days the Fishway was manned varied from 6 in. to 24 in.

As in previous seasons, fish passage data was entered on a field data sheet and uploaded into a computer. Files were uploaded each evening, checked and corrected as necessary. Data reporting was PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheets. Passage data and operational conditions were supplied electronically to YHPC's on-site coordinator/manager and other appropriate YHPC personnel on a daily basis. Passage information was subsequently provided electronically by YHPC personnel to members of the FPTAC.

RESULTS

Spring Fishway Operation

Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 97,990 fish of 23 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (87,068) was the dominant fish species passed and comprised almost 89% of the fish passed. Some 224 American shad were counted as they passed through the ladder. Other predominant fishes passed included quillback (4,104), channel catfish (2,858), shorthead redhorse (1,491), carp (669) walleye (602) and smallmouth bass (553). Passage varied daily and ranged from 103 fish on 25 April to 8,002 fish on 12 May when 8.2% of the season total was passed.

American Shad Passage

A total of 224 American shad passed upstream through the ladder in 2012. Some 71 shad passed in April and 153 shad passed in May. No shad passed in June. Peak shad passage occurred on 26 April when some 68 shad (30.4% of season total) passed.

American shad were collected and passed at water temperatures of 50.9°F to 76.1°F, River flows of 25,600 cfs to 94,900 cfs and East Channel flows of 3,100 cfs to 16,000 cfs (Tables 2 and 3, Figures 3 and 4). Passage during April occurred at Rivers flows that varied from 32,100 to 38,800. Water temperature during this period ranged from 50.9° F to 57.2° F and East Channel flows varied 2,133 cfs to 5,240 cfs. Passage during May occurred at River flows that increased from 26,300 cfs to 94,900 cfs before declining to 28,600 on 26 May. Water temperature during this period ranged from 59.9°F to 76.1°F and East Channel flows varied from 3,100 cfs to 16,000 cfs

The hourly passage of American shad through the fish ladder is given in Table 4. Over 41% of the shad (93) passed between 0800 hrs and 1059 hrs; hourly passage varied from no shad to 9 shad. Some 78 shad passed from 1100 to 1359 hrs. A total of 53 shad passed between 1400 hrs and the end of manned operation each day (1600 and/or 1700 hrs). The peak hourly passage of shad (18) occurred on 26 April between 1400 hrs and 1459 hrs.

Per the FPOP, counting was extended hourly on 1 of 43 days that the fishway was manned. On 26 April, 2 shad passed between 1600 hrs and 1700 hrs.

Other Alosids

No other alosids (alewife, blueback herring and hickory shad) were observed passing through the ladder (Table 1).

Observations

Once each day, visual observations of fish activity were made on a random basis below the Main Dam. On several occasions several gizzard shad were observed and a few were observed trying to swim over the Main Dam. No shad or other alosids were observed below the Main Dam.

Observations were made at the "weir cut" several times each day in an attempt to see if American shad or other fishes passed upstream through this section of the Fishway. On several occasions carp, quillback and gizzard shad were observed trying to swim over the 67 ft. weir. However, no fish were observed trying to swim through the fixed wheel gates.

Downstream Fish Passage

As in previous years, YHPC anticipated making periodic observations for adult shad in the forebay and opening the trash gate if/when large numbers of adults were observed. They also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC.

Adult Passage

In addition to the daily observations, a limited number of American Shad were tagged with radio transmitters this year and released near Harrisburg. In addition to physical observations, a detector was used to find the tagged Shad. No physical observations of post-spawned adult American shad were noted by Station personnel that made periodic observations of the forebay area between 26 April and 02 August 2012. During this period (26 April to 02 August) station personnel opened the trash sluice opened on 24 days. Although no adult shad were observed using the sluice gate, results obtained during the 2012 adult shad downstream passage radio telemetry study showed that 73% of the 59 shad that passed downstream of the project did not pass through the projects turbines. Thirty (50.8%) of the radio tagged shad passed over the Main Dam and 12 (20.3%) tagged shad passed downstream of the project passed through the sluice gate.

Juvenile Passage

The Juvenile Downstream Passage Protocol provides for:

- Monitoring the forebay to determine when outmigrating juveniles arrive at the project
- Starting "Downstream Operation" when juveniles arrive at York Haven; Downstream Operation begins each evening at sunset and continue until about 11:30 p.m. Downstream Operation includes:
    - ➢Turning on temporary lighting at the trash sluiceway and opening the sluiceway
    - ➢Operating only Units 1-6 when river flow is insufficient for operation of any of the remaining units
    - ➢Operating Units 7-20 only when river flow exceeds the hydraulic capacity of available Units 1-6; the operating priority for Units 7-20 is Unit 7, Unit 8, Unit 9 etc.
- Monitoring and sampling in the forebay as river water temperatures drop and/or River flows increase to determine when the juvenile shad emigration has ended for the season
- Ceasing "Downstream Operation" at the end of the run, in consultation with members of the FPTAC.

In accordance with the protocol, monitoring of the York Haven forebay for the presence of juvenile American shad began on 10 September when water temperature was 74.0°F and River flow at Harrisburg was 4,110 cfs (Figure 5). Monitoring continued through 16 November. River flows from 10 September to 29 October, were less than station capacity, averaged 10,155 cfs and ranged from 5,850 cfs to 16,700 cfs. Heavy rain from hurricane Sandy on 29 and 30 October caused River flows to increase; flows peaked at 108,000 cfs on 1 November. Between 2 November and 16 November River flows declined and ranged from to 93,800 cfs to 18,400 cfs. Average daily water temperature during the observation period (10 September to 16 November) dropped a total of 30 degrees and ranged from a high of 74.0°F to a low of 44.0°F.

The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that typically monitored the forebay twice daily. Observations were typically made daily by station personnel between 0700 hrs and 0800 hrs and within one hour of dusk. In addition, cast netting was conducted and observations in the forebay were made at dusk by a Kleinschmidt biologist on 18 and 24 October that supported and verified observations made by station personnel. Weekly cast netting and observations by Kleinschmidt's biologist were stopped after rains from hurricane Sandy pushed river flows to 108,000 cfs which resulted in heavy spill at York Haven.

Given that fish activity was non-existent there was no need to implement "Downstream Operation". As a means of ensuring the downstream migration wasn't occurring without being noticed routine contact was maintained with others conducting juvenile shad sampling programs in the lower River. According to personnel conducting these sampling programs juvenile shad abundance was low in 2012. Only a few juveniles were collected in the River, one juvenile shad were collected at Columbia and no juveniles were collected at City Island while haul seining in 2012.

LITERATURE CITED

Kleinschmidt. 2000. Summary of operation at the York Haven Fishway in 2000. Prepared for York Haven Power Company, GPU Energy by Kleinschmidt, Strasburg, Pennsylvania. 21 pp.

Kleinschmidt. 2002. Summary of operation at the York Haven Fishway in 2001. Prepared for York Haven Power Company, GPU Energy/FirstEnergy by Kleinschmidt, Strasburg, Pennsylvania. 21 pp.

TABLES

Table 1. Summary of the daily number of fish that passed by the York Haven Hydroelectric Project through the serpentine vertical notch ladder at the East Channel Dam in 2012.

Date	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May	2-May	3-May	4-May
Observation Time (hrs.)	8	8	9	8	8	8	8	8	8	8
Water Temperature (°F)	54.5	54.5	57.2	50.9	53.6	53.6	57.2	59.9	59.9	59
American shad		68	2	1				11	3	6
Alewife										
Blueback herring										
Gizzard shad	41	291	1,255	1,317	662	946	906	1,374	1,336	859
Hickory shad										
Striped bass		**2**	1	1						
White perch										
American eel										
Rainbow trout										
Brown trout										
Brook trout										
Muskellunge										
Carp		6	7	2		11	15	35	25	14
Quillback	24	799	186	10	5	52	205	416	287	505
White sucker	4	21	2			2		8	3	2
Shorthead redhorse	20	124	43	16	5	59	101	186	156	290
White catfish										
Yellow bullhead										
Brown bullhead										
Channel catfish	5	61	44	11	4	6	32	155	100	109
Rock bass							36			
Redbreast sunfish										
Green sunfish										
Pumpkinseed										
Bluegill										
Smallmouth bass		2	2			3		129	97	83
Largemouth bass								2		
Yellow perch										
Walleye	9	60	17	3	4	18	34	79	61	118
Northern hog sucker										
Fallfish										
Flathead catfish										
Striped bass hybrid			6	3	1	2	1	1		
Tiger muskie										
TOTAL	**103**	**1,434**	**1,565**	**1,364**	**681**	**1,099**	**1,330**	**2,396**	**2,068**	**1,986**

Table 1. (continued)

Date	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May
Observation Time (hrs.)	8	8	8	8	8	8	8	8	8	8
Water Temperature (^{o}F)	64.4	66.2	62.6	58.1	58.1	61.3	61.7	61.7	62.6	63.5
American shad	16	25	11	12	14	3	0	13	11	3
Alewife										
Blueback herring										
Gizzard shad	1,157	1,470	1,619	2,573	5,113	5,462	6,711	7,893	7,636	5,302
Hickory shad										
Striped bass	1									
White perch										
American eel										
Rainbow trout	1									
Brown trout				1	1				2	
Brook trout										
Muskellunge										
Carp	14	56	7	8		4	1	15	2	10
Quillback	769	116	28	88	122	5		21	39	30
White sucker	1	1						1		1
Shorthead redhorse	253	48	18	66	58	1	1	1	6	6
White catfish										
Yellow bullhead										
Brown bullhead	1									
Channel catfish	515	134	76	66	74	49	25	58	65	19
Rock bass										
Redbreast sunfish	1									
Green sunfish										
Pumpkinseed	1									
Bluegill	2									
Smallmouth bass	65	2		4	3				6	14
Largemouth bass										
Yellow perch										
Walleye	118	10	2	8	17				3	6
Northern hog sucker										
Fallfish										
Flathead catfish										
Striped bass hybrid	2		1	1	1					3
Tiger muskie										
TOTAL	**2,917**	**1,862**	**1,762**	**2,827**	**5,403**	**5,524**	**6,738**	**8,002**	**7,770**	**5,394**

Table 1. (continued

Date	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May
Observation Time (hrs.)	8	8	8	8	8	8	8	8	8	8
Water Temperature (^oF)	64.4	64.4	63.5	64.4	66.2	66.2	67.1	67.1	68.9	69.8
American shad	10	2		1	2	1	2		1	
Alewife										
Blueback herring										
Gizzard shad	2,513	602	1,546	6,739	4,041	2,148	874	871	617	203
Hickory shad										
Striped bass										
White perch										
American eel										
Rainbow trout										
Brown trout								1		
Brook trout										
Muskellunge										
Carp	7	5	2	8	23	42	21	15	25	11
Quillback	86	9	1	5		6	30	14	14	5
White sucker							1			
Shorthead redhorse	13	1			1	1		2	2	5
White catfish										
Yellow bullhead										
Brown bullhead										
Channel catfish	26	59	25	28	25	15	14	4	14	9
Rock bass										
Redbreast sunfish										
Green sunfish										
Pumpkinseed	1									
Bluegill						1	3		1	
Smallmouth bass	15					1		8	44	4
Largemouth bass										
Yellow perch										
Walleye	21			1	1	1	1		2	1
Northern hog sucker										
Fallfish										
Flathead catfish		15	30	10	2	1	1	23		
Striped bass hybrid		2			1					
Tiger muskie		1								
TOTAL	**2,692**	**696**	**1,604**	**6,792**	**4,096**	**2,217**	**947**	**938**	**720**	**238**

Table 1. (continued)

Date	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun
Observation Time (hrs.)	8	8	8	8	8	8	8	8	8	8
Water Temperature (^{o}F)	72	72	74.3	74.3	76.1	76.1	76.1	73.5	69.8	69.8
American shad	1	1	2	1	1					
Alewife										
Blueback herring										
Gizzard shad	97	1,185	442	909	1,144	1,392	1,173	1,047	163	638
Hickory shad										
Striped bass										
White perch										
American eel										
Rainbow trout		1								
Brown trout										
Brook trout										
Muskellunge									1	
Carp	18	38	40	15	42	49	16	24	9	1
Quillback	3	88	22	25	48	3	3	32	3	
White sucker										
Shorthead redhorse		2			5		1			
White catfish										
Yellow bullhead										
Brown bullhead										
Channel catfish	4	67	37	171	377	151	60	75	33	19
Rock bass										
Redbreast sunfish		1								
Green sunfish					1		1			
Pumpkinseed				1	1		1	1		
Bluegill				1						
Smallmouth bass		26	30	9	6					
Largemouth bass										
Yellow perch										
Walleye			7							
Northern hog sucker										
Fallfish										
Flathead catfish		4	1	4	9	107	9	1	6	46
Striped bass hybrid										
Tiger muskie										
TOTAL	**123**	**1,413**	**581**	**1,136**	**1,634**	**1,702**	**1,264**	**1,180**	**215**	**704**

Table 1. (continued)

Date	4-Jun	5-Jun	6-Jun	Total
Observation Time (hrs.)	8	8	8	281
Water Temperature (°F)	68	67.1	68	
American shad				224
Alewife				0
Blueback herring				0
Gizzard shad	2,665	1,583	553	87,068
Hickory shad				0
Striped bass				5
White perch				0
American eel				0
Rainbow trout				2
Brown trout				5
Brook trout				0
Muskellunge				1
Carp	15	2	9	669
Quillback				4,104
White sucker				47
Shorthead redhorse				1,491
White catfish				0
Yellow bullhead				0
Brown bullhead				1
Channel catfish	14	8	15	2,858
Rock bass				36
Redbreast sunfish				2
Green sunfish				2
Pumpkinseed		1		7
Bluegill				8
Smallmouth bass				553
Largemouth bass				2
Yellow perch				0
Walleye				602
Northern hog sucker				0
Fallfish				0
Flathead catfish	1	3	4	277
Striped bass hybrid				25
Tiger muskie				1
TOTAL	2,695	1,597	581	97,990

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the dam, water temperature and East channel and fishway water elevations during

	River	East	Main	Water				Stop	Elevation (ft)					
	Flow	Channel	Channel	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow	Flow	(^{o}F)	Avg.	Min.	Max.	Gate	Avg	Mi	Max	Avg	Min	Max.
25-Apr	26,600	2,200	24,400	54.5	18	12	24	closed	279.	27	279.	273.	273.	273.6
26-Apr	40,800	4,000	36,800	54.5	13	8	18	closed	279.	27	279.	274.	274.	274.7
27-Apr	44,000	5,200	38,800	57.2	15	14	16	closed	280.	28	280.	275.	275.	275.1
28-Apr	40,900	4,300	36,600	50.9	24	24	24	closed	279.	27	279.	274.	274.	274.8
29-Apr	38,200	4,300	33,900	53.6	24	24	24	closed	279.	27	279.	274.	274.	274.6
30-Apr	35,400	3,300	32,100	53.6	24	24	24	closed	279.	27	279.	274.	274.	274.4
1-May	32,200	3,200	29,000	57.2	24	24	24	closed	279.	27	279.	274.	274.	274.2
2-May	29,400	3,100	26,300	59.9	24	24	24	closed	279.	27	279.	274.	274.	274.0
3-May	28,700	3,100	25,600	59.9	24	24	24	closed	279.	27	279.	274.	274.	274.0
4-May	30,200	3,000	27,200	59.0	24	24	24	closed	279.	27	279.	274.	274.	274.9
5-May	46,600	5,200	41,400	64.4	22	20	24	closed	280.	28	280.	275.	275.	275.1
6-May	47,400	5,000	42,400	66.2	24	24	24	closed	279.	27	279.	274.	274.	274.9
7-May	51,000	5,200	45,800	62.6	20	20	20	closed	280.	28	280.	275.	275.	275.4
8-May	44,400	5,200	39,200	58.1	24	24	24	closed	280.	27	280.	275.	275.	275.0
9-May	47,900	5,200	42,700	58.1	12	12	12	closed	280.	28	280.	275.	275.	275.0
10-May	59,700	6,200	53,500	61.3	8	8	8	closed	280.	28	280.	275.	275.	275.9
11-May	67,200	10,900	56,300	61.7	6	6	6	closed	280.	28	280.	276.	276.	276.5
12-May	62,500	9,000	53,500	61.7	8	8	8	closed	280.	28	280.	276.	276.	276.8
13-May	54,200	7,000	47,200	62.6	10	10	10	closed	280.	28	280.	275.	275.	275.7
14-May	46,600	5,200	41,400	63.5	16	16	16	closed	280.	28	280.	275.	275.	275.0
15-May	49,200	5,200	44,000	64.4	20	20	20	closed	280.	28	280.	275.	275.	275.1
16-May	94,900	16,000	78,900	64.4	8	8	8	closed	281.	28	281.	278.	277.	278.5
17-May	101,000	16,000	85,000	63.5	8	8	8	closed	281.	28	281.	278.	278.	278.4
18-May	83,400	13,000	70,400	64.4	8	8	8	closed	281.	28	281.	277.	277.	277.5
19-May	64,700	10,900	53,800	66.2	10	10	10	closed	280.	28	280.	276.	276.	276.9
20-May	52,300	6,200	46,100	66.2	12	12	12	closed	280.	28	280.	275.	275.	275.5
21-May	43,400	5,000	38,400	67.1	12	12	12	closed	279.	27	280.	275.	274.	275.0
22-May	38,600	4,300	34,300	67.1	18	18	18	closed	279.	27	279.	274.	274.	274.7
23-May	36,200	4,000	32,200	68.9	18	18	18	closed	279.	27	279.	274.	274.	274.6
24-May	38,000	4,000	34,000	69.8	18	18	18	closed	279.	27	279.	274.	274.	274.5
25-May	36,300	4,000	32,300	72.0	24	24	24	closed	279.	27	279.	274.	274.	274.5
26-May	32,300	3,700	28,600	72.0	24	24	24	closed	279.	27	279.	274.	274.	274.1
27-May	32,000	3,100	28,900	74.3	24	24	24	closed	279.	27	279.	274.	274.	274.1
28-May	44,100	5,000	39,100	74.3	24	24	24	closed	279.	27	279.	274.	274.	274.5
29-May	42,300	5,200	37,100	76.1	18	18	18	closed	280.	28	280.	274.	274.	274.8
30-May	41,200	5,000	36,200	76.1	15	12	12	closed	279.	27	278.	274.	274.	274.7
31-May	45,200	5,000	40,200	76.1	18	18	18	closed	279.	27	280.	274.	374.	274.9
1-Jun	36,900	4,000	32,900	73.5	18	18	18	closed	279.	27	279.	274.	274.	274.7
2-Jun	45,600	4,300	41,300	69.8	14	12	18	closed	279.	27	280.	274.	274.	275.1
3-Jun	57,700	8,300	49,400	69.8	8	8	8	closed	280.	28	280.	275.	275.	275.9
4-Jun	51,100	6,200	44,900	68.0	12	12	12	closed	280.	28	280.	275.	275.	275.4
5-Jun	46,900	5,600	41,300	67.1	18	18	18	closed	280.	28	280.	275.	275.	275.1
6-Jun	41,700	5,000	36,700	68.0	18	18	18	closed	279.	27	279.	274.	274.	274.8

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2012.

	River	Elevation (ft)																				
	Flow	Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
Date	(cfs)	Avg.	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.
25-Apr	26,600	279.0	279.0	279.1	273.5	273.5	273.6	274.2	274.1	274.3	277.4	277.3	277.5	278.6	278.4	278.8	277.3	277.3	277.4	278.3	278.4	278.5
26-Apr	40,800	279.7	279.6	279.8	274.5	274.3	274.7	275.0	274.8	275.2	277.9	277.8	277.9	279.4	29.3	279.5	277.5	277.5	277.6	279.3	279.3	279.4
27-Apr	44,000	280.0	280.0	280.0	275.0	275.0	275.1	275.5	275.4	275.5	278.1	278.0	278.2	279.7	279.6	279.7	277.9	277.8	277.9	279.5	279.5	279.5
28-Apr	40,900	279.8	279.8	279.8	274.8	274.8	274.8	275.3	275.3	275.3	278.0	278.0	278.0	279.5	279.5	279.5	277.8	277.8	277.8	279.3	279.3	279.3
29-Apr	38,200	279.8	279.8	279.8	274.6	274.5	274.6	275.1	275.0	275.1	278.0	277.9	278.0	279.5	279.4	279.5	277.8	277.8	277.9	279.3	279.2	279.3
30-Apr	35,400	279.6	279.6	279.6	274.3	274.3	274.4	274.9	274.9	275.0	277.9	277.8	277.9	279.3	279.3	279.3	277.6	277.6	277.6	279.2	279.2	279.2
1-May	32,200	279.5	279.5	279.5	274.2	274.2	274.2	274.9	274.8	274.9	277.8	277.8	277.9	279.2	279.2	279.2	277.6	277.6	277.7	279.0	279.0	279.1
2-May	29,400	279.4	279.4	279.4	274.0	274.0	274.0	274.6	274.6	274.6	277.7	277.7	277.7	279.0	279.0	279.0	277.4	277.4	277.4	278.8	278.8	278.8
3-May	28,700	279.4	279.4	279.5	274.0	274.0	274.0	274.6	274.5	274.6	277.8	277.7	277.9	279.0	279.0	279.1	277.6	277.5	277.6	278.8	278.8	278.9
4-May	30,200	279.3	279.3	279.3	274.8	274.9	274.9	274.4	274.3	274.5	277.7	277.7	277.8	278.9	278.9	279.0	277.5	277.4	277.5	278.9	278.9	278.9
5-May	46,600	280.0	280.0	280.1	275.0	275.0	275.1	275.5	275.5	275.6	278.0	278.0	278.1	279.9	279.9	280.0	280.1	277.8	277.8	277.9	279.6	279.7
6-May	47,400	279.9	279.9	279.9	274.9	274.9	274.9	275.5	275.5	275.5	278.2	278.0	278.3	279.7	279.7	279.7	277.9	277.8	277.9	279.6	279.6	279.6
7-May	51,000	280.0	280.0	280.1	275.4	275.4	275.4	275.7	275.7	275.7	278.4	278.3	278.4	280.1	280.0	280.0	278.0	278.0	278.0	279.8	279.8	280.0
8-May	44,400	280.0	279.9	280.0	275.0	275.0	275.0	275.5	275.5	275.5	278.1	278.1	278.2	279.8	279.7	279.8	278.0	278.0	278.0	279.5	279.5	279.5
9-May	47,900	280.0	280.0	280.0	275.0	275.0	275.0	275.5	275.5	275.5	278.2	278.1	278.3	279.8	279.7	279.8	277.8	277.8	277.8	279.6	279.6	279.6
10-May	59,700	280.2	280.2	280.2	275.8	275.7	275.9	276.3	276.2	276.4	278.6	278.5	278.7	280.2	280.2	280.2	278.0	278.0	278.0	280.1	280.1	280.1
11-May	67,200	280.7	280.7	280.7	276.5	276.5	276.5	277.0	277.0	277.0	278.9	278.7	278.9	280.5	280.5	280.5	278.5	278.5	278.5	280.4	280.4	280.4
12-May	62,500	280.6	280.6	280.6	276.8	276.8	276.8	276.8	276.8	276.8	278.6	278.6	278.6	280.4	280.4	280.4	278.3	278.3	278.3	280.2	280.2	280.3
13-May	54,200	280.3	280.3	280.3	275.7	275.7	275.7	276.4	276.4	276.4	278.4	278.4	278.4	280.1	280.0	280.1	278.1	278.1	278.2	280.0	280.0	280.0
14-May	46,600	280.0	280.0	280.0	275.0	275.0	275.0	275.7	275.7	275.7	278.1	278.1	278.1	279.8	279.8	279.8	278.0	278.0	278.0	279.7	279.7	279.7
15-May	49,200	280.0	280.0	280.1	275.0	275.0	275.1	275.7	275.7	275.8	278.3	278.3	278.4	279.8	279.8	279.8	278.0	278.0	278.0	279.7	279.7	279.7
16-May	94,900	281.6	281.1	281.7	278.2	277.4	278.5	278.4	277.9	279.0	279.5	279.0	279.8	281.4	281.0	281.6	279.2	278.8	279.4	281.2	280.8	281.5
17-May	101,000	281.6	281.6	281.7	278.3	278.2	278.4	279.0	278.9	279.0	279.6	279.5	279.7	281.4	281.4	281.5	279.3	279.2	279.4	281.4	281.3	281.4
18-May	83,400	281.2	281.1	281.3	277.4	277.3	277.5	277.0	277.8	278.0	279.1	279.0	279.2	281.1	281.1	281.2	278.7	278.6	278.9	280.9	280.9	281.0
19-May	64,700	280.7	280.7	280.8	276.8	276.8	276.9	276.8	277.8	276.8	278.4	278.4	278.5	280.4	280.4	280.5	278.3	278.3	278.4	280.3	280.3	280.4
20-May	52,300	280.2	280.2	280.3	275.4	275.4	275.5	275.9	275.9	276.0	278.7	278.7	278.8	280.0	280.0	280.1	278.0	277.9	278.0	279.9	279.8	279.9
21-May	43,400	279.9	279.8	280.0	275.0	274.9	275.0	275.6	275.5	275.6	278.2	278.1	278.3	279.7	279.7	279.7	277.8	277.8	277.8	279.6	279.5	279.5
22-May	38,600	279.8	279.8	279.8	274.7	274.7	274.7	275.4	275.4	275.4	278.0	278.0	278.0	279.5	279.5	279.5	277.8	277.8	277.8	279.4	279.4	279.4
23-May	36,200	279.7	279.7	279.7	274.6	274.6	274.6	275.3	275.3	275.3	277.9	277.9	277.9	279.4	279.4	279.4	277.6	277.6	277.6	279.3	279.3	279.3
24-May	38,000	279.7	279.7	279.7	274.5	274.5	274.5	272.3	272.3	272.3	278.0	278.0	278.0	279.5	279.5	279.5	277.7	277.7	277.7	279.5	279.5	279.5
25-May	36,300	279.7	279.7	279.7	274.5	274.5	274.5	275.4	275.4	275.4	278.0	278.0	278.0	279.5	279.5	279.5	277.7	277.7	277.7	279.5	279.5	279.5
26-May	32,300	279.6	279.6	279.6	274.1	274.1	274.1	275.3	275.3	275.3	277.9	277.9	277.9	279.4	279.4	279.4	277.6	277.6	277.6	279.3	279.3	279.3
27-May	32,000	279.4	279.4	279.4	274.1	274.1	274.1	275.0	275.0	275.0	277.7	277.6	277.7	279.1	279.1	279.1	277.5	277.5	277.5	279.1	279.0	279.1
28-May	44,100	279.9	279.8	279.9	274.5	274.4	274.5	275.5	275.4	275.5	278.1	278.0	278.1	279.4	279.4	279.4	277.8	277.8	277.8	279.4	279.4	279.4
29-May	42,300	280.0	280.0	280.0	274.8	274.8	274.8	275.6	275.6	275.6	278.1	278.1	278.1	279.6	279.5	279.6	277.8	277.8	277.8	279.4	279.4	279.4
30-May	41,200	279.9	279.8	278.9	274.7	274.6	274.7	275.6	275.5	275.6	278.1	278.0	278.1	279.6	279.5	279.6	277.8	277.7	277.8	279.4	279.3	279.4
31-May	45,200	279.9	279.9	280.0	274.8	374.8	274.9	275.6	275.6	275.7	277.9	277.9	278.0	279.8	279.8	279.9	277.7	277.7	277.8	279.6	279.6	279.7
1-Jun	36,900	279.7	279.7	279.8	274.6	274.6	274.7	275.3	275.3	275.4	278.0	277.9	278.0	279.5	279.4	279.6	277.0	277.7	277.7	279.4	279.4	279.5
2-Jun	45,600	279.8	279.7	280.0	274.9	274.6	275.1	275.6	275.3	275.8	278.0	277.9	278.1	279.6	279.4	279.7	277.8	277.7	278.0	279.5	279.3	279.7
3-Jun	57,700	280.5	280.5	280.5	275.9	275.9	275.9	276.4	276.4	276.4	278.5	278.5	278.5	280.3	280.3	280.3	278.2	278.2	278.2	280.2	280.2	280.2
4-Jun	51,100	280.2	280.2	280.2	275.4	275.4	275.4	275.9	275.9	276.0	278.3	278.3	278.3	280.0	280.0	280.0	278.0	278.0	278.0	279.9	279.9	279.9
5-Jun	46,900	280.1	280.1	280.1	275.1	275.1	275.1	275.8	275.7	275.8	278.2	278.2	278.2	279.9	279.8	279.9	278.0	278.0	278.0	279.8	279.7	279.8
6-Jun	41,700	279.9	279.9	279.9	274.8	274.8	274.8	275.5	275.5	275.5	278.1	278.1	278.1	279.7	279.7	279.7	277.8	277.8	277.8	279.6	279.6	279.6

Table 4. Hourly summary of American shad passage through the serpentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2012.

Date	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May	2-May	3-May
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1700	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)									
0800 - 0859	0	3	0	0	0	0	0	6	1
0900 - 0959	0	9	0	0	0	0	0	2	0
1000 - 1059	0	4	1	0	0	0	0	0	0
1100 - 1159	0	10	0	0	0	0	0	1	0
1200 - 1259	0	2	0	1	0	0	0	0	0
1300 - 1359	0	6	0	0	0	0	0	0	2
1400 - 1459	0	18	1	0	0	0	0	1	0
1500 - 1559	0	14	0	0	0	0	0	1	0
1600 - 1700	-	2	-	-	-	-	-	-	-
Total Catch	**0**	**68**	**2**	**1**	**0**	**0**	**0**	**11**	**3**

Date	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May
Observation Time (Start)	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**
Observation Time (End)	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**
Military Time (Hours)									
0800 - 0859	2	4	6	3	5	6	2	0	1
0900 - 0959	1	0	5	1	2	2	1	0	0
1000 - 1059	1	2	2	3	1	3	0	0	2
1100 - 1159	0	5	3	0	3	1	0	0	1
1200 - 1259	2	3	3	2	1	0	0	0	2
1300 - 1359	0	1	3	1	0	2	0	0	4
1400 - 1459	0	1	3	1	0	0	0	0	2
1500 - 1559	0	0	0	0	0	0	0	0	1
1600 - 1700	-	-	-	-	-	-	-	-	-
Total Catch	**6**	**16**	**25**	**11**	**12**	**14**	**3**	**0**	**13**

Table 4. ***(continued)***

Date	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)									
0800 - 0859	1	0	1	0	0	0	0	0	0
0900 - 0959	1	0	0	2	0	0	1	0	0
1000 - 1059	2	0	1	0	0	0	0	0	0
1100 - 1159	4	0	1	0	0	0	0	0	0
1200 - 1259	2	0	4	0	0	1	0	1	0
1300 - 1359	0	1	1	0	0	0	0	0	1
1400 - 1459	1	0	1	0	0	0	1	0	1
1500 - 1559	0	2	1	0	0	0	0	0	0
1600 - 1700	-	-	-	-	-	-	-	-	-
Total Catch	**11**	**3**	**10**	**2**	**0**	**1**	**2**	**1**	**2**

Date	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May
Observation Time (Start)	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**
Observation Time (End)	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**
Military Time (Hours)									
0800 - 0859	0	0	0	0	0	0	0	0	0
0900 - 0959	0	0	0	1	0	0	0	1	0
1000 - 1059	0	1	0	0	0	0	0	0	0
1100 - 1159	0	0	0	0	1	0	0	0	0
1200 - 1259	0	0	0	0	0	1	0	0	0
1300 - 1359	0	0	0	0	0	0	1	0	0
1400 - 1459	0	0	0	0	0	1	0	0	0
1500 - 1559	0	0	0	0	0	0	0	0	0
1600 - 1700	-	-	-	-	-	-	-	-	-
Total Catch	**0**	**1**	**0**	**1**	**1**	**2**	**1**	**1**	**0**

Table 4. ***(continued)***

Date	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun		
Observation Time (Start)	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**	**0800**		
Observation Time (End)	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**1600**	**Total**	%
Military Time (Hours)									
0800 - 0859	0	0	0	0	0	0	0	**41**	**18.3**
0900 - 0959	0	0	0	0	0	0	0	**29**	**12.9**
1000 - 1059	0	0	0	0	0	0	0	**23**	**10.3**
1100 - 1159	0	0	0	0	0	0	0	**30**	**13.4**
1200 - 1259	0	0	0	0	0	0	0	**25**	**11.2**
1300 - 1359	0	0	0	0	0	0	0	**23**	**10.3**
1400 - 1459	0	0	0	0	0	0	0	**32**	**14.3**
1500 - 1559	0	0	0	0	0	0	0	**19**	**8.5**
1600 - 1700	-	-	-	-	-	-	-	**2**	**0.9**
Total Catch	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**224**	**100.0**

Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.

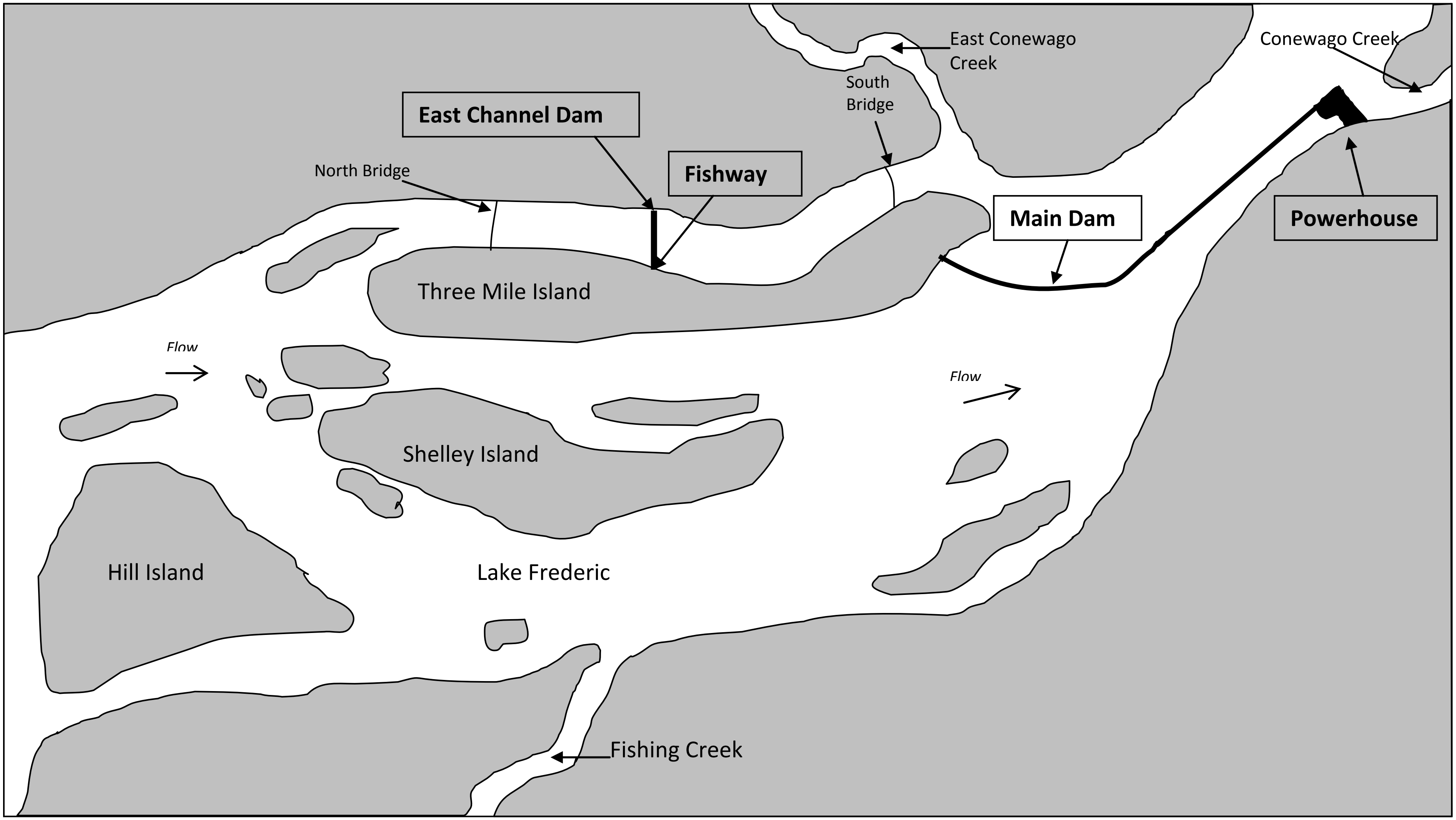


Figure 2. General Arrangement - York Haven Fishway.

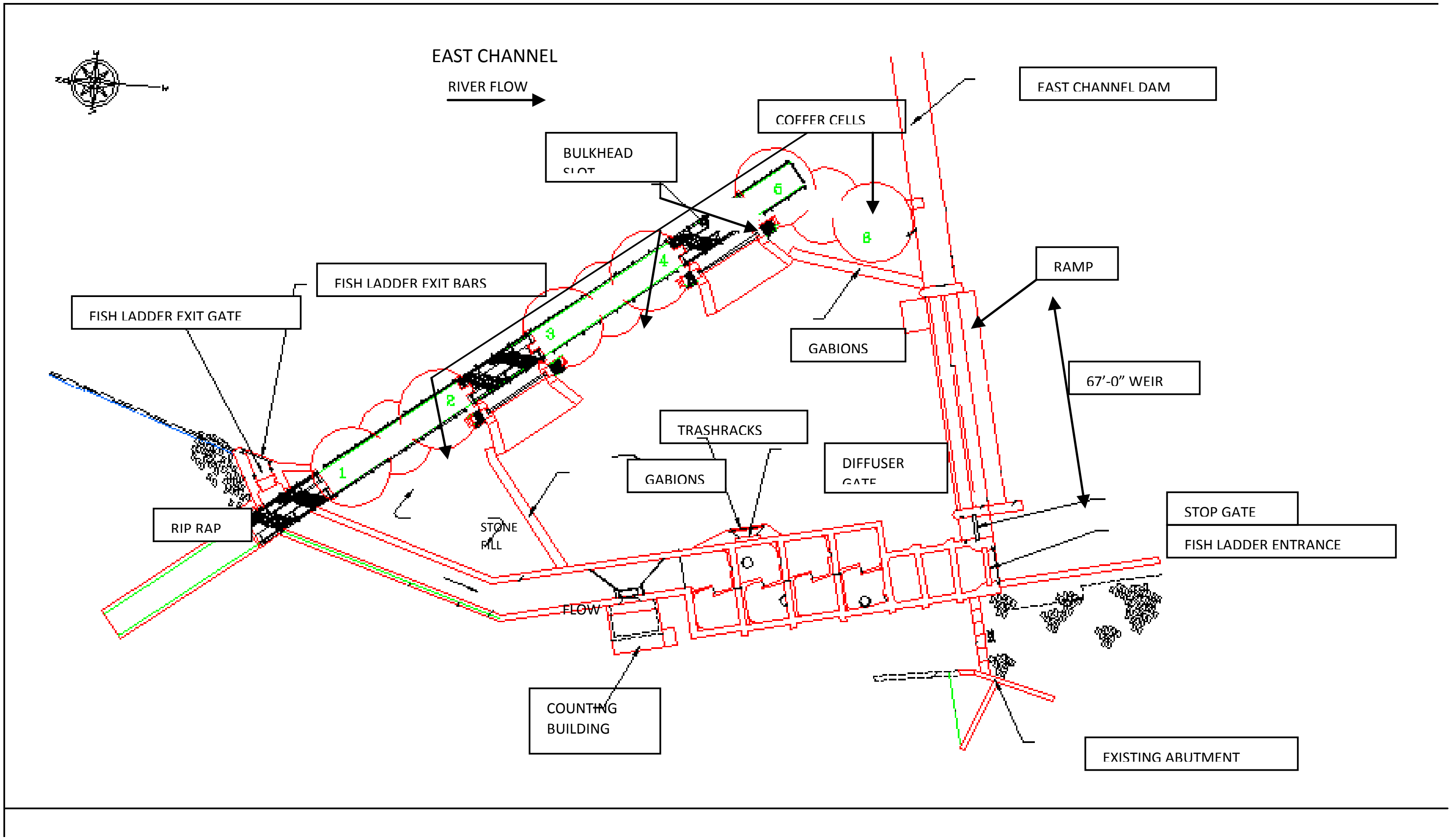


Figure 3. Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2012

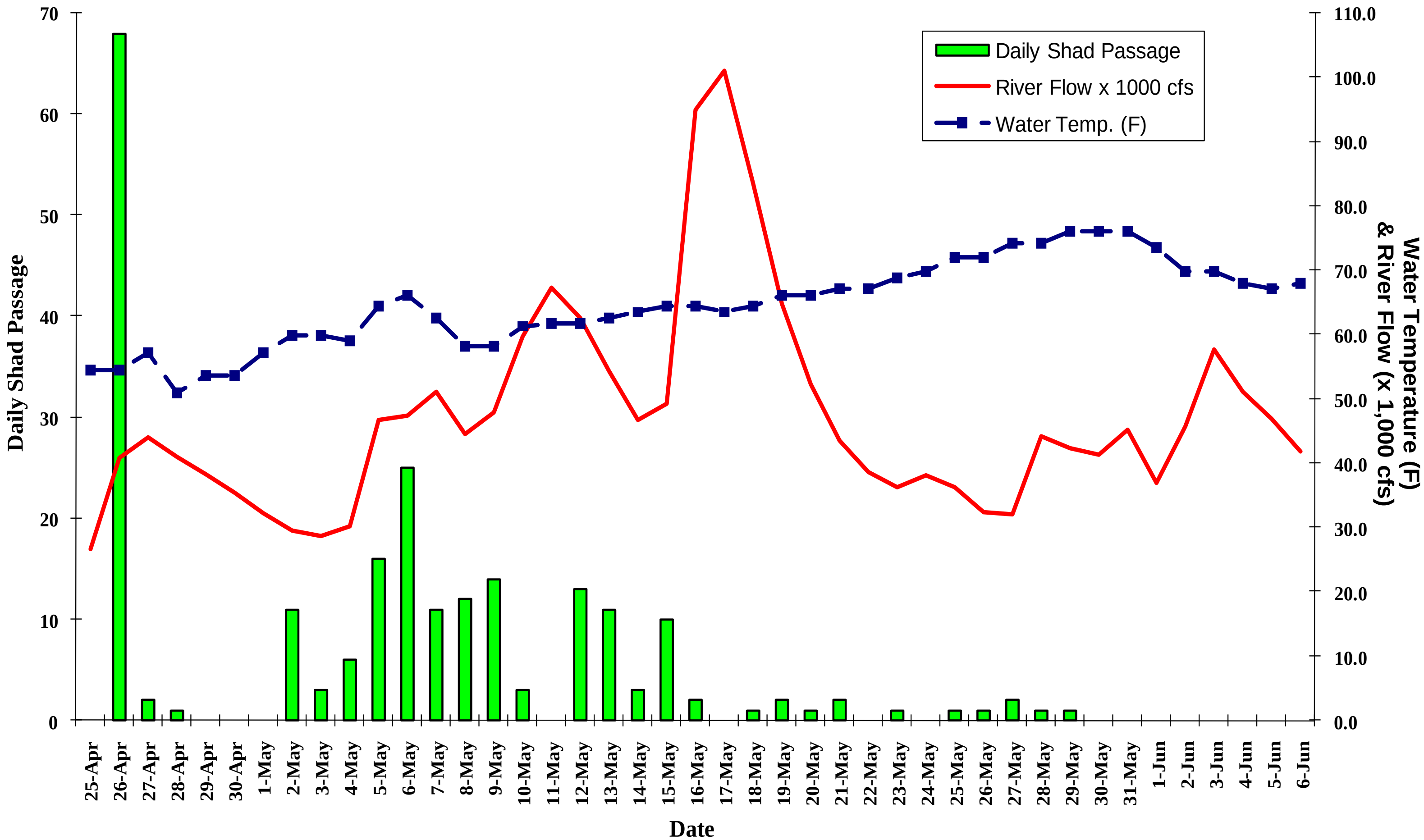


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2012

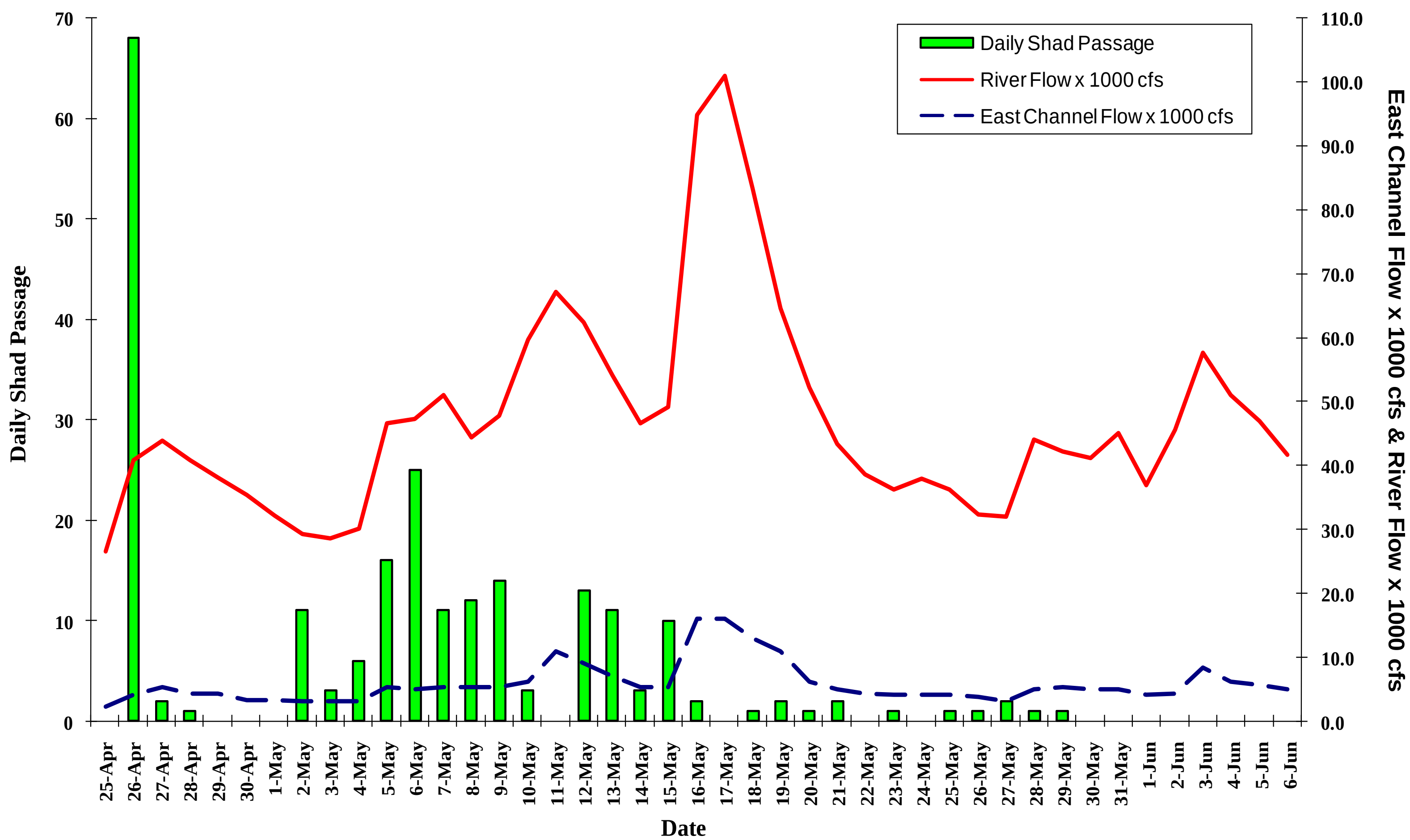
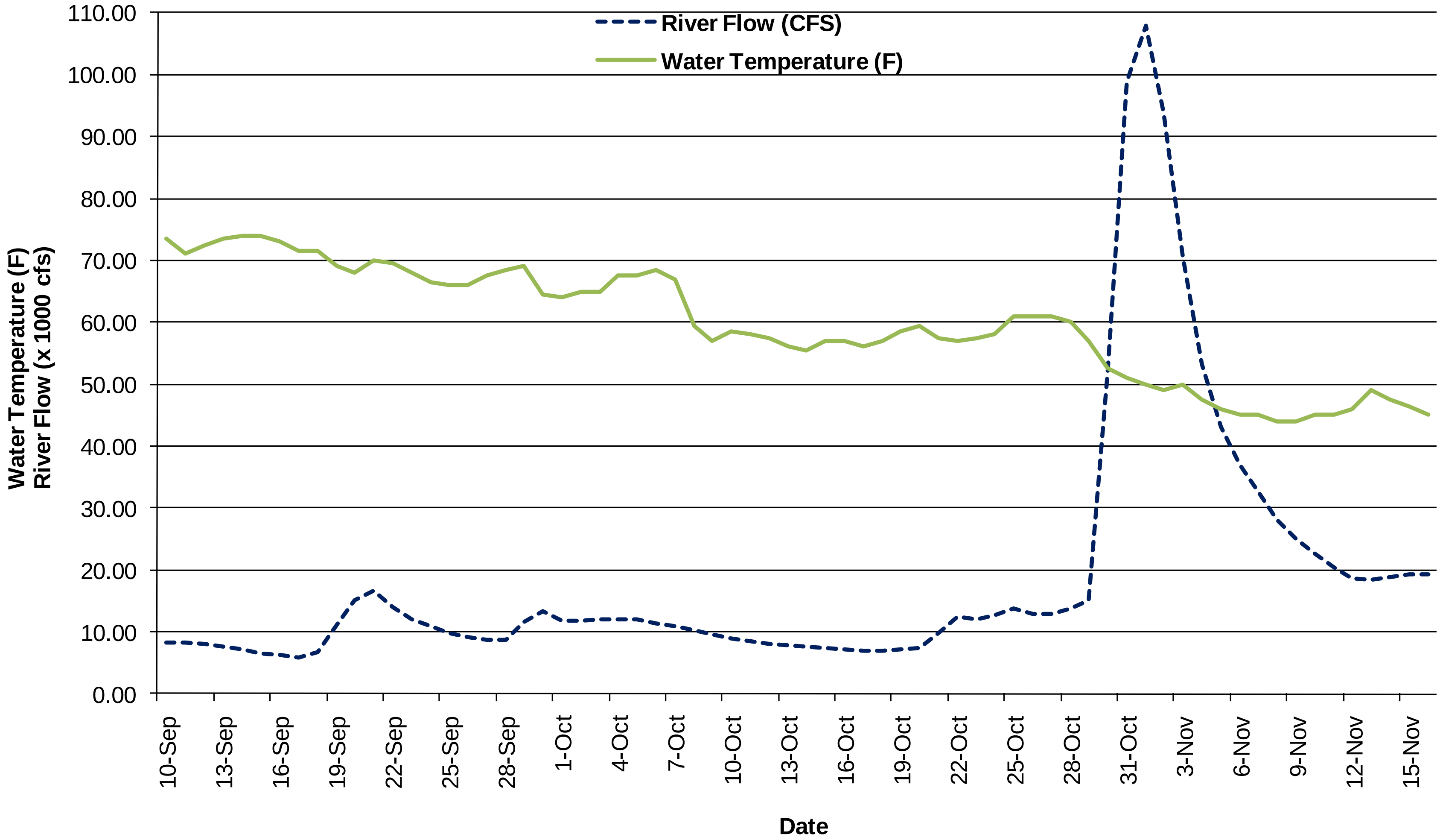


Figure 5. Plot of River Flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River and Average Daily Water Temperature at the York Haven Power Station, 10 September to 16 November, 2012



POTOMAC RIVER EGG COLLECTION - 2012

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ABSTRACT

During March and April, 2012 we used monofilament gill nets to collect 1,187 adult American shad from the Potomac River (rkm 150). The purpose of sampling was to supply fertilized eggs to Pennsylvania's Van Dyke American Shad Hatchery in support of Susquehanna River American shad restoration efforts. Sampling took place over 23 days and supplied a total of 258 L of American shad eggs (11.2 million) with a 51% fertilization rate resulting in 5.7 million viable eggs. This was the U.S. Fish and Wildlife Service's (Service) seventh year delivering eggs for Susquehanna River American shad restoration, resulting in the second highest number of viable eggs delivered.

INTRODUCTION

American shad (*Alosa sapidissima*) are an anadromous pelagic species ranging from Labrador to Florida, along the Atlantic coast (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 at sea. Spawning movements follow a latitudinal cline and although variable, spawning generally peaks from 14 to 21 ^{o}C (Stier and Crance 1985). Generally, April is the peak spawning month for American shad in the Potomac River.

Shad were 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, American shad have undergone population fluctuations as a result of anthropogenic effects. Initial population declines resulted from commercial harvest coinciding with increases in human population and gear efficiency. Habitat loss (damming) and degradation (pollution) followed and remain significant challenges to restoration. Attempts to mitigate dam effects on American shad and other Susquehanna River species began in 1866. In that year Pennsylvania drafted an Act, which directed dam owner/operators to maintain fish passage structures (The Native Fish Conservancy 2005). The Act established a commissioner's office that evolved into the Pennsylvania Boat and Fish Commission (The Native Fish Conservancy 2005).

The 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 and its tributaries. The Service's current Potomac River egg harvest operation is part of this, nearly forty year, multi-agency restoration effort. The Service's Maryland Fishery Resources Office's (MFRO) role is to deliver viable American shad eggs to the Van Dyke American Shad Hatchery near Thompsontown, PA. Once there, the shad eggs are incubated until hatching and larvae 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, MD (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. Bottom habitat is characterized by an abrupt transition from the deep channel ($\approx$ 18.3 m) area to relatively shallow depths ($\leq$ 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 Service boats with a crew of three each, fished for American shad nightly. Two different types of net were used in 2012 egg collections. One net was for targeting ripe females and the other for targeting ripe males. The net used to target females was 6.1 m deep by 91.4 m long floating monofilament gill net with 14.0 cm stretch mesh panels. The net to target males was 5.2 m deep by 91.4 m long floating monofilament gill net with 11.7 cm stretch mesh. Up to four nets per boat were joined in series and drifted parallel to shore in water depths ranging from approximately 7.6 to 16.8 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.

Tidal condition (transitioning high or low) was noted and surface temperature (^{o}C), dissolved oxygen (mg/L), conductivity (microsiemens) and salinity (ppt) were recorded (Yellow Springs Instruments Model 85) each night (Figure 1). The number of running, green, or spent female American shad, ripe male American shad, and bycatch were recorded (Table 1, Figure 2). Gill net effort was recorded but varied since the goal was to maximize catch during each sampling event. Catch per unit effort (CPUE) was calculated as daily combined male and ripe female catch per total hours fished per total net square footage (CPUE= (n/hr/m^2)). All CPUE values were multiplied by 1000 as a scalar for data display (Figure 1). American shad were sub-sampled for otolith extraction, total length (nearest mm) and weight (nearest 0.25 kilogram). as a permit requirement of the Potomac River Fisheries Commission.

RESULTS

During spring 2012, the Potomac River was sampled a total of 23 days from March 26-April 12. During the 23 days of fishing, ≥ 5.0 L of eggs were collected 17 times (74%). MFRO shipped a total of 258 L (Range = 5.0 – 25.7 L, $\bar{x}$ = 13.8 L/shipment) of eggs from the Potomac River (M. Hendricks, pers. comm.). The overall egg viability was 51%, although daily shipments had a range of 6.1 – 69.5% (M. Hendricks, pers. comm.).

Gill netting produced 6,995 fish from the Potomac River, representing ten fish species from six families (Table 1). In 2012, green females were more common than ripe females with a 1.26:1 ratio, but females were more common than ripe males with a 1.50:1 ratio (Figure 2).

From late March to late April, surface water temperature displayed a rising trend while dissolved oxygen decreased (Figure 1). Surface water temperatures ranged from 14.3 to 17.8 ^{o}C ($\bar{x}$ = 16.1 ^{o}C) while dissolved oxygen ranged from 10.3 to 14.1 mg/L ($\bar{x}$ = 12.3 mg/L) (Figure 1). CPUE for shad was variable and there was no apparent relation to tide or lunar cycle. CPUE was the highest on the nineteenth day (4/19/2012) of sampling (0.0863/hr/m^2) and lowest on the first day (3/26/2012) of sampling (0.019/hr/m^2). The highest CPUE values were between the seventeenth day (4/18/2012) and nineteenth day (4/23/2012) of sampling. During this time the CPUE ranged from 0.027/hr/m^2 to 0.086/hr/ft^2 with an average of 0.051/hr/m^2 (Figure 1).

DISCUSSION

American shad harvest in numbers sufficient enough to yield egg shipments was consistent on the Potomac River. The greatest numbers of ripe/running male and female American shad were caught between surface water temperatures of 15.9-16.9 ^{o}C as opposed to 2011 sampling when the greatest numbers of ripe/running male and female American shad were collected between water temperatures of 16.8-18.6 ^{o}C. As in past years, males were caught continuously throughout the spawning season (Table 2). Catching males throughout the entire sampling season can be directly attributed to continuing to use a smaller mesh gill net during the 2012 season. In the Potomac River males are substantially smaller than females. To collect a higher number of males, at least one smaller mesh gill net (11.75 cm) was set, along with up to eight larger mesh gill nets (14 cm stretch mesh “female” nets). The smaller mesh nets were used in an effort to keep the sex ratio consistent with one male to two females throughout the entire season. Constant availability of sperm was expected to increase overall egg viability, thus resulting in more fry stocked into the Susquehanna River watershed.

Conclusion

The USFWS provided Pennsylvania with 258 L of eggs, with an overall viability of 51% (5,664,920 viable eggs) (Table 3). An early spring and an unusual increase in water temperature early in the year allowed for fishing consistently throughout the American Shad spawning temperatures. On three occasions his year, fishing did not occur due to high winds and the associated wave heights. The 2012 overall viability of 51% is the greatest viability to date and greater than the seven year average (42%) since Potomac River egg collection began in 2006.

Project Summary

Over the past six years the USFWS has provided Pennsylvania with almost 26 million viable shad eggs.

Year	Volume (L)	Viable Eggs (N)	Viability (%)
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

The MFRO thanks those who participated in this year’s sampling Katie Dowling, Julie Devers, Sheila Eyler, Ashlee Horne, John Gill, and Josh Newhard.

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U.S. Fish and Wildlife Service Chesapeake Bay Field Office Home Page. 2006. American shad *Alosa sapidissima*. http://www.fws.gov/chesapeakebay/SHAD. HTM>. August 8, 2006.

FIGURES

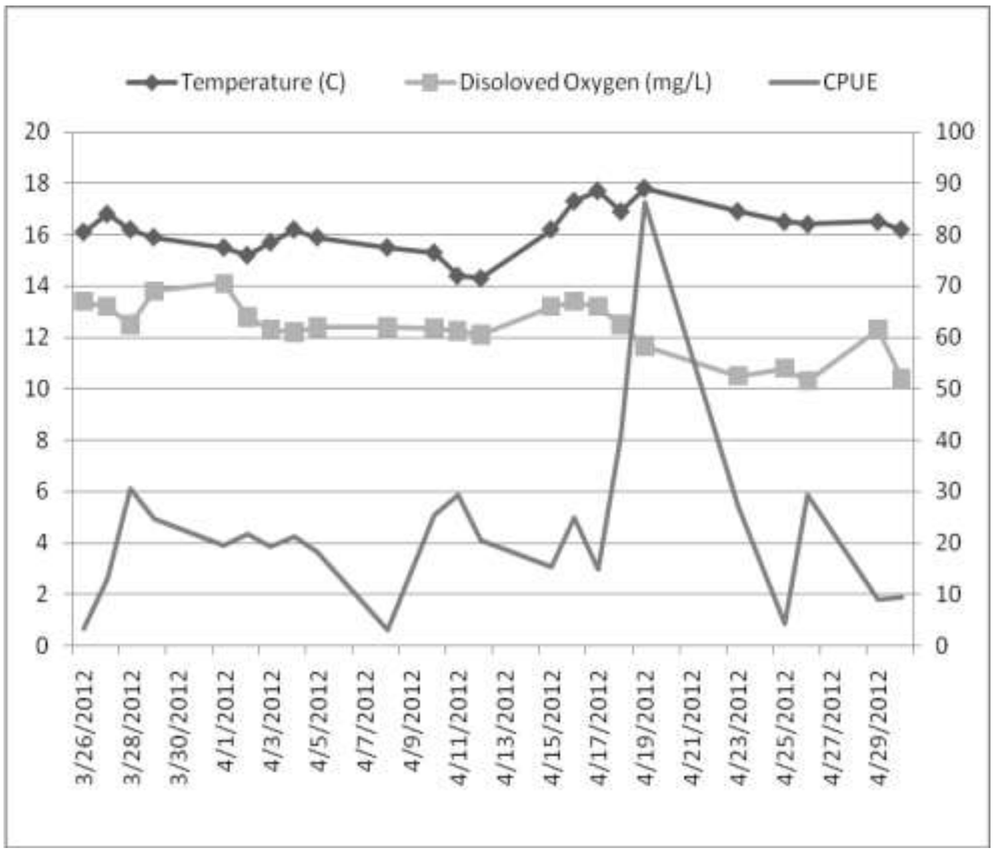

Figure 1. Spring 2012 American shad catch per unit effort, surface dissolved oxygen, and surface temperature, by sample date, for the Potomac River at Marshall Hall, MD. Surface salinity (not depicted) was always ≤ 0.2 ppt.

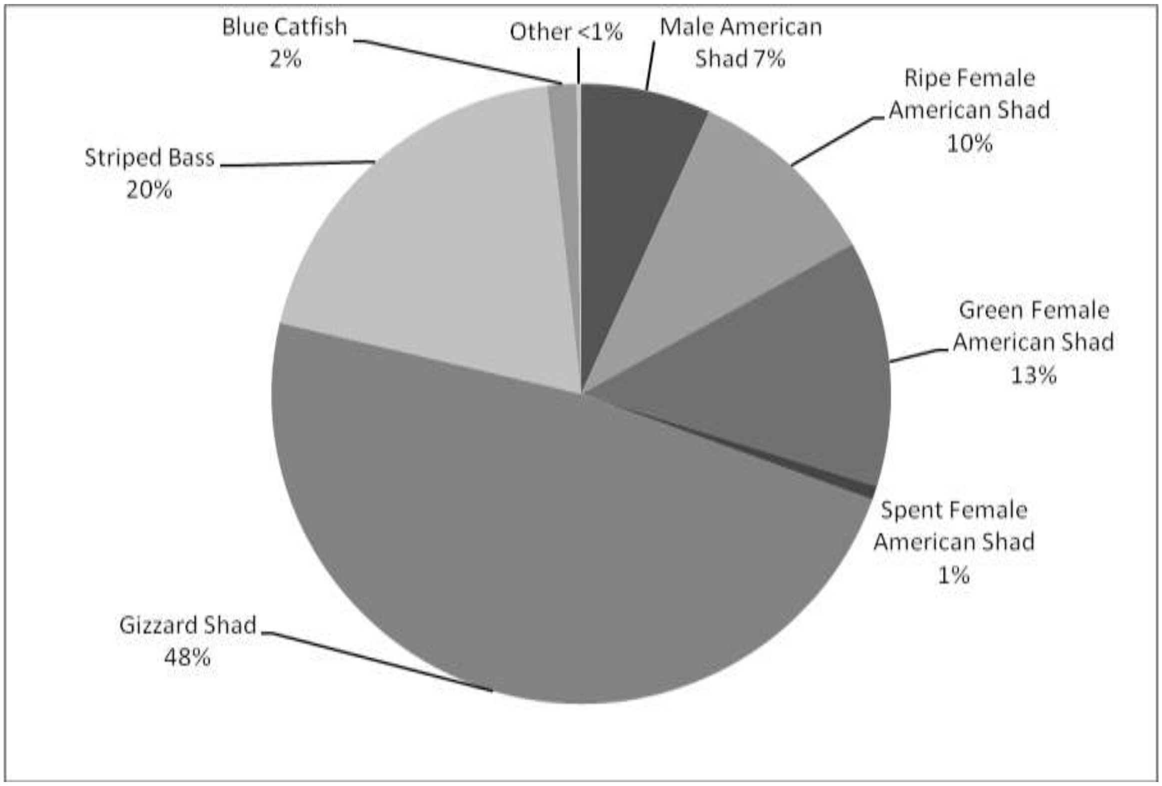

Figure 2. Spring 2012 species composition from Potomac River gill net sampling at Marshall Hall, MD. Other species and number caught listed in Table 1.

TABLES

Table 1. List of species and number collected in gill nets from the Potomac River during spring, 2012.

Family	Scientific Name	Common Name	Number Captured
Catostomidae	*Carpiodes cyprinus*	quilback sucker	1
Clupeidae	*Alosa mediocris*	hickory shad	2
	Alosa sapidissima	American shad	1,187
	Brevoortia tyrannus	Atlantic menhaden	5
	Dorosoma cepedianum	gizzard shad	3,367
Cyprinidae	*Carassius auratus*	goldfish	2
Ictaluridae	*Ictalurus furcatus*	blue catfish	108
	Ictalurus punctatus	channel catfish	3
Lepisosteidae	*Lepisosteus osseus*	longnose gar	3
Moronidae	*Morone saxatilis*	striped bass	1,367

Table 2. American shad catch totals with respect to male and female ratio, the associated viability and liters of eggs produced during spring, 2012.

Date	Ripe Male	Running Female	Ratio Male:Female	Liters	Viability
3/26/2012	1	1	1:1	0.00	0.00
3/27/2012	17	23	1:1.35	9.00	0.49
3/28/2012	55	28	1.96:1	15.10	0.60
3/29/2012	26	24	1.08:1	13.70	0.70
4/1/2012	36	43	1:1.19	14.80	0.39
4/2/2012	39	60	1:1.53	17.05	0.56
4/3/2012	26	65	1:2.5	15.80	0.63
4/4/2012	49	47	1.04:1	19.40	0.64
4/5/2012	43	8	5.3:1	16.55	0.51
4/8/2012	3	69	1:23	0.00	0.00
4/10/2012	46	55	1.62:1	21.20	0.56
4/11/2012	42	31	1.35:1	16.55	0.59
4/12/2012	29	44	1.51:1	8.05	0.52
4/15/2012	29	81	1:2.79	8.80	0.59
4/16/2012	30	49	1:1.6	9.65	0.06
4/17/2012	22	24	1:1.09	10.20	0.55
4/18/2012	67	28	2.39:1	25.70	0.60
4/19/2012	16	9	1.77:1	0.00	0.00
4/23/2012	47	54	1:1.14	18.50	0.66
4/25/2012	8	36	1:4.5	0.00	0.00
4/26/2012	68	45	1.51:1	17.95	0.12
4/29/2012	6	47	1:7.83	0.00	0.00
4/30/2012	7	28	1:4	0.00	0.00

Table 3. 2012 Shipment and viability summary for American shad eggs, delivered to the Van Dyke Hatchery from various collection sites (Hendricks 2012, unpublished).

Site	Shipments (N)	Volume (L)	Eggs (N)	Viable Eggs (N)	Viability (%)
Potomac R.	17	258.0	11,183,457	5,664,920	51
Delaware R.	12	116.1	8,991,955	694,762	8
Susq.Conowingo	6	60.7	3,827,377	941,595	27
Grand total	35	434.8	24,002,789	7,301,277	30

COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER - 2012

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INTRODUCTION

A key element in the restoration of American shad (*Alosa sapidissima*) to areas above dams in the Susquehanna, Lehigh and Schuylkill Rivers is the stocking of hatchery-reared larvae. These larvae imprint to the tributary/river reach in which they are stocked and return to spawn 3 to 6 years later. Hatchery production of larvae is dependant upon reliable sources of good quality eggs. Cost-effective collection of eggs requires intensive sampling efforts in well- documented spawning areas where ripe brood fish are abundant.

The Delaware River was first used as a source of American shad eggs in 1973. Between 1973 and 1975, approximately 1.6 million eggs were collected from known spawning grounds in the Delaware River and stocked (as eggs) into the Schuylkill River. In 1976, the Lehigh and Schuylkill Rivers each received 80,000 eggs. The Susquehanna River received its first fry from the Delaware River in 1976 when the surviving larvae from 1.5 million eggs were stocked. Collections of shad eggs from the Delaware River were discontinued from 1977 to 1982. In 1983, egg collection resumed, and has continued annually to the present.

The Pennsylvania Fish and Boat Commission (PFBC) conducts an annual American shad egg collection operation in the Delaware River. The objective of this activity in 2012, as in past years, was to collect up to 15 million American shad eggs for larval production and stocking within basin waters. Ultimately, the goal of this operation is the restoration of a self-sustaining spawning population of adult American shad in the Schuylkill and Lehigh Rivers.

METHODS

Brood fish were captured in gill nets set in the Delaware River at Smithfield Beach (RM 218), beginning on May 13, 2012 and terminating on May 31, 2012. Seventeen 200-foot gill nets were set on three nights, 16 nets were set on two nights, 14 nets were set on one night, 13 nets were set on one night, twelve nets were set on one night, ten nets were set on three nights, and nine nets were set on one night (Table 1). Gill net mesh sizes ranged from 4.5 to 6.0 inches (stretch). Nets were anchored on the upstream end and allowed to fish parallel to shore in concentrated arrays. Nets were typically set near the downstream end of the pool along the both New Jersey and Pennsylvania shorelines, with mostly smaller mesh sizes (< 5.0) deployed on the Pennsylvania shoreline. In 2012, 59 to 83% of nightly net sets were along the New Jersey shoreline. The number of nets set on either shoreline was based on professional judgment and the success of netting the previous night. Netting began at dusk and nets were retrieved at approximately midnight or earlier. On a typical evening shad were picked from the nets two to four times, usually at the top of the hour, beginning after full dark, around 9:00 pm. Additional runs to harvest shad were conducted if warranted due to high catch rates or to reduce the total time captured shad remained in the gill net.

For the 2012, sampling season, all shad were placed in non-circulating, un-aerated water in galvanized tubs immediately upon retrieval from the gill nets, as per traditional practice in prior years. All collected American shad were strip-spawned onshore immediately after returning from picking the gill nets. Prior to stripping, adult shad were quickly wiped clean to minimize the volume of slime accumulated in the receiving pan; and during the stripping process care was take to reduce the occurrence of fish slime from dripping into the pan as well. Ripe females were stripped into dry pans for fertilization of the eggs. Depending on the number of males collected, several were simultaneously stripped with the females. If only a few males were collected, all females were stripped prior to stripping males to ensure milt was available to all eggs. Once gametes were mixed, a small amount of fresh water was added to activate the sperm and the solution was actively mixed using a feather for five minutes, followed by several washings for the removal of excess sperm and debris. Cleaned, fertilized eggs were then placed into fine mesh floating boxes and anchored in the river current. Directional fins were added to the mesh areas to further promote a continuous flushing with fresh river water. Eggs were water-hardened for one to three hours.

In 2012, we abandoned the experimental egg coolers used in 2010 and 2011 and used traditional egg bagging methods. Water-hardened shad eggs were removed from the floating boxes and placed into buckets where excess water was decanted. Approximately 3 liters of eggs were then gently scooped into large, double-lined plastic bags with 3 to 5 liters of fresh water. Medical-grade oxygen was bubbled into the bags to produce super-saturation and they were sealed with nylon zip-ties, placed into coolers and transported to the Area 5 office. The next morning (approximately 6-7 hours after packaging at Smithfield Beach), the eggs were transported by truck 150 miles to the PFBC Van Dyke Hatchery near Thompsontown, PA. After strip-spawning, catch data was recorded for all shad including sex, length (total and fork), weight, ovarian stage (ripe/running, mature/gravid, spent), and ovarian weight of mature/gravid American shad, only. With the exception of mature/gravid American shad, fish weights were not representative of total weights due to the stripping of gonads prior to sample processing. Scales and otoliths were collected from a sub-sample for age determination.

RESULTS AND DISCUSSION

Table 1 summarizes daily Delaware River shad egg collections during May, 2012. Spawning operations commenced on May 13, when river flow was 5560 cfs (USGS gauge at Montague, NJ), and river temperature was 16.5˚ C (61.7˚ F). All collection events yielded sufficient egg volumes for shipment to the Van Dyke Hatchery. Sampling was canceled on May 16 due to high river flows (Table 1). Egg shipment volumes ranged from 3.0 L to 30.8 L and were dependent on the number and spawning readiness of collected females and availability of males. Spawning ready males were limiting during egg take operations on 5/30 and 5/31. Egg-take ended on 5/31, when river flow was 4,930 cfs and temperature was 22.0˚ C (71.6˚ F). Flow conditions during the 2012 egg-take operation were near the long-term mean except for a spike in flow on 5/18 (Figure 1). Egg collections were apparently hampered by an early spring which resulted in much higher than normal water temperatures during most of April (Figure 2). Water temperatures had returned to near normal by the time egg-take had begun on May 13 but egg viability for 2012 was an all-time low of 7.8%, presumably due to the extreme fluctuations in water temperature.

A total of 979 adult American shad were caught (Table 1), which was above the long-term average of 780. Nightly catches ranged from 1 to 146 shad. The overall sex ratio (male to female) was 0.28:1, and ranged from 0.10:1 to 0.74:1 for nightly catches (male to female ratios for 9 collection events were below 0.30:1). Some 116.1L (9.0 million) fertilized eggs were collected and shipped to the Van Dyke Hatchery in 2012, compared to the long-term average of 6.1 million. Egg viability per shipment was highly variable in 2012 ranging from a low of 0% to a high of 22.5%, with an overall viability of 7.8%. Egg viability is related to a multitude of factors; this years' ultra-low viability is thought to be due to the unusually early spring.

A total of 301 thousand American shad larvae were stocked in the Lehigh River, and 200 thousand were stocked in the Schuylkill River. No larvae were stocked in the Delaware River at Smithfield Beach since we did not meet our goals for the Lehigh and Schuylkill Rivers (750 thousand fry stocked in each the Schuylkill and Lehigh rivers). From 1983 to 2012, 202 million American shad eggs were collected from the Delaware River (Figure 3). From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 17.8 million in the Lehigh River, 7.7 million in the Schuylkill River, and 0.4 million in the Delaware River.

Egg collection CPUE (Figure 4) was the highest since 1995. Anglers also reported excellent catches of shad. Anglers reported many 30-40 fish days and one angler reported a 100 fish day. By some accounts, 2012 was an even better year than 2011 with larger fish than 2011. The catch was dominated by 7 year old females from the excellent 2005 year class, with a large number of 5 year olds from the 2007 year class. Of the shad caught at Smithfield Beach, 46% were age 7, while 43% were age 5. Ages 4,6,8 and 9 made up only 11% of the catch combined.

SUMMARY

Fishing occurred from 13 May through 31 May 2012. Eggs were collected and shipped on 12 of the 13 nights of fishing. A total of 979 adult shad were captured and 116.1 liters of eggs were shipped for a hatchery count of more than 9.0 million eggs. Overall, the viability for Delaware River American shad eggs was 7.8%.

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FIGURES

Figure 1. American shad eggs collected in the Delaware River at Smithfield Beach, 2012.

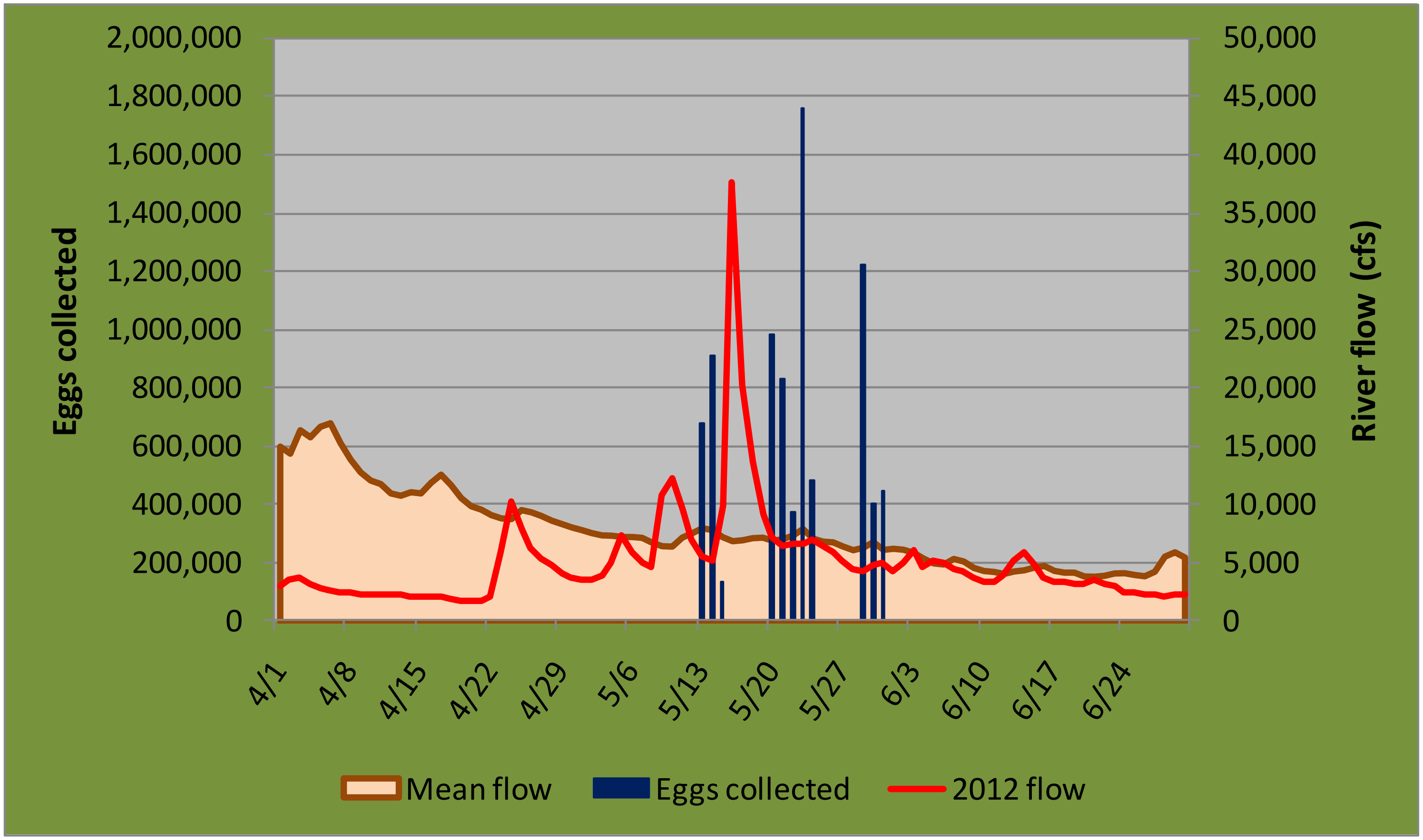


Figure 2. Mean daily water temperature in the Delaware River at Pond Eddy, April 1, 2012 to July 1, 2012, compared to the long term mean.

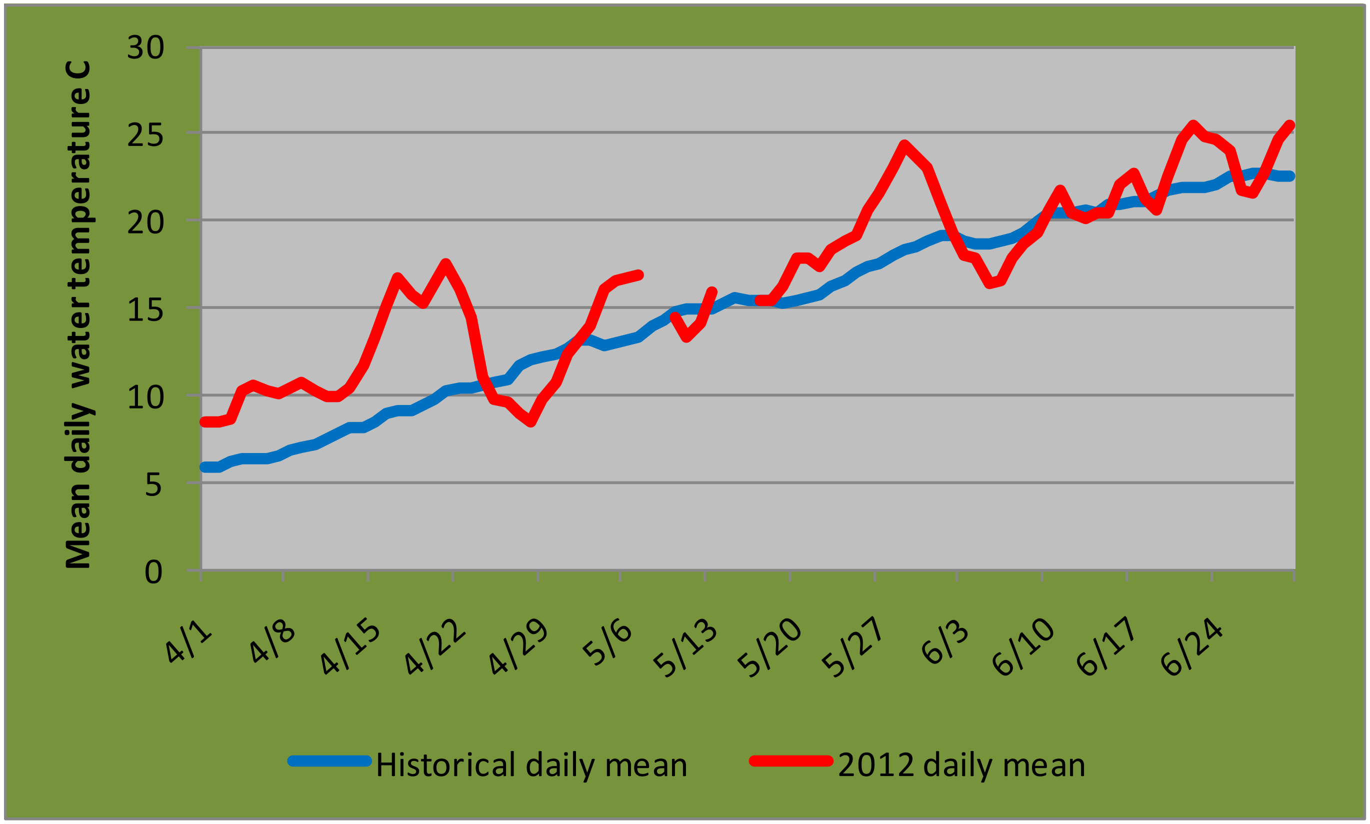


FIGURE 3. AMERICAN SHAD EGGS COLLECTED FROM THE DELAWARE RIVER, 1983 - 2012.

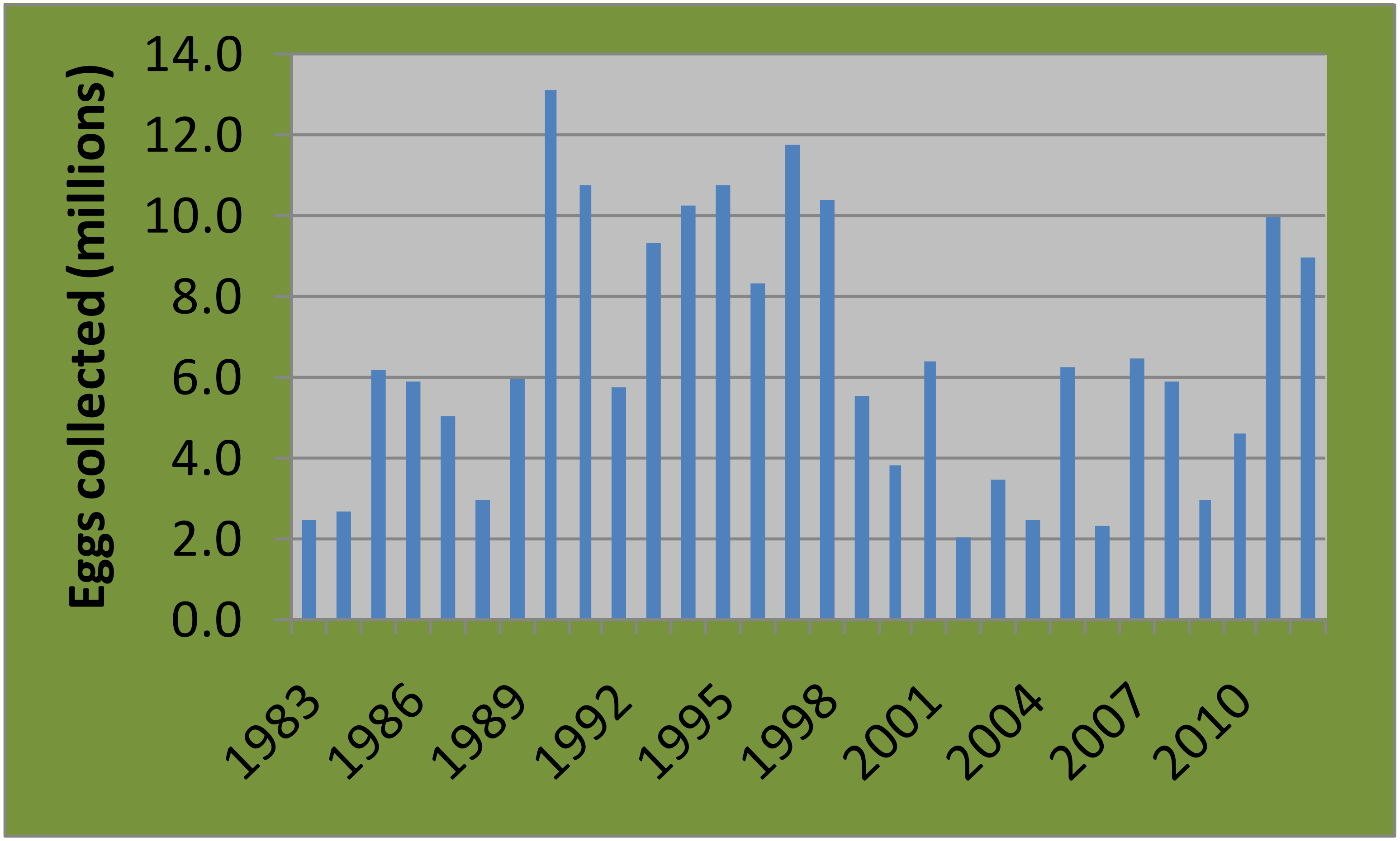
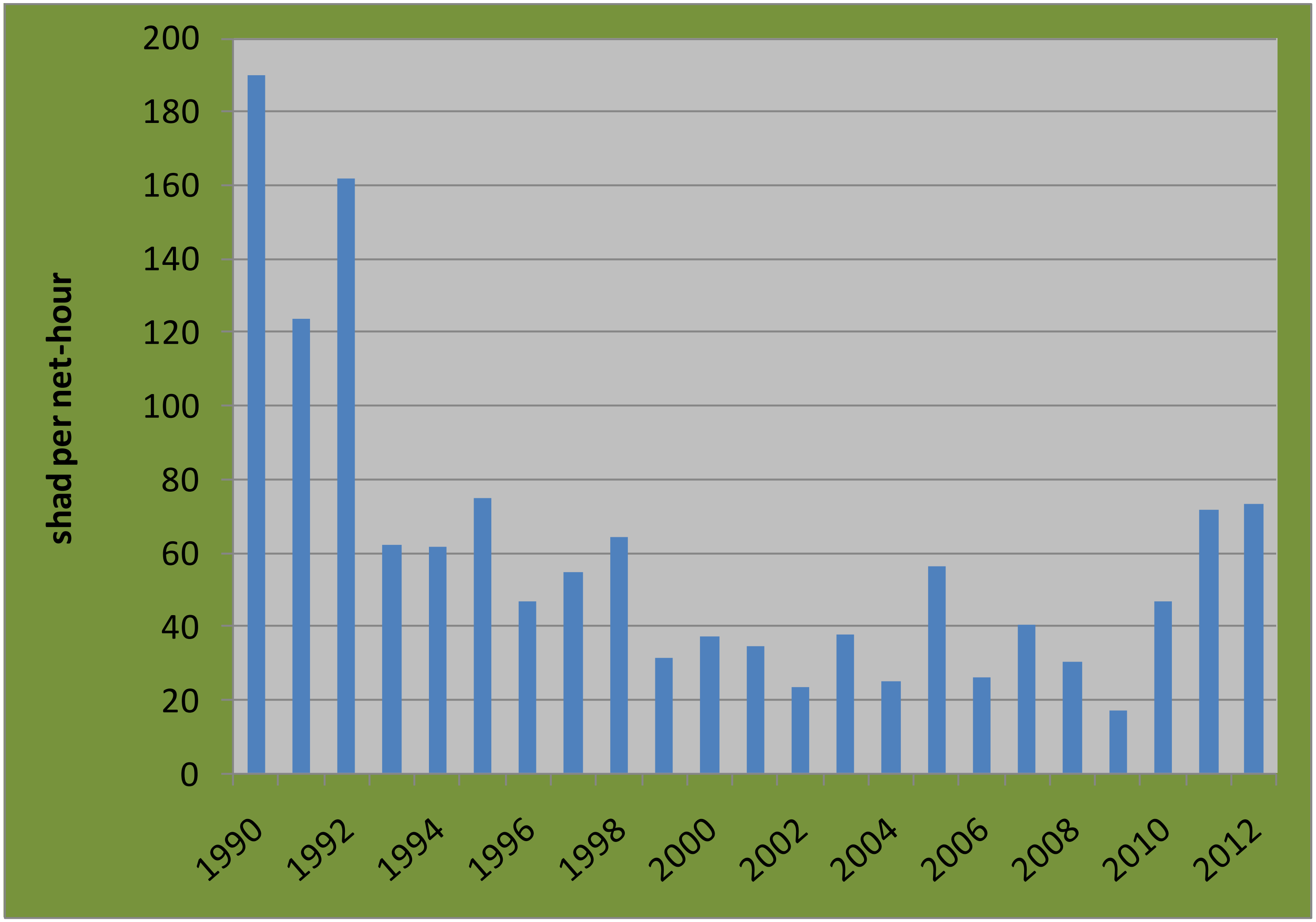


FIGURE 4. CATCH-PER-UNIT-EFFORT FOR ADULT AMERICAN SHAD COLLECTED BY GILL NET AT SMITHFIELD BEACH, DELAWARE RIVER, 1990-2012.



TABLES

TABLE 1. DELAWARE RIVER AMERICAN SHAD EGG COLLECTIONS, 2012.

							Egg			
			Females				Volume		Viable	Percent
Date	Total shad	Total nets	Gravid	Ripe	Spent	Males	Liters	Eggs	Eggs	Viable
5/13/2012	118	9	12	55	1	50	6.4	681,306	32,116	4.7%
5/14/2012	122	10	12	48	24	38	17.5	912,661	156,365	17.1%
5/15/2012	18	10	2	8	2	6	3.0	133,098	29,947	22.5%
5/16/2012	Canceled due to high water									
5/17/2012	1	10	0	0	0	1				
5/20/2012	98	12	25	51	4	18	11.7	984,404	84,939	8.6%
5/21/2012	53	13	6	34	4	9	8.7	828,402	64,828	7.8%
5/22/2012	47	17	8	21	9	9	6.0	371,253	80,488	21.7%
5/23/2012	146	17	19	90	10	27	30.8	1,759,652	236,917	13.5%
5/24/2012	50	17	10	26	3	11	5.9	480,897	9,160	1.9%
5/28/2012	91	12	19	40	10	22	7.9	775,253	0	0.0%
5/29/2012	123	16	17	68	24	14	9.8	1,219,906	3,269	0.3%
5/30/2012	53	16	6	29	13	5	3.9	400,202	0	0.0%
5/31/2012	59	16	12	31	9	7	4.5	444,920	0	0.0%
Total	**979**	**175**	**148**	**501**	**113**	**217**	**116.1**	**8,991,955**	**698,031**	**7.8%**

AMERICAN SHAD SPAWNING TESTS CONDUCTED AT CONOWINGO DAM – 2012

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INTRODUCTION

The Conowingo Dam West Fish Lift was built in 1972 and has been operated annually during the months of April, May and early June. Initially it was an integral part of the anadromous fish restoration effort, which combined the operation of the West Fish Lift, hand sorting of target species and a fleet of transport trucks to carry American shad and other Alosids to upriver release sites. Since the completion of permanent fish lifts at Conowingo Dam (1991), Holtwood and Safe Harbor Dam (1997), and a fish ladder at York Haven Dam (2000), the role of the Conowingo West Fish Lift changed. Beginning in 2001, the Conowingo West Fish Lift has operated under contract as (1) a source of fishes for special on-site spawning studies to provide the PA Fish and Boat Commission Van Dyke Shad Hatchery with a source of fertilized American shad eggs, (2) provide adult shad for studies conducted by the Maryland Department of Natural Resources at the Manning Hatchery and (3) a source of otoliths and scales from adult American shad to analyze the age structure and origin of returning adult shad. The West Fish Lift when operated 6-8 hours per day and six days per week from late April through early June typically captures 3,000 to10,000 adult American shad. Most of these fish are in a pre-spawn condition and based on studies at the USFWS Lamar facility many of these fish could be induced to spawn within several days after injection of hormone implants. The advantage of conducting spawning studies on site at Conowingo Dam rather than at a distant hatchery is the elimination of stress associated with lengthy transport times.

Hormone induced hickory shad spawning tests began at the Conowingo West Fish lift in 2003 and were conducted annually through 2008. In 2009 and 2011, hickory shad spawning tests were successfully conducted without the use of hormones. No hickory shad spawning tests were conducted in 2010 or 2012.

METHODS AND MATERIALS

The methods used to conduct the hormone induced spawning tests at the Conowingo West Fish lift in 2012 were generally similar to those used in the past ten years. Beginning with the 2008 tests and continuing for the 2012 tests, the study plan for the American shad spawning tests was submitted to the U.S. Department of Interior Fish and Wildlife Service Aquatic Animal Drug Approval Partnership Program, Bozeman MT, for approval. The approved American shad study plan for 2012 was assigned Study Number 11-375-11-8. The study protocols for the use of Salmon Gonadotropin-Releasing Hormone Analog (sGnRHa) under the investigational new animal drug (INAD) #11-375 required the use of hormone pellets manufactured solely by Syndel Industries Inc. The smallest dose of sGnRHa available from Syndel was 75ug per pellet and all treatment fish received this dose in the 2012 tests. Other requirements under this INAD included keeping detailed records of hormone inventory, collecting length and weight data on test fish and reporting results to Bozeman MT. Hormone injected fish that survive the spawning tests also cannot be released back into the river and must be euthanized. In the 2008 spawning tests with hickory and American shad, both species received hormone injections and each species received a separate Study number. Since the 2009 and 2011 spawning tests with hickory shad did not include hormone injections, those tests were not subject to the same INAD protocols which applied to the American shad tests.

Spawning tests for American shad were conducted in a 10 ft diameter or 12 ft diameter fiberglass tank. These two tanks were assembled on-site at the West Fish Lift in early April and plumbed in a configuration identical to that used since 2001 (Figure 1). Both tanks were supplied with approximately 40 gpm of river water through a wall mounted 2-inch fitting. A screened 4-inch PVC drainpipe in the bottom of each tank provided the only exit for the demersal shad eggs and water from the tank. The water level in both spawning tanks was maintained by an external standpipe that also provided a source of water for the rectangular 72 by 36 by 16 inch raised egg collection tank. The calculated volumes for the 10 ft and 12 ft tanks were 6,400 and 9,200 liters respectively. An egg sock fastened to the discharge from the spawning tank prevented the eggs from exiting the egg tank via the standpipe drain that maintained the water level in the egg tank.

Individual tests with hormone treated American shad lasted 2 to 3 days and were usually terminated following the first large pulse of eggs. With the approval of the Bozeman Montana office, no control fish were utilized in 2012. This request to eliminate controls was prompted by the anticipation of an abbreviated testing/spawning season. Because of additional Exelon Relicensing studies scheduled in 2012 requiring the use of adult shad, the demand for American shad was high. The Conowingo adult shad turbine survival study required 323 fish. The Conowingo EFL upstream fish passage effectiveness study required 35 adult shad from the WFL as angling for adult shad was not productive after early May, and the York Haven downstream fish passage study required 64 shad. Also, an additional 148 shad were utilized for the PPL Holtwood PIT-tag study.

Oxygen and temperature were monitored daily in the spawning tanks during each test. The egg sock was examined daily during each spawning test. Following the initial pulse of egg production (usually the second morning after hormone injection) the eggs were removed from the sock and placed into a 10 gal plastic bucket. The eggs were then sieved using a colander with 0.25 in holes to remove scales and other debris. After sieving, the eggs were transferred to a framed nylon net suspended in the egg tank. A No. 20 standard testing sieve was used to transfer the washed eggs from the nylon net into a graduated 2 liter measuring cup. Volume measurements in the field were approximations. The final volume and viability determinations for all shipments were made at the PFBC Van Dyke Hatchery. The packaging of eggs for shipment followed well-established techniques. Up to five liters of water hardened eggs were mixed with 5 liters of river water in double plastic bags. Pure oxygen was introduced into the inner bag before being sealed with tape or rubber band. The bags were placed into marked insulated shipping containers and driven to the Van Dyke Hatchery by PFBC or Normandeau personnel; eggs were always driven to the hatchery on the same day they were collected.

No attempts were made to hand strip American shad following their removal from the spawning tanks. Hormone injected fish that survived to the end of each test were disposed of in an offsite pit. River release of hormone laden fish is prohibited under the INAD agreement that is in effect.

The Conowingo West Fish Lift was the source of all 481 pre-spawned American shad used in this year’s spawning tests. All fish were measured for total length and a sub-sample (133) of weights was taken prior to placement of fish into the spawning tanks. Some American shad were kept in oxygenated holding tanks for up to 2 days until a sufficient number of shad needed to stock a spawning tank was collected.

RESULTS

A total of eight on-site spawning tests with 481 American shad from 24 April to 29 May produced 64.5 liters of eggs (Table 1 and Appendix Table A-1). Over 60.7 liters of eggs were shipped to the Van Dyke Hatchery and the remaining 3.8 liters were released into the river below Conowingo Dam. The overall estimated viability of the eggs shipped to Van Dyke was 24.6% (Table 1). The total volume of eggs produced per female in 2012 (0.338 liters) was slightly above the average of 0.320 liter observed for the previous ten years (Figure 2). The volume of viable eggs produced per female in the 2012 tests averaged 0.083 liters (Figure 2) and was the highest volume since 2001. Injected fish usually produced the first and largest pulse of eggs within 48 hrs followed by little or no egg production past 72 hrs. Water temperatures and oxygen levels in the spawning tanks were monitored daily and ranged from 15.3 to 26.8°C and 5.4 to 10.8 ppm. The overall mortality rate for adult American shad during the 2012 tests was 6.9%. Mortality rates have ranged from 2 to 15% in previous years (Table 2).

SUMMARY

This was the 12th year of hormone induced American shad spawning tests at the Conowingo West Fish Lift. The overall viability (24.6%) of the 2012 American shad eggs was above the ten year average of 18.4% (Table 2). The demand for adult American shad for other studies and the unexpected difficulty of collecting sufficient numbers of shad on a regular basis were the reasons a full complement of 15± tests with 936 injected fish could not be completed before the end of the American shad run that typically ends in early June. The elimination of control tests enabled eight spawning test groups to be completed from the West Lift. During the end of May and the first day of June, river temperature reached 26.0°C and many of the American shad caught at the

West Lift were spent, partially spent or in poor physical condition. This combination of conditions resulted in poor egg production for the last spawning test.

TABLES

Table 1.

Summary of egg production data for hormone (sGnRHa) induced spawning tests conducted with American shad at Conowingo Dam and shipped to the Van Dyke Shad Hatchery, Spring, 2012.

Test Group	Start/Stop Date	Male/Female	Liters Collected	River Release	Release Date	Total Liters Shipped	Date Shipped
1	4-24/4-26	45/30	12.5			12.5	26-Apr
2	4-24/4-26	30/11	2.1			2.1	26-Apr
3	4-27/4-29	45/30	10.3			10.3	29-Apr
4	5-1/5-3	30/20	7.1			7.1	3-May
5	5-4/5-6	45/30	14.9			14.9	6-May
6	5-21/5-23	30/20	8.2			8.2	23-May
7	5-24/5-26	45/30	5.6			5.6	26-May
8	5-29/5-31	20/20	3.8	3.8	31-May		
Totals		**290/191**	**64.5**	**3.8**		**60.7**	

Shipping Date	Liters Shipped	No. eggs	No. Viable	Viabil.(%)
26-Apr	12.5	639,385	124,831	19.5%
26-Apr	2.1	129,107	25,206	19.5%
29-Apr	10.3	929,657	236,061	25.4%
3-May	7.1	353,400	47,453	13.4%
6-May	14.9	921,945	358,954	38.9%
23-May	8.2	507,379	74,385	14.7%
26-May	5.6	346,503	74,705	21.6%
Totals	**60.7**	**3,827,376**	**941,595**	**24.6%**

Total Males	**290**
Total Females	**191**
Total Fish	**481**
Mean egg vol.(liters) / test group	**8.0625**
Mean No. of Eggs / Liter	**63,054**
Mean No. of Eggs/Female	**20,039**
Mean No. of Viable Eggs/ Female	**4,930**

Table 2.

Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-2012.

Year:	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Start/Finish date	4-30/6-4	4-24/6-6	4-28/6-5	4-27/5-27	4-27/6-6	4-20/6-3	5-4/5-30	4-25/6-6	4-30/5-29	4-30/5-29	5-12/6-7	4-23/6-1
Tank diameter (ft)	12	10,12	10,12	10,12	10,12	10,12	10,12	10,12	10,12	10,12	10,12	10,12
Tank volume (liters)	9,200	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600	15,600
Number of test groups	10	10	12	10	11	20	14	16*	16*	17*	15	8
Total fish	599	1,000	1,504	1,055	1,135	1,557	1,504	1010	994	1,075	936	481
Males/Females per trial	36/24	66/34	75/50	75/50	75/50	47/31	75/50	38/25	37/25	37/25	36/26	36/23
Stocking density (fish/liters)	1/153	1/156	1/125	1/125	1/125	1/124	1/125	1/125	1/125	1/125	1/125	1/125
Male:Female ratio	3:2	2:1	3:2	3:2	3:2	3:2	3:2	3:2	3:2	3:2	3:2	3:2
Hormone injected	LHRHa	sGnRHa	LHRHa	LHRHa	LHRHa	LHRHa	LHRHa	sGnRHa	sGnRHa	sGnRHa	sGnRHa	sGnRHa
Liquid, Pellet	P	P	L+P	L+P	L+P	L+P	L+P	P	P	P	P	P
Dose (ug) Male/Female	75/150	150/150	150/150	150/150	150/150	150/150	25-45/75-95	75/75	75/75	75/75	75/75	75/75
Eggs collected (liters)	103	146.8	234	90.4	160.5	169.25	89.6	110.5	98.7	122.2	116.9	64.5
Liters of eggs /Female	0.429	0.432	0.387	0.244	0.418	0.270	0.148	0.272	0.318	0.279	0.298	0.338
No. eggs/liter	63,140	51,235	51,187	59,775	53,828	60,747	80,638	58,429	60,864	63,699	69,179	63,054
Total number of eggs shipped	6,503,420	7,521,346	11,970,764	5,403,660	7,998,778	10,281,444	6,773,594	5,749,467	5,885,504	7,344,503	7,362,613	3,827,376
Viability (%)	33.2	10.1	17.7	20	23.9	21.7	8.9	9.8	23.2	18.2	15.7	24.6
Total number of viable eggs	2,159,135	760,935	2,118,852	1,080,732	1,913,801	2,232,459	603,345	526,816	1,366,478	1,334,705	1,156,430	941,595
Total liters of viable eggs	34.20	14.85	41.42	18.1	35.6	36.75	7.97	9.64	22.45	20.95	16.72	14.93
Adult mortality rate (%)	6.0	3.6	2.0	11.5	3.3	3.5	8.3	10.3	15.0	10	9.4	6.9

*Includes 3-4 control groups

FIGURES

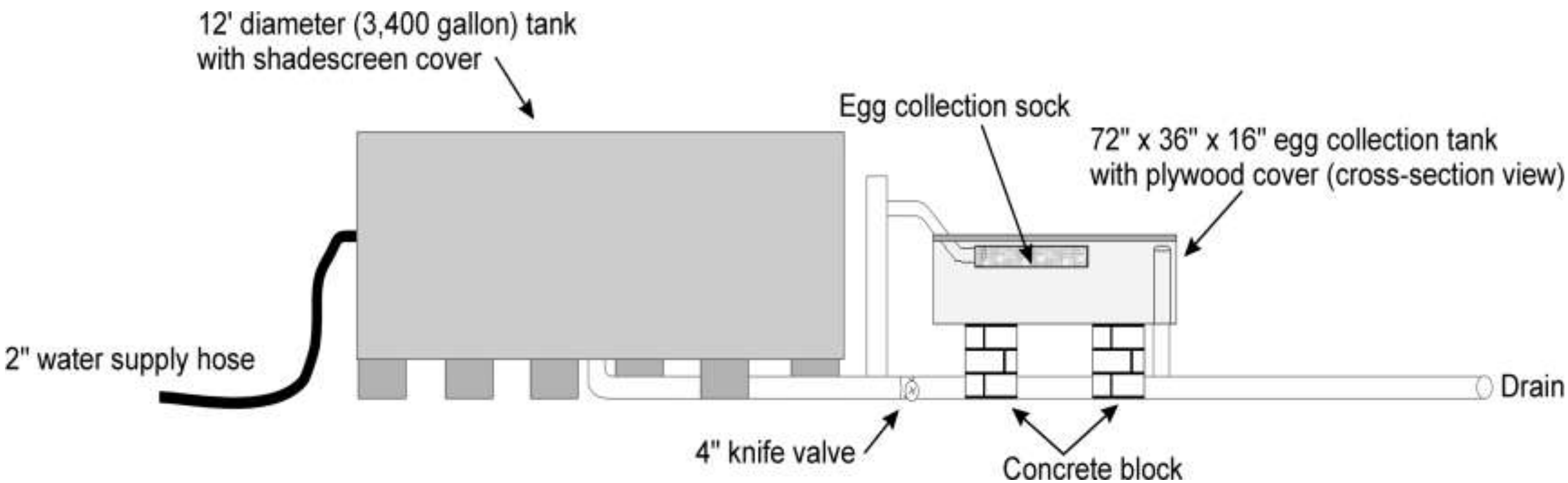

Figure 1

Schematic of tank spawning system used at Conowingo Dam West Fish Lift.

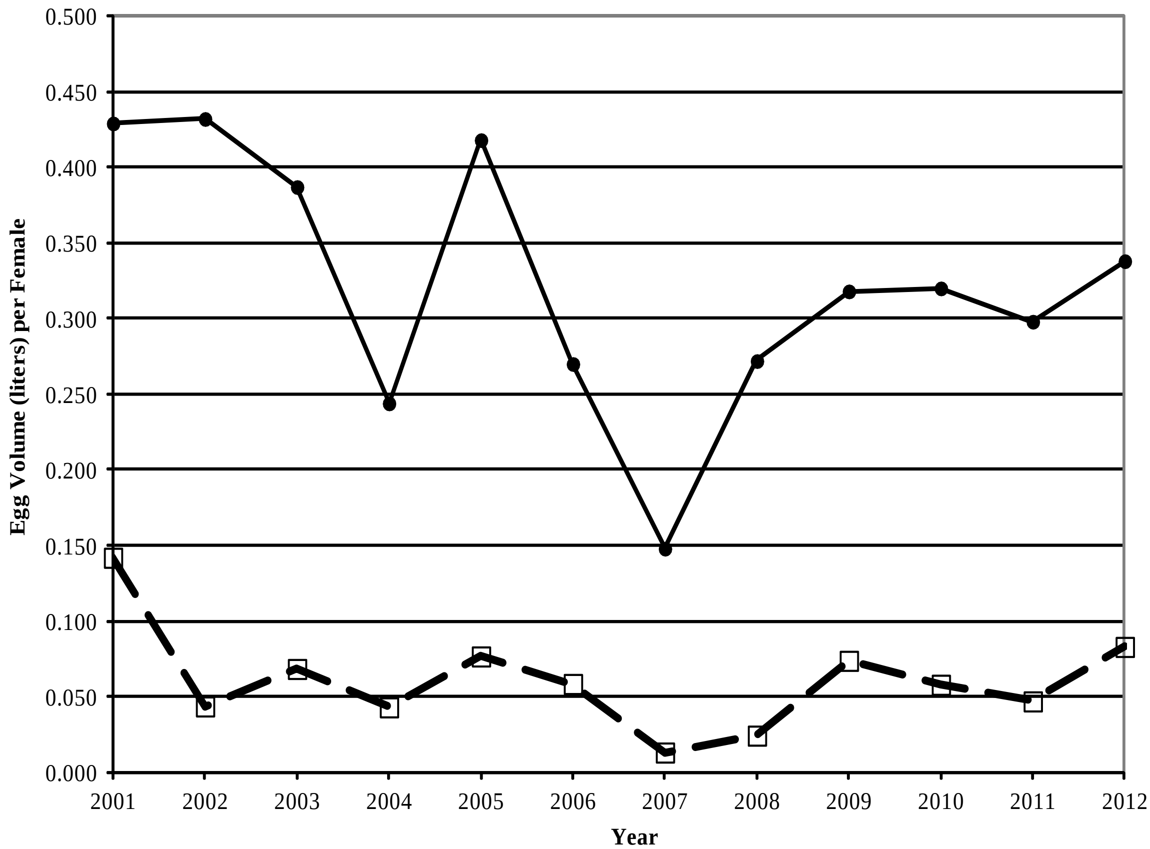

Figure 2. Comparison of total American shad egg volume (solid line) and viable egg volume (broken line) per female for the spawning tests conducted at Conowingo Dam, 2001-2012.

APPENDIX A

Appendix Table A-1.

Individual test group data for hormone induced American shad spawning tests conducted at Conowingo Dam West Fish Lift, Spring 2012.

Test Group 1

M/F	45/30	12 ft tank					
Start Date	4/24/12	1100		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	4/26/12	1530					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
4/24/12	1325	18.3	5.8				
4/25/12	1045	17.4	5.4				
4/26/12	0840	18.2	9.4	12.0	12.0		4f

Test Group 2

M/F	30/11	10 ft tank					
Start Date	4/24/12	1045		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	4/26/12	1530					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
4/24/12	1326	18.2	8.4				
4/25/12	1426	17.9	6.5				
4/26/12	0845	18.2	7.6	2.0	2.0		3f

Appendix Table A-1. Continued.

Test Group 3

M/F	45/30	12 ft tank					
Start Date	4/27/12	1015		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	4/29/12	1500					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
4/27/12	1455	17.7	6.8				
4/28/12	1740	17.5	7.2				
4/29/12	0840	15.3	8.6	10.0	10.0		1f

Test Group 4

M/F	30/20	10ft tank					
Start Date	5/1/11	0920		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/3/11	1030					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
5/1/12	1130	15.3	9.6				
5/1/12	1436	15.6	10.8				
5/2/12	0015	15.3	10.0				
5/2/12	1630	15.4	10.6				
5/3/12	1000	15.6	10.5	7.0	7.0		1m, 4f

Appendix Table A-1.
Continued.

Test Group 5

M/F	45/30	12 ft tank					
Start Date	5/4/12	0950		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/6/12	1200					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
5/4/12	1400	17.0	9.7				
5/5/12	0825	17.1	9.2				
5/5/12	1710	17.8	8.4				
5/6/12	0900	17.6	8.0	14.0	14.0		1m, 1f

Test Group 6

M/F	30/20	10 ft tank					
Start Date	5/21/12	1215		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/23/12	1500					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
5/21/12	1648	21.4	7.9				
5/22/12	0900	20.8	7.4				
5/22/12	1645	22.8	8.0				
5/23/12	0820	21.3	7.5				
5/23/12	0930			8.0	8.0		3m, 2f

Test Group 7

M/F	45/30	12 ft tank	
Start Date	5/24/12	1040	Dose/fish 75 ug sGnRHa (pellet implant)
End Date	5/26/12	1000	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
5/24/12	1200	22.5	5.8				
5/24/12	1635	23.1	6.5				
5/25/12	0800	22.2	6.4				
5/25/12	1650	23.0	6.2				
5/26/12	1000	22.8	6.2	5.8	5.8		3f

Test Group 8

M/F	30/20	10 ft tank	
Start Date	5/29/12	1215	Dose/fish 75 ug sGnRHa (pellet implant)
End Date	5/31/12	1630	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs (Liters) Collected	Eggs Shipped	River Releases	Morts Removed
5/29/12	1345	26.3	7.6				
5/30/12	1620	26.8	9.4				
5/31/12	1630			3.8		3.8	3m, 7f

AMERICAN SHAD HATCHERY OPERATIONS, 2012

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Benner Spring Fish Research Station

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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 diadromous fishes 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 was 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 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 due to budget constraints.

As in previous years, production goals for American shad for 2012 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 natural spawning of wild adults. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

EGG SHIPMENTS

A total of 24.0 million American shad eggs (434.8 L) was received in 35 shipments in 2012 (Table 1). This was the second highest quantity of eggs received since 2003 (Table 2, Figure 1). Overall American shad egg viability (which we define as the percentage of eggs that ultimately hatch) was 30.4%, yielding 7.3 million viable eggs. Seventeen Potomac River egg shipments (11.1 million eggs) were received from March 28 to April 27, 2012, with an overall viability of 50.7% (Table 1), resulting in 5.7 million viable eggs.

Delaware River egg shipments were received from May 14 to June 1. A total of twelve shipments, consisting of 9.0 million eggs were processed at Van Dyke. This was the second largest egg take since 1998 (Table 3, Figure 1); however, overall egg viability of 7.7% was the lowest on record for the Delaware River (Figure 2).

American shad eggs were also obtained from tank-spawning efforts at Conowingo Dam, operated by Normandeau Associates. Broodstock were obtained from the West Fish Lift at Conowingo Dam.

All American shad were injected with hormones and allowed to spawn naturally. The tank-spawn array at Conowingo uses water pumped directly from the river and is subject to natural fluctuations in water temperature. Spawning trials of American shad in 2012 produced 3.8 million eggs, in six shipments delivered to the Van Dyke Hatchery. Overall viability of those eggs averaged 27.1% (or some 942 thousand hatched eggs). This has become a consistent source of American shad eggs for the restoration program, but viability has been low, ranging from 9% to 33%.

No eggs were collected from the Hudson River in 2012 due to concerns over declines in the Hudson River stock. 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 River has 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.

SURVIVAL

Survival of individual tanks followed patterns similar to those observed in the past in that the majority of the tanks experienced their highest mortality after nine days of age (Figure 3). No tanks suffered complete mortality in 2012.

The fluidized bed system installed in 2008 worked extremely well and pH of the fish culture water ranged from 6.86 to 7.45 with a mean of 7.2. 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 100.9% with a maximum of 105.8%. The high value occurred on May 11 when warm air temperatures occurred. Oxygen injection was turned down and the fish monitored, with no negative effects noted. Nitrogen saturation averaged 100.2% with a maximum of 102.1%. Total gas saturation averaged 100.3% with a maximum of 101.2%. As a result, no incidents of gas bubble disease occurred. Larvae stocked in 2012 appeared active and robust.

LARVAL PRODUCTION

Production and stocking of American shad larvae, summarized in Tables 2, 3, and 4, totaled 3.9 million. A total of 2.8 million were released in the Juniata River, 150 thousand in the North Branch Susquehanna River in Pennsylvania, 172 thousand in the West Branch Susquehanna River and 271 thousand in Bald Eagle Creek. Due to an 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.

Delaware River egg collections in 2012 yielded the second greatest quantity of eggs since 1998. However, eggs collected from the Delaware River were not sufficient to meet the goals for stocking larvae in the Delaware River Basin, largely because of low egg viability. Larvae were stocked in the Lehigh River (301 thousand), the Schuylkill River (200 thousand). No larvae were stocked in the Delaware River.

TETRACYCLINE MARKING

All American shad larvae stocked received marks produced by immersion in tetracycline (Table 6). Immersion marks for American shad were administered by 4h bath treatments in 427-ppm oxytetracycline. In addition to immersion markings, cultured fingerling shad were fed tetracycline lace feed (88g tetracycline per one kilogram of feed) for three consecutive days prior to stocking, producing a fingerling tag.

All American shad larvae were marked according to stocking site and/or egg source (Table 6). Some 172 thousand larvae received marks on days 3 and18 and were stocked in the West Branch Susquehanna River. Bald Eagle Creek, a tributary to the West Branch, received some 271 thousand larvae marked on days 3, 6, 9, 12, and 15. Some 425 thousand larvae were marked on days 3, 6 and 9 (Susquehanna River egg source) and stocked in the Raystown Branch immediately below Raystown Dam. This is a new stocking site this year and was added due to prolonged muddy water in the main Juniata River. This site maintains clear water, has prolific insect life and appears to be a good site to stock shad larvae. Some 2.4 million larvae were given an OTC mark on day 3 and stocked in the Juniata River at Millerstown or the Raystown Branch below Raystown Dam. Unfortunately, we did not give unique marks to these fish to determine stocking site. Of the 2.4 million larvae marked on day 3, 1.5 million were stocked in the Juniata River and 1.3 million were stocked in Raystown Branch. The North Branch Susquehanna River in Pennsylvania received some 150 thousand larvae, marked on days 3, 6, 9, and 15. The Lehigh River received 301thousand larvae marked on days 9, 12, and 15. The Schuylkill River received 200 thousand larvae marked on days 3, 6, 9, and 12.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways at the Benner Spring State Fish Hatchery and examining otolith samples collected later. Otoliths were extracted and mounted in Permount on microscope slides. A thin section was produced by grinding the otolith on both sides. Otolith sections were examined for marks with an epi-fluorescent microscope with a UV light source.

Raceway culture was successful in 2012, yielding specimens for verification of each mark produced. All fingerling American shad examined exhibited marks, conforming to the marking protocol on Table 6. Digital photographs have been archived from representative samples of the marks detected for future reference. These will assist in identifying the origin of marks detected in out-migrating juveniles and returning adults from the 2012 cohort.

Groups of American shad which exhibited the intended mark in 100 percent of the specimens examined included the West Branch Susquehanna (3, 18), Bald Eagle Creek (3,6,9,12,15), Juniata River (3), Raystown Branch Juniata River (3, 3,6,9), North Branch Susquehanna (3,6,9,15) and the Schuylkill River (3,6,9,12). The Lehigh River group (9,12,15) exhibited mark retention of 97 percent with one of 30 specimens exhibiting a 3,6,9,12,18,21,24 tag. This specimen likely received 4 tags in tank H31ending on 5/26, and was then inadvertently transferred to adjacent tank H41 on a squeegee where it received 3 more tags on days18,21 and 24. The Bald Eagle Creek group (3,6,9,12,15) exhibited mark retention of 97 percent with one of 30 specimens exhibiting a 9,12,15 tag. This specimen was similarly transferred from tank H31 to tank H41 before it had received any tags in H31, but after H41 had already received the first two of its planned tags. American shad larvae grown out to fingerlings were fed OTC laced feed prior to stocking. None of those examined had retained the mark. This may have been due to not using vegetable oil in mixing the OTC powder and the feed. We speculate that the OTC may have dissolved in the water before the fish consumed the food and thus was not available to the fish.

SUMMARY

A total of 35 shipments of American shad eggs (24.0 million eggs) were received at Van Dyke in 2012. Total egg viability was 30.4% and survival of viable eggs to stocking was 47%, resulting in production of 3.9 million larvae. Larvae were stocked in the Juniata River (1.5 million), Raystown Branch (1.3 million) the West Branch Susquehanna River (172 thousand), Bald Eagle Creek (271 thousand), and the North Branch Susquehanna River in Pennsylvania (150 thousand). Delaware River source American shad larvae were stocked in the Lehigh (301 thousand) and the Schuylkill (200 thousand) rivers. No American shad larvae were stocked in the Delaware River because our stocking goals in the Lehigh and Schuylkill Rivers were not met.

No major mortality occurred due to disruption of flow. Installation of a fluidized bed system in 2008 and closer monitoring of the oxygen injection system resulted in pH and gas saturation levels that contributed to high survival.

All American shad larvae cultured at Van Dyke were marked by 4-hour immersion in oxytetracycline. Marks for American shad were assigned based on release site and/or egg source river. All raceway cultured shad examined for marks had marks as intended except for a few specimens that were not marked**.** Fingerling shad fed OTC laced food did not retain the feed mark.

RECOMMENDATIONS FOR 2013

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55°F.
3. Routinely feed all larvae beginning at hatch.
4. Continue to hold egg jars on the 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 hatching.
5. Continue to siphon eggshells from the rearing tank within hours of egg hatch.
6. Continue to feed left over AP-100 only if freshly manufactured supplies run out.
7. Use MSXXX jars preferentially to promote egg layering and maintain good egg survival.
8. Continue to collect American shad eggs from the Potomac River as an additional source of out-of-basin eggs.
9. Mark American and hickory shad at 427ppm OTC.
10. Continue using PENNOX 343 (now FDA approved) for marking alosines.
11. Continue to utilize a fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and reduce dissolved aluminum.
12. Continue to record pH, hardness and alkalinity on a regular basis to monitor fish culture water quality.
13. Continue to utilize additional packed column de-gassers to reduce the need for oxygen injection.

14. 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.
15. Mark all tanks of larvae beginning at 11:00AM, to ensure consistency in daily mark application.
16. Consider other options for hickory shad restoration, including direct stocking of eggs or stocking of pre-spawn adults, based on the absence of adult hickory shad in extensive collections conducted at the release sites during 2009-2012 by the Philadelphia Water Department.
17. Investigate the potential of increasing egg production at 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.
18. Rear raceway cultured juvenile shad in warming pond water regardless of pH.
19. Utilize Raystown Branch, Juniata River, below Raystown Dam as a primary stocking location for American shad larvae.

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FIGURES

FIGURE 1. AMERICAN SHAD EGGS INCUBATED AT VAN DYKE, 1983-2012.

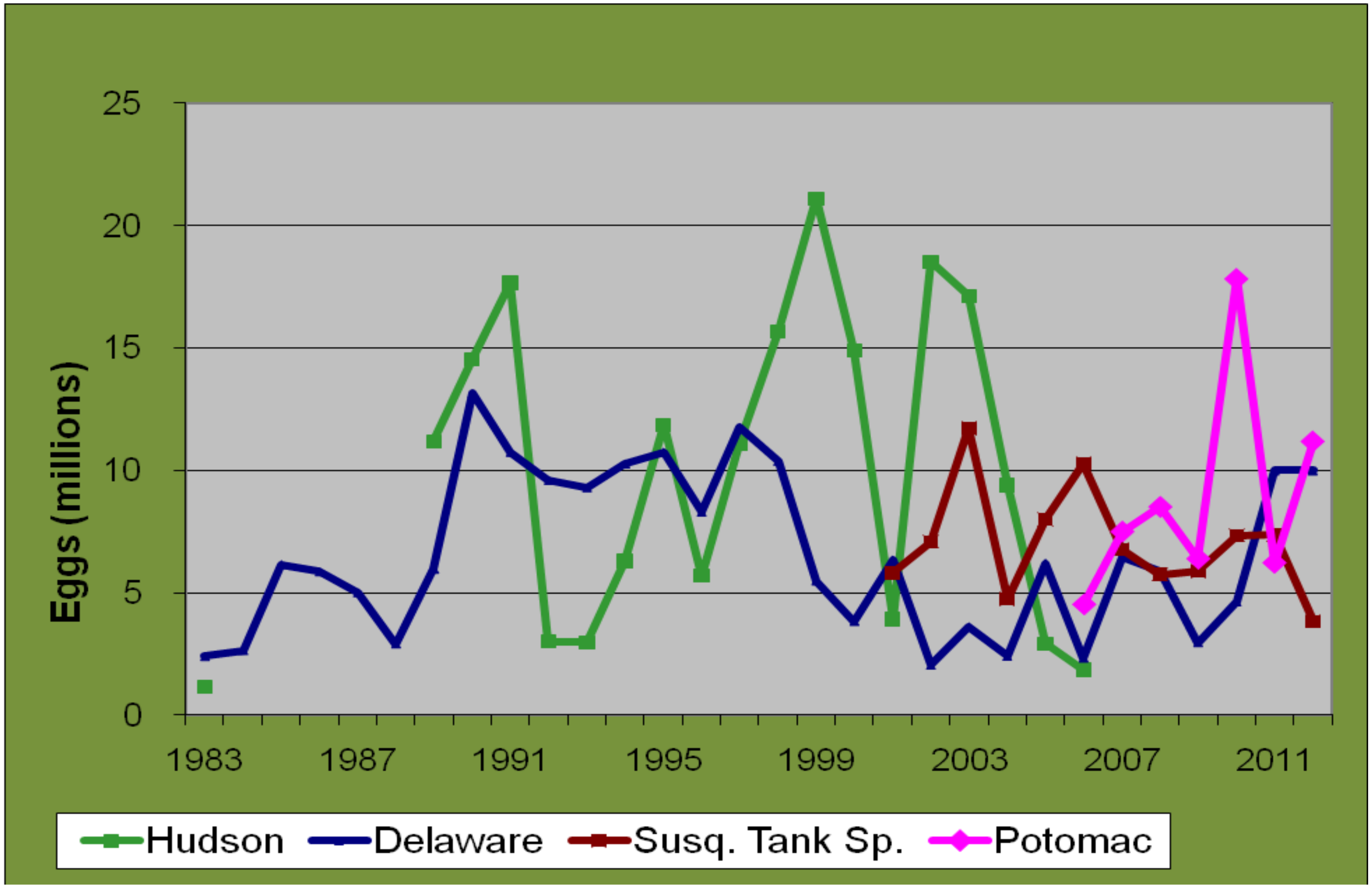


FIGURE 2. EGG VIABILITY (PERCENTAGE OF COLLECTED EGGS THAT ULTIMATELY HATCH) FOR AMERICAN SHAD STRIP SPAWNING OPERATIONS ON THE DELAWARE, POTOMAC AND HUDSON RIVERS.

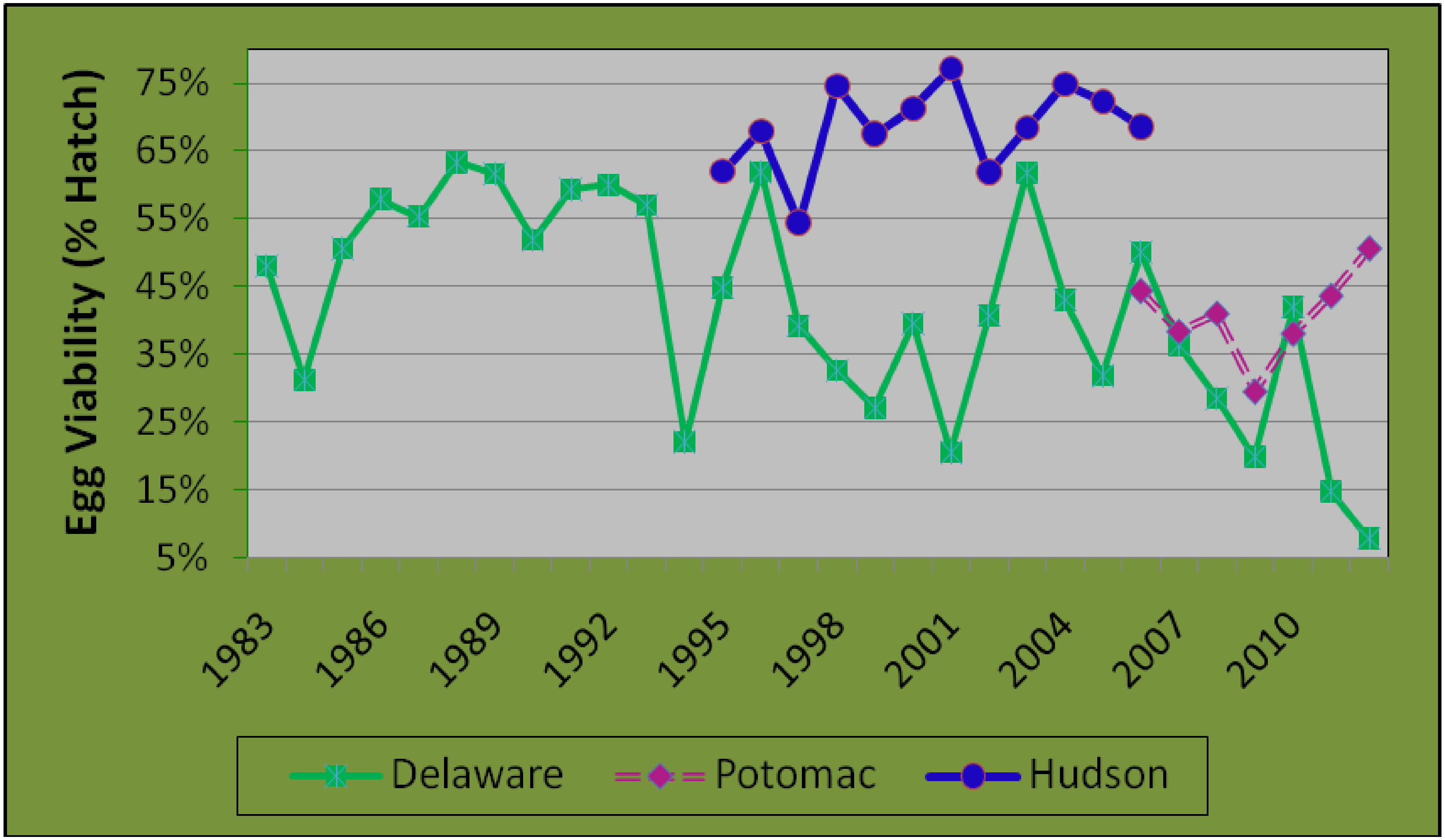
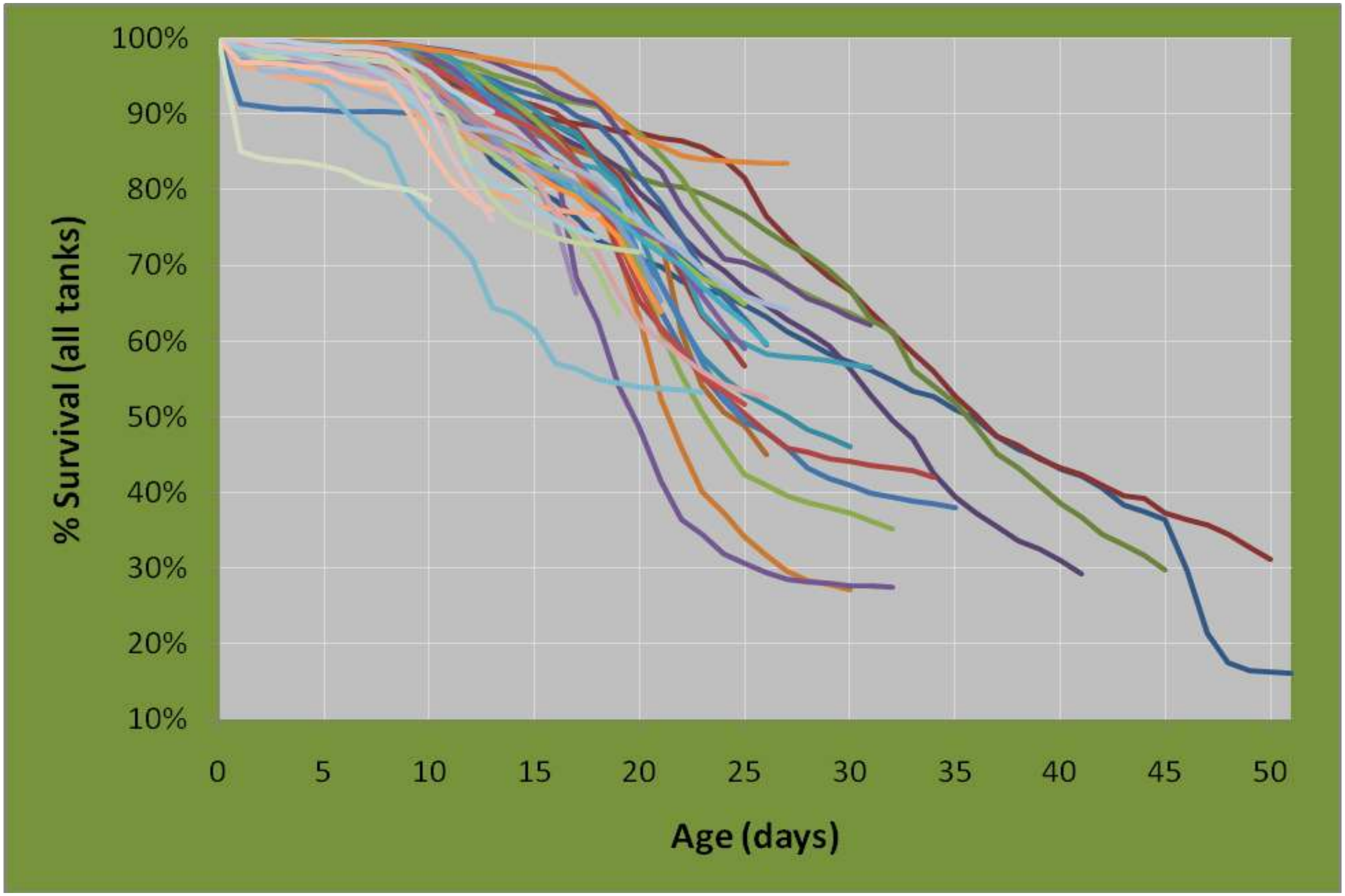


FIGURE 3. SURVIVAL OF AMERICAN SHAD LARVAE, ALL TANKS, VAN DYKE, 2012.



TABLES

Table 1. Egg shipments received at Van Dyke, 2012.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American shad	Potomac	3/27/12	3/28/12	9.0	357,894	174,485	48.8%
2	American shad	Potamac	3/28/12	3/29/12	15.1	650,480	390,888	60.1%
3	American shad	Potomac	3/29/12	3/30/12	13.7	533,825	371,087	69.5%
4	American shad	Potomac	4/1/12	4/2/12	14.8	547,762	213,441	39.0%
5	American shad	Potomac	4/2/12	4/3/12	17.1	678,010	378,236	55.8%
6	American shad	Potomac	4/3/12	4/4/12	15.8	603,173	380,251	63.0%
7	American shad	Potomac	4/4/12	4/5/12	19.4	877,635	559,703	63.8%
8	American shad	Potomac	4/5/12	4/6/12	16.6	612,531	313,616	51.2%
9	American shad	Potomac	5/10/12	5/11/12	21.2	817,665	454,599	55.6%
10	American shad	Potomac	4/11/12	4/12/12	16.6	606,195	358,699	59.2%
11	American shad	Potomac	4/12/12	4/13/12	8.1	294,856	153,356	52.0%
12	American shad	Potomac	4/15/12	4/16/12	8.8	521,038	306,885	58.9%
13	American shad	Potomac	4/16/12	4/17/12	9.7	512,645	31,184	6.1%
14	American shad	Potomac	4/17/12	4/18/12	10.2	409,738	227,364	55.5%
15	American shad	Potomac	4/18/12	4/19/12	25.7	1,129,104	673,087	59.6%
16	American shad	Potomac	4/23/12	4/24/12	18.5	789,108	522,839	66.3%
17	American shad	Susquehanna	4/26/12	4/26/12	14.6	768,492	150,037	19.5%
18	American shad	Potomac	4/26/12	4/27/12	18.0	1,241,798	155,199	12.5%
19	American shad	Susquehanna	4/29/12	4/29/12	10.3	929,657	236,061	25.4%
20	American shad	Susquehanna	5/3/12	5/3/12	7.1	353,400	47,453	13.4%
21	American shad	Susquehanna	5/6/12	5/6/12	14.9	921,945	358,954	38.9%
22	American shad	Delaware	5/13/12	5/14/12	6.4	681,306	32,116	4.7%
23	American shad	Delaware	5/14/12	5/15/12	17.5	912,661	156,365	17.1%
24	American shad	Delaware	5/15/12	5/16/12	3.0	133,098	29,947	22.5%
25	American shad	Delaware	5/20/12	5/21/12	11.7	984,404	84,939	8.6%
26	American shad	Delaware	5/21/12	5/22/12	8.7	828,402	64,828	7.8%
27	American shad	Susquehanna	5/22/12	5/23/12	8.2	507,379	74,385	14.7%
28	American shad	Delaware	5/22/12	5/23/12	6.0	371,253	80,488	21.7%
29	American shad	Delaware	5/23/12	5/24/12	30.8	1,759,652	236,917	13.5%
30	American shad	Delaware	5/24/12	5/25/12	5.9	480,897	9,160	1.9%
31	American shad	Susquehanna	5/26/12	5/26/12	5.6	346,503	74,705	21.6%
32	American shad	Delaware	5/28/12	5/29/12	7.9	775,253	0	0.0%
33	American shad	Delaware	5/29/12	5/30/12	9.8	1,219,906	0	0.0%
34	American shad	Delaware	5/30/12	5/31/12	3.9	400,202	0	0.0%
35	American shad	Delaware	5/31/12	6/1/12	4.5	444,920	0	0.0%
Totals			**No. of shipments**					
	American shad	**Potomac**	**17**		**258.0**	**11,183,457**	**5,664,920**	**50.7%**
		Delaware	**12**		**116.1**	**8,991,955**	**694,762**	**7.7%**
		Susq.- Conowingo	**6**		**60.7**	**3,827,377**	**941,595**	**27.1%**
		Grand total	**35**		**434.8**	**24,002,789**	**7,301,277**	**30.4%**

TABLE 2. ANNUAL SUMMARY OF AMERICAN SHAD PRODUCTION, 1976-2012.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of Fry stocked (exp.3)	No. of Finglerling 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	4,169	9	4,178	0.18	0.78
2012	435	24.0	30.4	7.3	3,437	2	3,439	0.14	0.47

*Includes fry reared at Manning Hatchery.

Total 268,058

Total since 1985 (OTC marked) 236,661

TABLE 3. AMERICAN SHAD EGGS USED IN PENNSYLVANIA'S SHAD RESTORATION PROGRAM, BY EGG SOURCE.

Year	Hudson Gill Net	Delaware Gill Net	Susquehanna Conowingo Tank Spawn	Susquehanna Lapidum Gill Net	Susquehanna Muddy Run Gill Net	Susquehanna Lamar Tank Spawn	Connecticut Gill Net	Pamunkey Gill Net	Mattaponi Gill Net	James Gill Net	Savannah Gill Net	Columbia Gill Net	Potomac Gill Net	Total
1971				8.42										8.42
1972				7.10										7.10
1973				4.74			4.30	8.45	6.48				34.64	58.61
1974							0.53	9.75	6.80	19.20		8.18	5.56	50.02
1975								1.88		7.15		18.42	5.70	33.15
1976		4.10										54.80		58.90
1977							0.35	4.40	0.57	3.42		8.90		17.64
1978								6.90		10.11		0.00		17.01
1979								3.17		4.99		0.00		8.16
1980								6.73		6.83		0.00		13.56
1981								4.58		1.26		5.78		11.62
1982								2.03		1.25		22.57		25.85
1983	1.17	2.40						5.49		5.91		19.51		34.48
1984		2.64						9.83		0.74		27.88		41.09
1985		6.16						5.28		2.05		12.06		25.55
1986		5.86						5.62		1.07		39.97		52.52
1987		5.01						4.35		0.11		23.53		33.00
1988		2.91						1.92		0.05		26.92		31.79
1989	11.18	5.96						1.91		0.53		23.10		42.68
1990	14.53	13.15				0.33		0.48			0.12			28.61
1991	17.66	10.75				0.30	1.10							29.80
1992	3.00	9.60					5.71			0.17				18.49
1993	2.97	9.30					7.45	1.78						21.50
1994	6.29	10.27					4.09	0.53	0.03					21.22
1995	11.85	10.75												22.61
1996	5.69	8.31				0.41								14.41
1997	11.08	11.76												22.84
1998	15.68	10.38				1.66								27.72
1999	21.10	5.49												26.59
2000	14.88	3.83												18.71
2001	3.92	6.35	5.81			5.05								21.13
2002	18.51	2.04	7.08			7.99								35.62
2003	17.12	3.61	11.72	0.56	0.02									33.04
2004	9.39	2.41	4.74	0.75										17.29
2005	2.92	6.21	8.00										0.00	17.14
2006	1.86	2.33	10.28										4.51	18.98
2007	0.00	6.46	6.77										7.49	20.72
2008		5.87	5.75										8.50	20.12
2009		2.96	5.89										6.38	15.23
2010		4.63	7.34										17.84	29.82
2011		9.99	7.36										6.22	23.57
2012		8.99	3.83										11.18	24.00
Total	190.81	200.49	84.57	21.57	0.02	15.74	23.53	85.08	13.88	64.84	0.12	291.62	108.03	1,100.30

TABLE 4. AMERICAN SHAD STOCKING, 2012.

Date	Tank		Species	Number	Location	OTC mark (days)	Origin	Age	Size
5/25/12	A1	1	American shad	28,172	North Branch Susq. River	3,6,9,15	Potomac	51	Fry
5/25/12	A2	1	American shad	121,501	North Branch Susq. River	3,6,9,15	Potomac	50	Fry
5/21/12	A3	1	American shad	109,991	West Branch Susq. River	3,18	Potomac	45	Fry
5/21/12	A4	1	American shad	62,329	West Branch Susq. River	3,18	Potomac	41	Fry
5/7/12	B1	1	American shad	117,138	Juniata R.	3	Potomac	26	Fry
5/7/12	B2	1	American shad	81,684	Juniata R.	3	Potomac	26	Fry
5/7/12	B3	1	American shad	123,953	Juniata R.	3	Potomac	25	Fry
5/7/12	B4	1	American shad	103,808	Juniata R.	3	Potomac	25	Fry
5/14/12	C1	1	American shad	173,938	Juniata R.	3	Potomac	30	Fry
5/14/12	C2	1	American shad	100,000	Juniata R.	3	Potomac	30	Fry
5/14/12	C3	1	American shad	84,275	Juniata R.	3	Potomac	29	Fry
5/14/12	C4	1	American shad	35,273	Juniata R.	3	Potomac	29	Fry
5/21/12	D1	1	American shad	84,047	Juniata R.	3	Potomac	34	Fry
5/21/12	D2	1	American shad	98,375	Juniata R.	3	Potomac	34	Fry
5/21/12	D3	1	American shad	62,459	Juniata R.	3	Potomac	32	Fry
5/21/12	D4	1	American shad	49,675	Juniata R.	3	Potomac	32	Fry
5/22/12	E1	1	American shad	86,686	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	31	Fry
5/21/12	E2	1	American shad	256,381	Juniata R.	3	Potomac	27	Fry
5/21/12	E3	1	American shad	128,267	Juniata R.	3	Potomac	25	Fry
5/22/12	E4	1	American shad	87,595	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	25	Fry
5/22/12	F1	1	American shad	115,140	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	26	Fry
5/22/12	F2	1	American shad	101,072	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	26	Fry
5/23/12	F3	1	American shad	92,910	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	26	Fry
5/23/12	F4	1	American shad	171,857	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	21	Fry
5/23/12	G1	1	American shad	166,029	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	21	Fry
5/23/12	G2	1	American shad	117,530	Raystown Br. Juniata R., below Raystown Lake	3,6,9	Susquehanna	19	Fry
5/24/12	G3	1	American shad	98,628	Raystown Br. Juniata R., below Raystown Lake	3	Potomac	19	Fry
5/24/12	G4	1	American shad	156,737	Raystown Br. Juniata R., below Raystown Lake	3,6,9	Susquehanna	18	Fry
6/8/12	H1	1	American shad	23,311	Raystown Br. Juniata R., below Raystown Lake	3,6,9	Susquehanna	28	Fry
6/2/12	H2	1	American shad	271,120	Bald Eagle Cr.	3,6,9,12,15	Susquehanna	19	Fry
6/18/12	H3	1	American shad	87,492	Lehigh R.	9,12,15	Delaware	26	Fry
6/18/12	H4	1	American shad	44,642	Lehigh R.	9,12,15	Delaware	26	Fry
6/18/12	I1	1	American shad	107,814	Lehigh R.	9,12,15	Delaware	20	Fry
6/8/12	I2	1	American shad	68,676	Raystown Br. Juniata R., below Raystown Lake	3,6,9	Susquehanna	10	Fry
6/18/12	I3	1	American shad	61,164	Lehigh R.	9,12,15	Delaware	18	Fry
6/14/12	A1	2	American shad	59,139	Schuykill R,	3,6,9,12	Delaware	13	Fry
6/14/12	A2	2	American shad	78,289	Schuykill R,	3,6,9,12	Delaware	13	Fry
6/14/12	A3	2	American shad	63,001	Schuykill R,	3,6,9,12	Delaware	13	Fry
6/13/12	A4	2	American shad	58,780	Raystown Br. Juniata R., below Raystown Lake	3,6,9	Susquehanna	10	Fry
10/1/12	Race way Cultu re		American shad	1,500	Juniata River, Lewistown Narrows	various imm. tags, single feed tag	Potomac/ Delaware/ Susquehanna		Fing.

TABLE 5. SUMMARY OF JUVENILE ALOSINES STOCKED FROM THE VAN DYKE HATCHERY, 2012.

	Site	Fry
American shad Releases	Millerstown (Rt. 17 Bridge)	1,499,272
	Raystown Br. Juniata R., below Raystown Lake	1,344,952
	Juniata River Subtotal	**2,844,223**
	Bald Eagle Creek	271,120
	North Branch Susquehanna River (PA)	149,672
	West Banch Susquehanna River	172,320
	Susquehanna River Basin Subtotal	**3,437,335**
	Schuylkill River	200,429
	Lehigh River	301,112
	Total American Shad Fry	**3,938,876**
	Juniata River — **American Shad Fingerling**	**1,500**
	Total	**3,940,376**

TABLE 6. SUMMARY OF MARKED ALOSINES STOCKED IN PENNSYLVANIA, 2012.

Number	Size	Immersion mark (days)	Stocking Location	Egg Source	Immersion mark	Immersion Mark Retention (%)	Feed Mark	Feed Mark Retention (%)	Fry Culture	Fingerling Culture
American shad										
172,320	Fry	3,18	W. Br. Susq. R.	Potomac	427ppm OTC	100%	-	-	Van Dyke	-
271,120	Fry	3,6,9,12,15	Bald Eagle Creek	Potomac	427ppm OTC	97%	-	-	Van Dyke	
425,034	Fry	3,6,9	Raystown Branch Juniata R.	Susquehanna	427ppm OTC	100%	-	-	Van Dyke	-
2,419,189	Fry	3	Raystown Branch Jun. R. or Juniata R.	Potomac	427ppm OTC	100%	-	-	Van Dyke	-
149,672	Fry	3,6,9,15	N. Br. Susq. R.(PA)	Potomac	427ppm OTC	100%	-	-	Van Dyke	-
3,437,335	Fry	Total Susquehanna River Basin								
301,112	Fry	9,12,15	Lehigh R.	Delaware	427ppm OTC	97%	-	-	Van Dyke	-
200,429	Fry	3,6,9,12	Schuylkill R.	Delaware	427ppm OTC	100%	-	-	Van Dyke	-
501,541	Fry	Total Delaware River Basin								
1,500	Fing.	various	Juniata R.	various	427ppm OTC	0	single	-	Van Dyke	Benner Spring
3,940,376		**Total American shad stocked**								

APPENDIX 1 – SURVIVAL OF AMERICAN SHAD LARVAE RELEASED AT VARIOUS SITES IN THE SUSQUEHANNA RIVER – 2012

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INTRODUCTION

Development of tetracycline marking has permitted evaluation of the relative success of the hatchery component of the American shad restoration program (Hendricks et al., 1991). Larvae are marked by 4h immersion in oxytetracycline hydrochloride. Detectable fluorophore from these marks is visible in the one otolith increment produced on the day of marking. Multiple marks, 3 or 4d apart, have been used to evaluate the relative survival of groups uniquely marked according to release site, egg source river, release time of day, or release habitat (Hendricks et al., 1992, Hendricks et al., 1993).

From 1976 to 1992, American shad larvae reared at the Van Dyke Research Station for Anadromous Fish were stocked into the Juniata River at 18-21d of age. The rationale behind that decision was based upon the observation that hatchery-reared shad larvae exhibit a period of high mortality from 9 to 14d of age associated with the transition from endogenous to exogenous feeding (Wiggins et al., 1985). During this "critical period" profound physiological and ecological changes take place, as old functions are replaced by new functions (Li and Mathias, 1987). It was assumed that improved survival in the wild could be attained by culturing the larvae through the critical period to ensure they received an adequate food supply and protection from predators.

In 1993, two tanks of Connecticut River larvae were marked at 5 days of age and stocked at 7 days of age to avoid anticipated high mortality due to an unknown (disease?) factor. These larvae stocked at 7d of age exhibited a recovery rate 1.6 times that of another uniquely marked tank and 4.0 times that of the remainder of the Connecticut River fish stocked between 22 and 26 days of age (St. Pierre, 1994).

Research conducted in 1994 demonstrated that larvae released at 7d of age experienced 7.8 times better survival compared to controls released at 20d of age, and 2.2 times better survival compared to production groups released at 14 to 18d of age (Hendricks, 1995). It was assumed that the observed differences in survival were due to age at release.

As a result, production larvae stocked in 1995 and 1996 were released at 7 days of age. In order to imprint larvae to other areas in the drainage, smaller numbers of larvae were released in tributary streams or other main-stem areas (North Branch and West Branch Susquehanna River) within the Susquehanna River Basin. In order to mark these larvae with unique tetracycline marks, they had to be stocked as older larvae. Recovery rates of these uniquely marked larvae stocked in

1995 and 1996 suggested that larvae released at 7 days of age may not survive any better than those released later. One explanation for this is that multiple releases at any one site may be attracting predators to that site, resulting in reduced survival. It was theorized that spreading larvae out by stocking at a number of sites may result in improved survival.

A study was designed in 1997 to test this hypothesis, however, logistical considerations forced us to deviate from the plan and no conclusions could be drawn regarding the benefit of spreading larvae out to various stocking sites (Hendricks, 1998). Due to insufficient unique marks, we have never been able to conduct a controlled experiment to test the benefits of stocking larvae at various sites. Results in 1997, 1998 and 1999 suggested that small groups of larvae stocked in tributaries at older ages can survive as well as those stocked in the Juniata River at 7-10 days of age.

In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2012 and summarizes results from 1995 to 2012.

MATERIALS AND METHODS

Production larvae, stocked in 2012, included 2.4 million released in the Juniata River or Raystown Branch of the Juniata River, 425 thousand in the Raystown Branch of the Juniata River (Susquehanna River egg source) , 150 thousand in the North Branch Susquehanna River in Pennsylvania, 172 thousand in the West Branch Susquehanna River and 271 thousand in Bald Eagle Creek. Due to the lack of certification that the larvae were VHS free, no larvae were stocked in the Potomac River or New York waters of the Susquehanna River. The majority of the larvae were planned to be stocked in the Juniata River, however, persistent turbid water forced us to stock many of those fish in the Raystown Branch of the Juniata River below Raystown Lake. The large size of this lake settles out turbidity from all but the very largest storm events, consequently, its tailwaters are almost always clear.

Juvenile American shad were sampled from biomonitoring collections (haul seine) at City Island and Columbia, intakes at Peach Bottom Atomic Power Station, and from strainers at Safe Harbor and Conowingo Dam. A sub-sample of 30 fish per site per sampling date was retained for otolith analysis. Shad were frozen whole and delivered to the Benner Spring Fish Research Station for otolith analysis. Otoliths were extracted, mounted, ground and analyzed according to standard procedures (Hendricks et al., 1991). The number of fish observed with each unique mark was expanded to the entire sample by multiplying by the total number of fish collected in a sample and dividing by the number of fish sub-sampled for otolith analysis. Data for 1995 to 2009 was similarly corrected to account for the total number of shad collected, not just those sampled. Recovery rates were calculated for each group by dividing the expanded number of fish recovered by the number stocked and multiplying by 10,000 to remove the decimal point and convert the rate to a whole number. Relative survival was calculated by dividing the recovery rate for each group by the highest recovery rate.

RESULTS AND DISCUSSION

Haul seine collections in 2012 yielded a single shad collected at Columbia. Strainer samples at Safe Harbor and Conowingo yielded 33 and 1 shad, respectively. Some 29 juvenile shad were collected from intakes at Peach Bottom Atomic Power Station.

All groups of uniquely marked larvae were represented in the catch. Potomac River source larvae stocked in the West Branch exhibited the best survival (relative survival set to 1.00, Table A1-1). Potomac River egg source larvae stocked in the North Branch Susquehanna River (PA) exhibited relative survival of 0.148 Potomac River egg source larvae stocked in Bald Eagle Creek exhibited a relative survival of 0.054 Susquehanna River egg source larvae stocked in the Raystown Branch Juniata River had a relative survival of 0.023. Potomac River egg source larvae stocked in the Juniata/Raystown Branch Juniata River had a relative survival of 0.022.

A summary of the results of 17 years of uniquely marking larvae according to stocking site is provided in Table A1-2. Recovery rates for 2012 varied from 0.10 to 4.48. The poor survival, as evidenced by the low recovery rate, in 2012 continues a trend evident since 2005. The cause of this poor survival is unknown.

In general, larvae stocked in the West Branch Susquehanna River have exhibited better survival than other sites since 2005. In four of those eight years, relative survival was 1.00 and mean eight year relative survival from 2005 to 2012 was 0.73. Only Swatara Creek had higher relative survival for that period (0.82) but Swatara Creek was only stocked three years during that eight year time period. This contrasts to the previous eight years when mean relative survival for the West Branch was 0.23, the lowest of all other groups. We speculate that water quality improvements associated with acid mine drainage abatement projects are responsible for recent improvement in survival of shad larvae stocked in the West Branch.

Over time, relative survival of larvae stocked at other sites has varied with no apparent trend For example, the Chemung River had the highest relative survival in 2002, but none were recovered in 2003. Relative survival has ranged from 0.00 (the lowest possible) to 1 (the highest possible) for West Conewago Creek, the Conestoga River, the North Branch Susquehanna River, and the Chemung River. Annual variation has exceeded 0.85 for the Juniata and Susquehanna River at Montgomery Ferry, West Conewago Creek, and Swatara Creek. Considering only those sites stocked in nine or more years, mean relative survival ranged from 0.22 (Conestoga River) to 0.64 (Swatara Creek). Except for larvae stocked in the Juniata, Raystown Branch Juniata, and middle Susquehanna Rivers, all sites are generally stocked only once per year. The lack of trends over time suggests that survival of any one group is likely to be highly influenced by environmental conditions at the site, at the time of stocking. Favorable conditions promote good survival while poor conditions result in poor survival.

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TABLES

Table A1-1. Relative survival of American shad fry stocked at various sites in the Susquehanna River Basin, as determined by tetracycline marking of juveniles collected at Columbia, Safe Harbor, Peach Bottom and Conowingo, 2012.

				Larvae released		Juveniles recovered			
Stocking site	Egg Source	Age at Release	Release dates	N	%	N	%	Recovery rate	Relative Survival
Juniata/Rayst Branch	Potomac	19 - 34	5/7 - 5/24	2,419,189	70.4%	24.3	45.9%	0.100	0.022
Raystown Br.	Susquehanna	10 - 28	5/23 - 6/13	425,034	12.4%	4.4	8.3%	0.104	0.023
N. Br. Susq. (PA)	Potomac	50 - 51	5/25	149,672	4.4%	9.9	18.7%	0.664	0.148
West Branch	Potomac	41 - 45	5/21	172,320	5.0%	7.7	14.6%	4.482	1.000
Bald Eagle Creek	Potomac	19	6/2	271,120	7.9%	6.6	12.5%	0.244	0.054
			Total	3,437,335		53			

Table A1-2. Annual summary of relative survival of American shad fry stocked at various sites in the Susquehanna River Basin, as determined by tetracycline marking of juveniles collected at City Island, Columbia, Safe Harbor, Peach Bottom and Conowingo, 1995-2012.

Stocking	Recovery Rate										
Site	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007
Juniata R./Susq. R. @												
Mont. Ferry	2.12	0.10	1.85	-	-	0.72	2.07	0.15	0.05	0.26	-	0.13
Juniata R.(various sites)	-	-	2.09	0.15	0.63	-	-	-	-	-	0.20	
Juniata R.(Susq. eggs)	-	-	-	0.10	-	-	1.32	0.37	0.14	0.31	0.12	
Juniata/Raystown Br.												
Raystown Branch												
Huntingdon	-	-	1.52	-	-	-	-	-	-	-	-	
Standing Stone Cr.	-	0.00	-	0.00	-	-	-	-	-	-	-	
Conodoguinet Cr.	2.52	0.12	0.29	0.05	0.51	0.54	0.07	0.00	0.06	-	0.24	0.15
mouth of Conodiguinet C	2.96	-	-	-	-	-	-	-	-	-	-	
Conestoga R.	3.28	0.00	0.26	0.00	0.87	0.13	0.22	0.00	0.00	-	0.06	
mouth of Conestoga Cr.	1.18	-	-	-	-	-	-	-	-	-	-	
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-	-	
Conewago Cr.	-	-	-	0.19	0.18	0.61	0.18	0.00	0.10	-	0.00	0.20
Swatara Cr.	-	-	-	0.20	0.69	0.00	1.15	0.00	0.19	-	0.22	
Bald Eagle Cr.												
W. Br. Susq. R.	-	0.09	0.86	0.00	0.00	0.17	0.09	0.54	0.07	1.64	0.29	0.16
N. Br. Susq. R.(PA)	-	0.34	2.02	0.21	0.19	0.40	1.06	0.00	0.09	-	0.00	0.00
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.64	0.04	-	0.00	
Chemung R.	-	-	-	-	-	-	-	1.02	0.00	-	0.06	
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.50	-	
Overall	2.13	0.12	1.77	0.15	0.54	0.62	1.37	0.27	0.07	0.41	0.14	0.13

Table A1-2. (continued).

Stocking Site	Recovery Rate 2008	2009	2010	2011	2012
Juniata R./Susq. R. @ Mont. Ferry	0.27		0.01		
Juniata R.(various sites)				0.07	
Juniata R.(Susq. eggs)			0.01	0.03	
Juniata/Raystown Br.					0.10
Raystown Branch					0.10
Huntingdon					
Standing Stone Cr.					
Conodoguinet Cr.	0.00	0.00	0.05		
mouth of Conodiguinet Cr.		0.00			
Conestoga R.	0.00		0.00		
mouth of Conestoga Cr.					
Muddy Cr.					
Conewago Cr.	0.00		0.00		
Swatara Cr.	0.24		0.10		
Bald Eagle Cr.				0.05	0.24
W. Br. Susq. R.	0.18	0.05	0.04	0.01	4.48
N. Br. Susq. R.(PA)	0.35	0.00	0.09	0.00	0.66
N. Br. Susq. R.(NY)					
Chemung R.					
Liverpool (Del. source)					
Ovei	0.18	0.02	0.02	0.02	0.15

Table A1-2. (continued).

	Relative Survival										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	2007
Juniata R./Susq. R. @												
Mont. Ferry	0.65	0.31	0.89	-	-	1.00	1.00	0.15	0.29	0.16	-	0.64
Juniata R.(various sites)	-	-	1.00	0.72	0.73	-	-	-		-	0.71	
Juniata R.(Susq. eggs)	-	-	-	0.49	-	-	0.64	0.37	0.73	0.19	0.42	
Juniata/Raystown Br.												
Raystown Branch												
Huntingdon	-	-	0.72	-	-	-	-	-	-	-	-	
Standing Stone Cr.	-	0.00	-	0.00	-	-	-	-	-	-	-	
Conodoguinet Cr.	0.77	0.37	0.14	0.25	0.59	0.74	0.03	0.00	0.32	-	0.85	0.73
mouth of Conodiguinet C	0.90	-	-	-	-	-	-	-	-	-	-	
Conestoga R.	1.00	0.00	0.12	0.00	1.00	0.18	0.11	0.00	0.00	-	0.22	
mouth of Conestoga Cr.	0.36	-	-	-	-	-	-	-	-	-	-	
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-	-	
Conewago Cr.	-	-	-	0.89	0.20	0.84	0.09	0.00	0.55	-	0.00	1.00
Swatara Cr.	-	-	-	0.96	0.80	0.00	0.56	0.00	1.00	-	0.78	
Bald Eagle Cr.												
W. Br. Susq. R.	-	0.28	0.41	0.00	0.00	0.23	0.05	0.54	0.36	1.00	1.00	0.80
N. Br. Susq. R.(PA)	-	1.00	0.97	1.00	0.21	0.56	0.51	0.00	0.47	-	0.00	0.00
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.62	0.22	-	0.00	
Chemung R.	-	-	-	-	-	-	-	1.00	0.00	-	0.20	
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.31	-	

Note: No juveniles were recovered from Holtwood, Peach Bottom or Conowingo in 2004.

Table A1-2. (continued).

	Relative Survival					
	2008	2009	2010	2011	2012	Mean
Juniata R./Susq. R. @						
Mont. Ferry	0.77		0.08			0.54
Juniata R.(various sites)				1.00		0.83
Juniata R.(Susq. eggs)			0.12	0.44		0.43
Juniata/Raystown Br.					0.02	0.02
Raystown Branch					0.02	0.02
Huntingdon						0.72
Standing Stone Cr.						0.00
Conodoguinet Cr.	0.00	0.00	0.53			0.38
mouth of Conodiguinet Cr.		0.00				0.45
Conestoga R.	0.00		0.00			0.22
mouth of Conestoga Cr.						0.36
Muddy Cr.						0.00
Conewago Cr.	0.00		0.00			0.36
Swatara Cr.	0.70		1.00			0.64
Bald Eagle Cr.				0.77	0.05	0.41
W. Br. Susq. R.	0.51	1.00	0.40	0.10	1.00	0.48
N. Br. Susq. R.(PA)	1.00	0.00	0.87	0.00	0.15	0.45
N. Br. Susq. R.(NY)						0.28
Chemung R.						0.40
Liverpool (Del. source)						0.31

Note: No juveniles were recovered from Holtwood, Peach Bottom or Conowingo in 2004.

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 Inflatable 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

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FIGURES

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

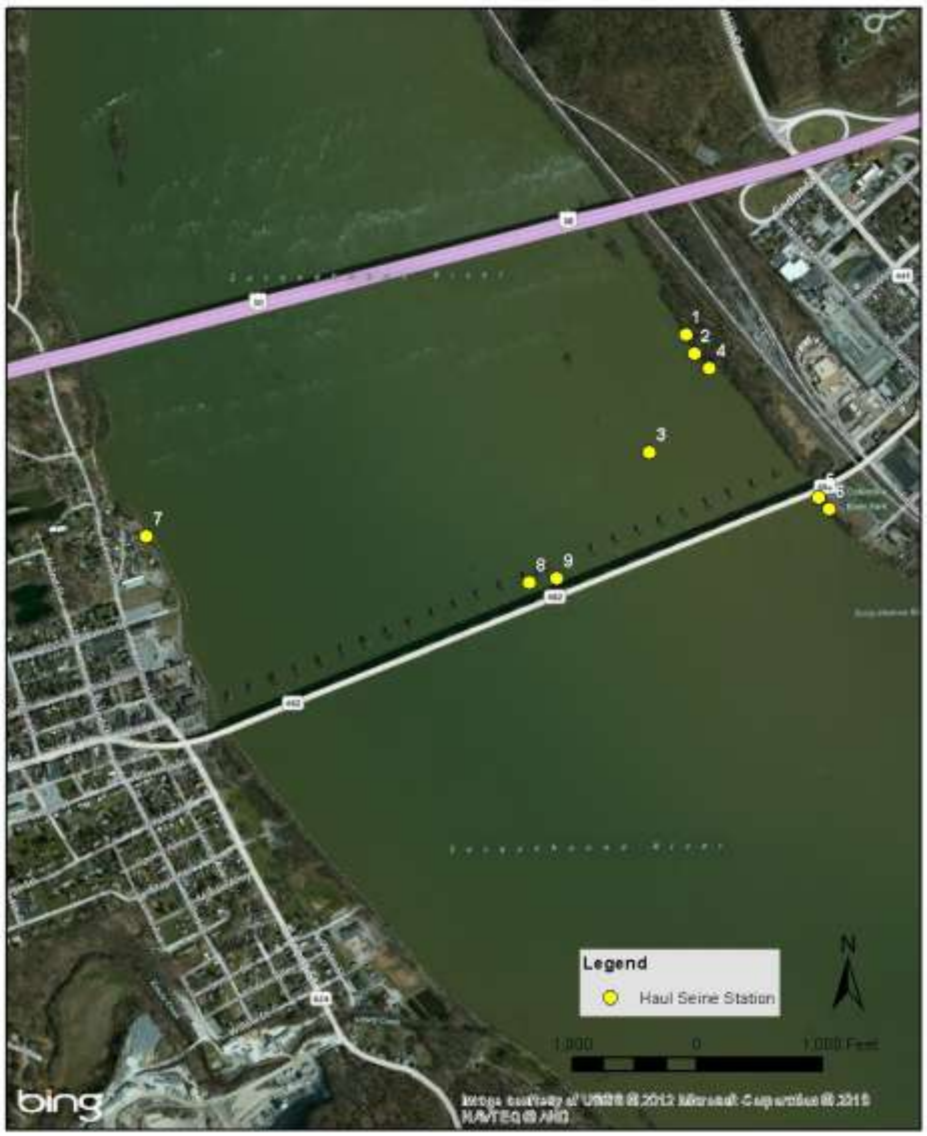


Figure 1.

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.

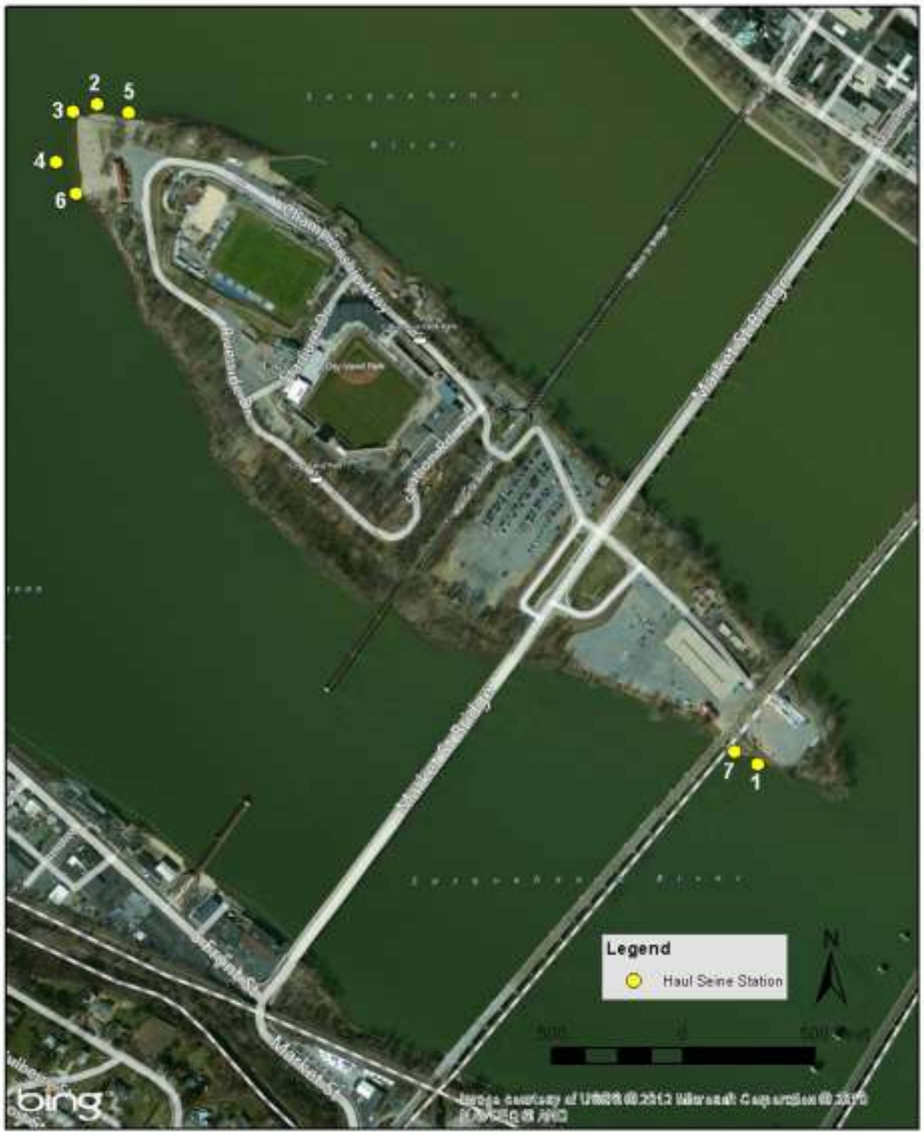


Figure 1.

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.

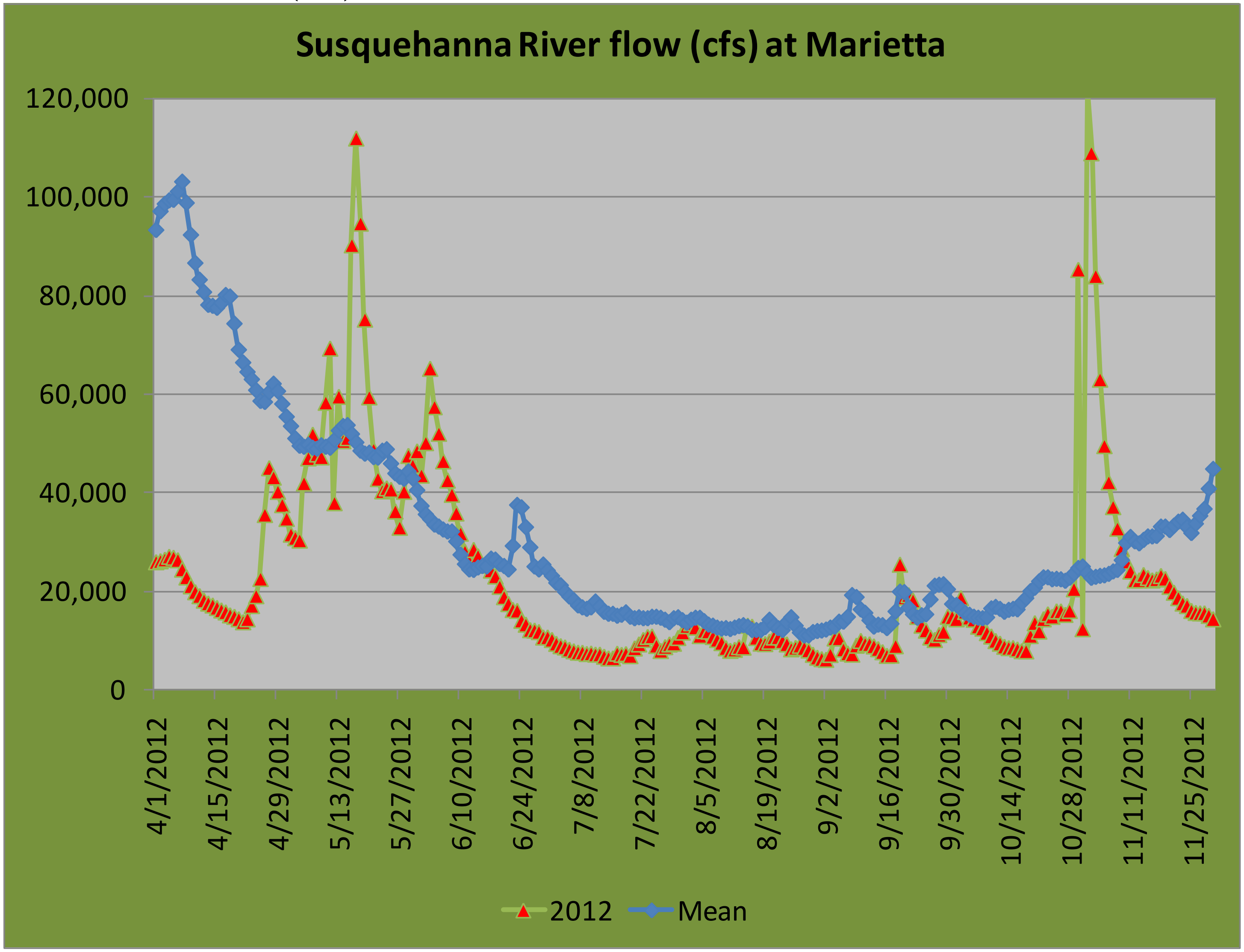
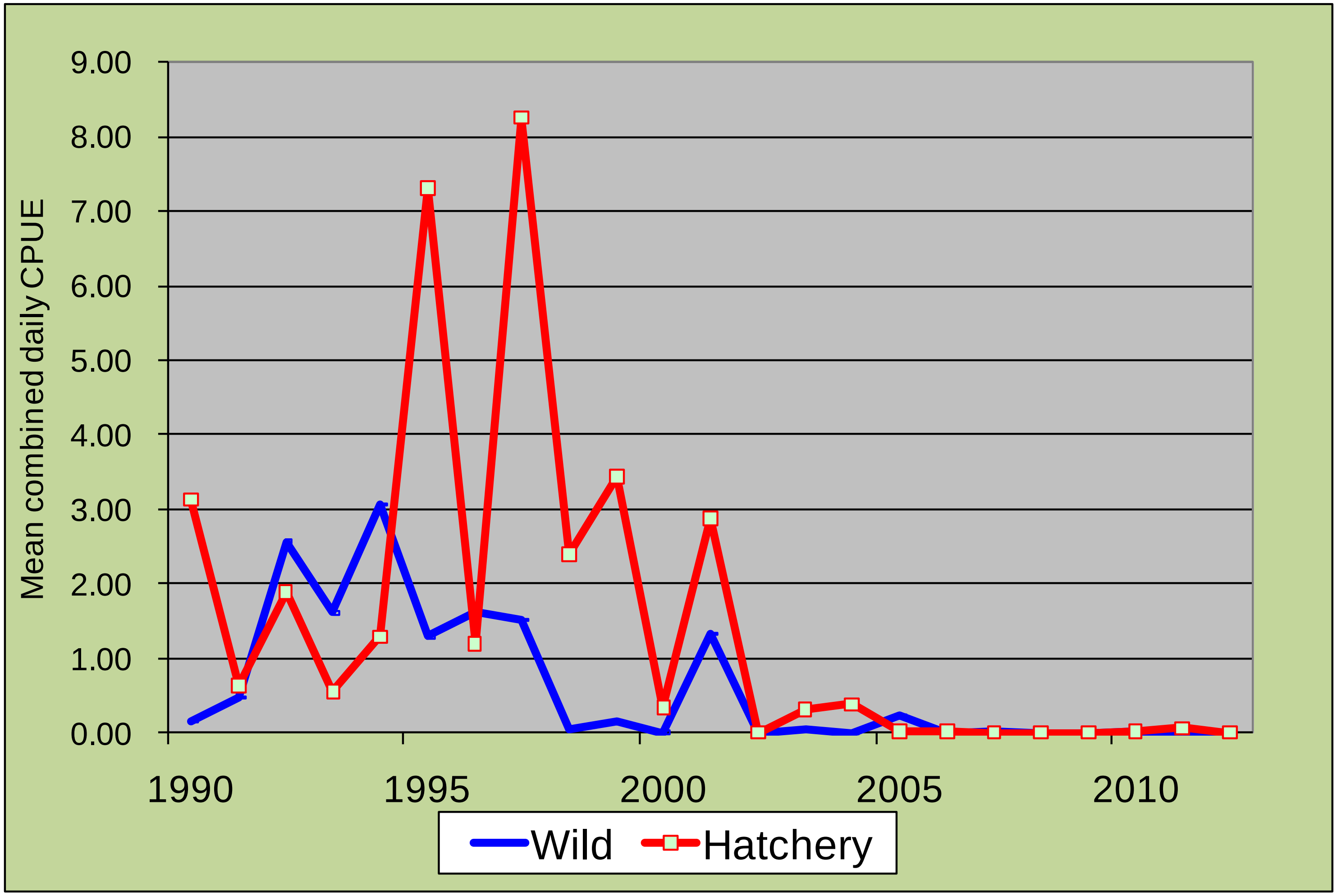


FIGURE 4. ANNUAL YOY AMERICAN SHAD CPUE FOR HAUL SEINE COLLECTIONS IN THE SUSQUEHANNA RIVER AT COLUMBIA.



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		
Year	No. Hauls	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Haul CPUE*	No. Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	No. Fish	Mean Combined Daily CPUE (Hatchery)	GM Combined Daily CPUE (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.

Year	No. Hauls	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Haul CPUE*	No. Wild Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	No. Hatchery Fish	Mean Combined Daily CPUE (Hatchery)	GM Combined Daily CPUE (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.

		Total					Wild				Hatchery			
Year	No. Lifts	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Lift CPUE*	Area under curve CPUE	No. Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	Area under curve CPUE	No. Fish	Mean Combined Daily CPUE (Hatchery)	GM Combined Daily CPUE (Hatchery)	Area under curve CPUE
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*.

	Historical Years															
Week	**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.

	Historical Years							Year
Week	**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**
TOTAL	***1***	***0***	***1***

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.

HATCHERY CONTRIBUTION AND COHORT ANALYSIS OF ADULT AMERICAN SHAD COLLECTED IN THE SUSQUEHANNA RIVER BASED ON TETRACYCLINE TAGGING – 2012

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ABSTRACT

A total of 128 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2012. Based on tetracycline marking and otolith microstructure, 76% of the 121 readable otoliths were identified as wild and 24% were identified as hatchery in origin. Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1986-2007 year classes, stocking of approximately 404 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 196 fingerlings was required to return one adult to the lifts. For wild fish, transport of 1.28 adults to upstream areas was required to return one wild fish to the lifts. Actual survival is even higher since not all surviving adults enter the lifts.

INTRODUCTION

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). Primary restoration approaches consisted of: 1) trapping of pre-spawn adults at Conowingo Dam and transfer to areas above dams (1972 to 1999), 2) direct fish passage (1997 to the present), and 3) planting of hatchery-reared fry and fingerlings (1976 to the present).

In order to evaluate and improve the program, it was necessary to know the relative contribution of the hatchery program to the overall restoration effort. Toward that end, the Pennsylvania Fish Commission developed a physiological bone mark which could be applied to developing fry prior to release (Lorson and Mudrak, 1987; Hendricks et al., 1991). The mark was produced in otoliths of hatchery-reared fry by immersion in tetracycline antibiotics. Analysis of otoliths of outmigrating juveniles allows discrimination of "wild" vs. hatchery reared fish. The first successful application of tetracycline marking at Van Dyke was conducted in 1984. Marking on a production basis began in 1985 but was only marginally successful (Hendricks, et al., 1986). In 1986, 97.8% tag retention was achieved (Hendricks, et al., 1987) and analysis of outmigrants indicated that 84% of the upstream production (above Conowingo Dam) was of hatchery origin vs. 17% wild (Young, 1987). Similar data has been collected in subsequent years.

Determination of the contribution to the overall <u>adult</u> population below Conowingo Dam of hatchery-reared and wild fish resulting from restoration efforts was more complicated. The adult population of shad below Conowingo Dam includes: 1) wild, upper bay spawning stocks which are a remnant of the formerly abundant Susquehanna River stock; 2) wild fish of upstream origin which are progeny of adults from out-of-basin or Conowingo trap and transfer efforts, 3) hatchery-reared fish originating from stockings in main stem or tributary areas upstream from Conowingo Dam and 4) hatchery-reared fish originating from stockings below the Conowingo Dam. The latter group were fish which received a "double" tetracycline mark and were planted below Conowingo Dam from 1986 to 1996.

Since mark retention did not approach 100% until 1987, adult hatchery shad from cohorts produced before 1987 did not exhibit 100% marking. For the years in which these fish returned to the river as adults, marking rates could therefore be used only to determine minimum contribution of hatchery-reared fish. For fish which did not exhibit a mark, otolith microstructure (Hendricks et al., 1994) was used to distinguish hatchery fish from wild fish.

METHODS

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad which entered the West lift. These collections were supplemented with fish sampled from tank-spawning trials at Conowingo Dam. Each sampled fish was sexed, measured and decapitated. Whole heads were frozen and delivered to the Van Dyke Hatchery. Otoliths (sagittae) were extracted, cleaned, and one otolith was mounted for mark analysis in Permount® on a microscope slide, while the other was stored in mineral oil in 24-well, cell culture clusters.

For mark analysis, otoliths were ground on both sides to produce a thin sagittal section and the specimen examined under UV light for the presence of a tetracycline mark.

Whole otoliths were aged by viewing with a dissecting microscope and a fiber optic light. The best contrast was obtained by directing the light from the side, parallel to the sagittal plane of the otolith. Ageing was done by a single researcher. After initial ageing, length at age was analyzed and apparent outliers were re-examined. We have assembled a collection of several hundred otoliths from known-aged shad based on the presence of a unique tetracycline mark. These were used as reference material.

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 2012. Age composition data was gathered as follows: for 1996 to 2012, age composition data were collected from the aforementioned otolith analysis. For 1991-1995, age composition data were taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1989 and 1990, age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transporting mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991).

Recruitment to the lifts by year class was determined for hatchery and wild origin fish by partitioning the lift catch for each year into its component year classes based upon age composition and otolith marking data. Only virgin adults were used to prevent double counting. Total recruitment by year class was determined for hatchery and wild groups by summing the data for each year class over its recruitment history. The number of larvae required to return one adult to the lifts (L/A) was determined for each year class by dividing the number of larvae stocked above dams by the total recruitment of adults which originated as hatchery larvae. Similarly, the number of fingerlings required to return one adult (F/A) was determined for each year class by dividing the number of fingerlings stocked above dams by the total recruitment of adults which originated as hatchery fingerlings. The number of transported adults required to return one adult (TA/A) was determined for each year class by dividing the number of adults transported upstream by the total recruitment of unmarked (wild) adults. Overall L/A, F/A and

TA/A were calculated by dividing the sum of the number stocked or transported by the sum of the total recruitment of the group, for the cohorts in question.

RESULTS AND DISCUSSION

A total of 128 shad was sacrificed for otolith analysis from Conowingo Dam in 2012. Of these, 616 were from tank-spawn trials and the remainder were from West Lift sacrifices or special collections. No samples were collected from the East Lift since it was operated in fish passage mode. There were 7 unreadable otoliths (Table 1). A total of 92 (76%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 29 (24%) fish exhibited tetracycline marks including single, double, triple, quadruple, sextuple and septuple marks.

Two shad were collected with an OTC tag at day 18 only. That mark was used in 2006 only and thus these two fish were known age (age 5). Both fish were aged (otoliths and scales) before the OTC tag was detected and determined to be age 5. Two similarly marked fish (known age 4) were collected in 2010and five were collected in 2011 (known age 5). Scales and otoliths of these fish have been archived for future reference.

Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. The contribution of wild (naturally produced) fish to the adult population entering the Conowingo Dam fish lifts during 1989-2011 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish showed an increasing trend from 1989 to 2000 and have decreased since 2000 (Figure 2). This is consistent with the coastwide depression of American shad stocks documented in the ASMFC stock assessment (ASMFC 2007).

Length frequencies, age frequencies, mean total length, and mean weight are detailed in Tables 3 to 7. In general, age, length and weight increased from 1993 to 2003, decreased from 2004 to 2009, increased in 2010 and 2011, and remained stable in 2012. Increases in size in 2007and 2011 were related to the scarcity of younger fish. Sex ratios (Table 8) have ranged from 1:0.05 to 1:2.0 (males: females) with no trend over time.

Tables 9 and 10 detail age and repeat spawning. Repeat spawning has been highly variable, ranging from 1% in 2001 to 45% in 2002, however, determination of repeat spawning is an inexact science.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 10, while percent virgin by year and age is presented in Table 11. Analysis of otoliths to assess hatchery contribution was not conducted prior to 1989. As a result, the catch for year classes prior to 1986 could not be partitioned into hatchery and wild and are not presented. Year classes after 2007 are not fully recruited and are not included in the analysis. For the period 1986-2007, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 68 to 1,795, with a mean of 404 (Table 12). L/A was high (477-724) for the early cohorts (1986 – 1989). During 1990 to 2002, L/A improved to 68-446, presumably due to improvements in fish culture practices. The highest L/A (1,795) was for the 2003 cohort, a year when high flows hampered stocking efforts.

L/A was surprisingly low in comparison to the reproductive potential of wild fish. If fecundity of wild females is assumed to be 200,000, then 2 of 200,000 eggs must survive to maturity to replace the spawning pair in a stable population. If we assume a fertilization rate of 60% (comparable to strip-spawning), 60,000 fertilized eggs would be required to produce one wild adult at replacement. This suggests that mortality in the wild is extremely high during incubation and/or for the first week after hatch.

This analysis was repeated for fingerlings stocked above Conowingo Dam (Table 13). For the period 1986-2003, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 44 to 305, with an overall value of 196. At first glance, it would appear that stocking fingerlings is advantageous over stocking larvae, however, on average, one must stock 100,000 larvae in a pond to harvest 10,000 to 20,000 fingerlings. Therefore, it would take 700 to 1,400 larvae, stocked in a pond, then harvested and stocked in the river as fingerlings to produce one adult. Considering the cost of pond culture, it is clearly better to stock larvae directly. In future years, F/A is unlikely to change since the last significant fingerling stockings were in 1994 and the last fingerlings recovered were in 1999. The appearance of 220 recruited adults for the 1995 cohort and 43 for the 1996 cohort, when no fingerlings were stocked, is an artifact of erroneous ageing, and highlights the problems with ageing American shad.

A similar analysis was tabulated for wild fish (Table 14). For the period 1986 to 2006, transport of an average of 1.28 adults was required to produce one returning adult, above the level required for replacement. The actual stock/recruitment ratio of wild fish is unknown since some of the wild fish which entered the lifts would have been of Upper Bay origin and not all recruited fish entered the lifts. These factors may act to cancel each other out, but the magnitude of each is not known.

Stress during trucking may account for reduced performance of transported spawners. The high fecundity of the species has the potential to overcome this, since just a few successful spawners can produce huge numbers of offspring. Another possible explanation is that there may be some threshold number of spawners required to ensure successful spawning. Whatever the cause, stock/recruitment ratios must continue to improve to allow for successful restoration.

Virtual survival rates by cohort and stocking site are reported in Table 15. As expected, some cohorts survived better than others, probably due to environmental conditions. The 1996 cohort exhibited the highest virtual survival rate (146) followed by 1997 (134). The decline in cohort survival since 1997 is troubling, particularly in light of poor hatchery performance in 2003 to 2007. High river flows in 2003 and 2004 negatively impacted survival of hatchery fish. Reduced egg availability was problematic in 2005 and 2006, and severe hatchery mortality problems were encountered in 2007. Cohorts beyond 2007 are not yet fully recruited.

Adult relative survival for individual stocking sites was highly variable between cohorts (Table 15). For example, relative survival for the Juniata River/Juniata or middle Susquehanna sites ranged from 0.00 to 1.00. For the North Branch Susquehanna River (PA) the range was from 0.00 to 0.58. For Swatara Cr., relative survival ranged from 0.00 to 0.82. For West Conewago Cr. and Conodoguinet Cr., relative survival ranged from 0.00 to 1.00. Conodoguinet Creek exhibited the highest survival for the 2001 cohort and a very high relative survival for the 2000 and 2002 cohorts (0.88 and 0.71 respectively. Both adult and juvenile relative survival rates were consistently poor for the West Branch Susquehanna River until 2002 when they were 0.49 and 0.54, respectively. Relative survival of adults for the West Branch was the highest of any site for the 2004, 2005, and 2007 cohorts. This may be reflective of recent water quality improvements associated with mine drainage abatement projects.

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FIGURES

FIGURE 1. ESTIMATED COMPOSITION OF ADULT AMERICAN SHAD CAUGHT AT CONOWINGO DAM, BASED ON OTOLITH MICROSTRUCTURE AND TETRACYCLINE MARKING.

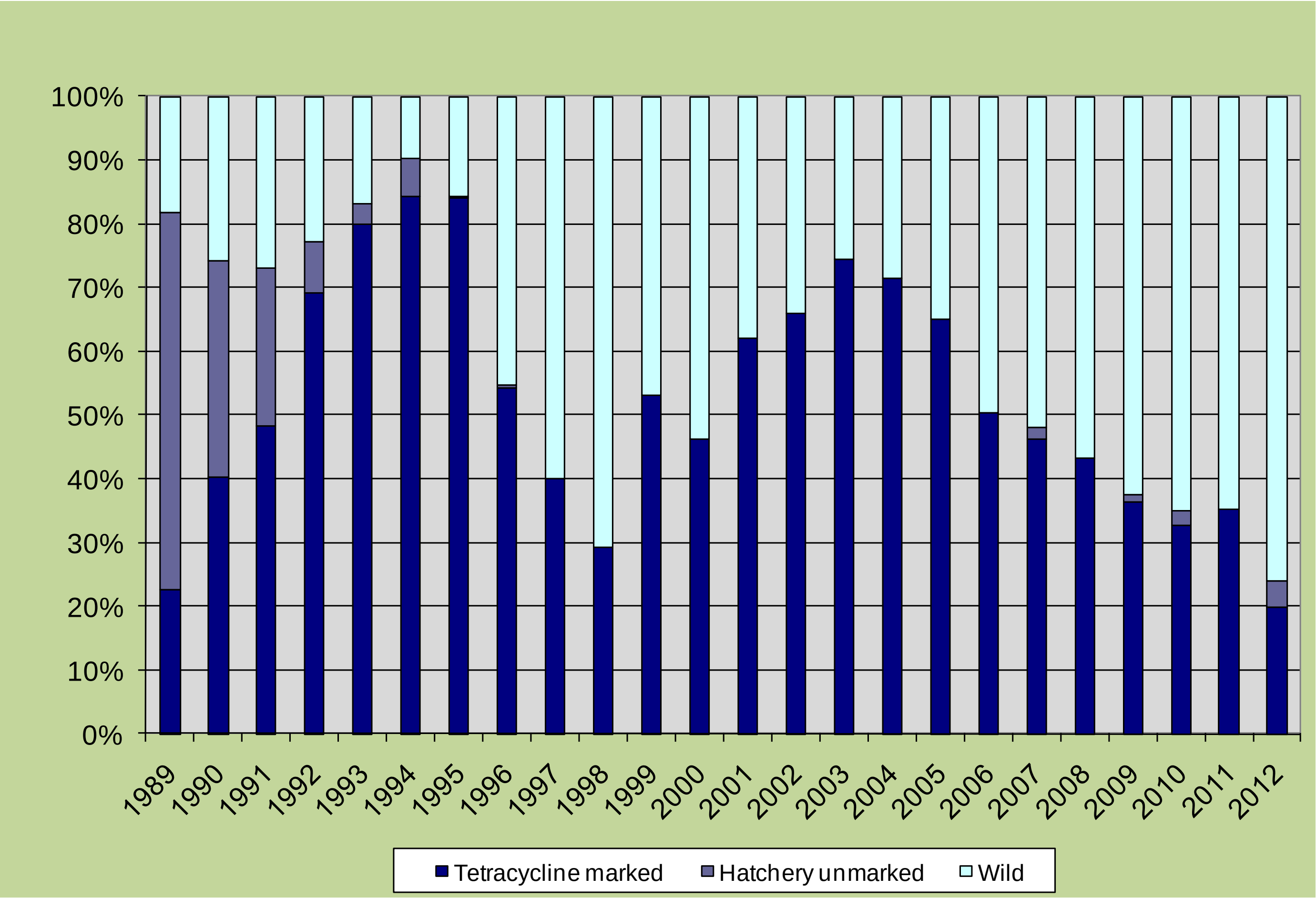
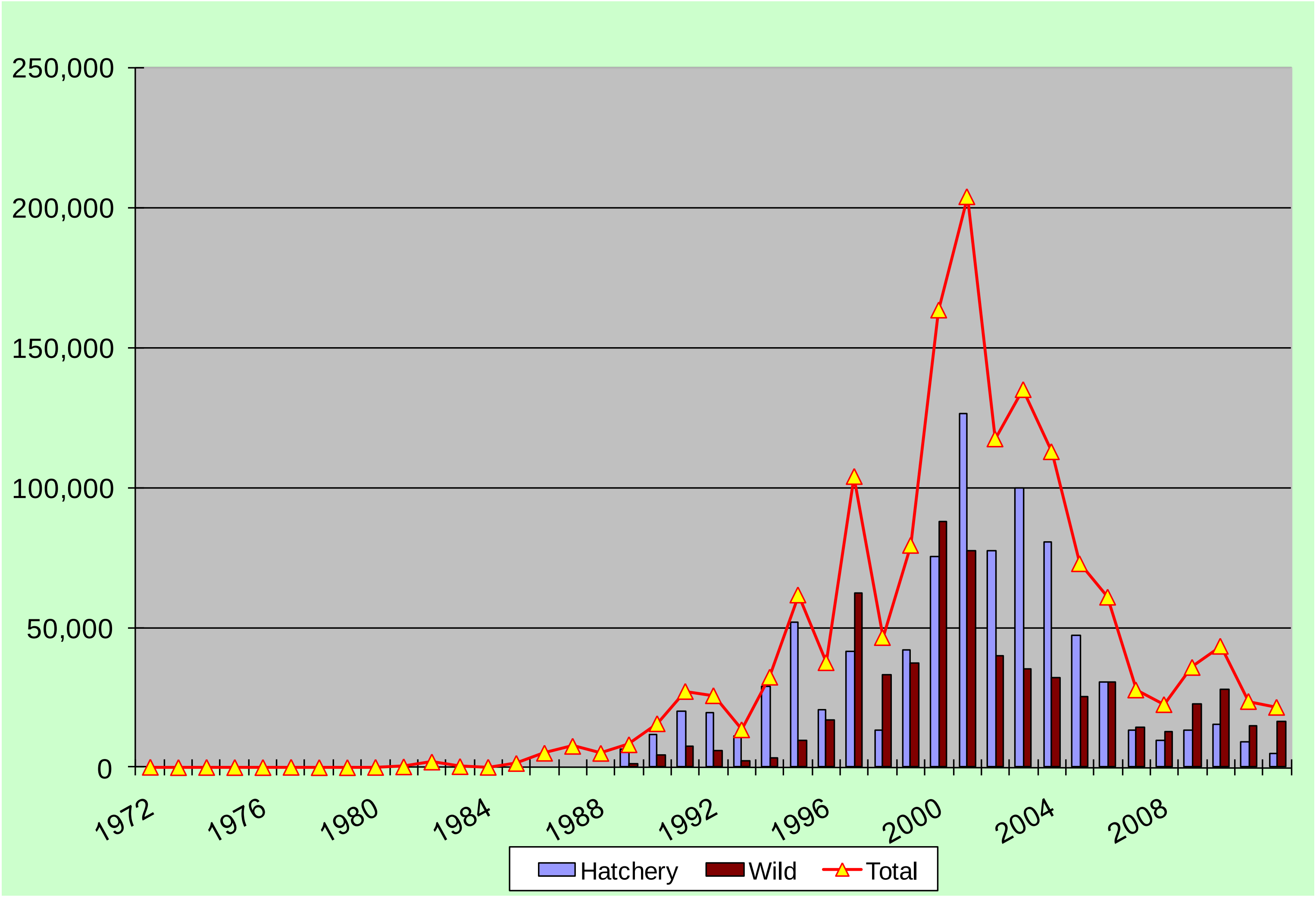


FIGURE 2. CATCH OF AMERICAN SHAD AT THE CONOWINGO DAM FISH LIFTS.



TABLES

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2012. One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis. Collections were supplemented with fish from tank-spawn trials.

		N	%
Wild Microstructure, No TC Mark		92	76%
Hatchery Microstructure			
Tagged, can't distinguish TC Mark*		5	4%
Single TC Mark	Day 3	1	1%
	Day 18	2	2%
Triple TC Mark	Days 3,6,9	14	12%
	Days 3,6,12	1	1%
	Days 15,18,21	2	2%
Quadruple TC Mark	Days 3,6,9,12	1	1%
	Days 3,6,9,17	1	1%
	Days 15,18,21,24	1	1%
Sextuple TC Mark	Days 3,9,12,15,18,21	1	1%
Septuple TC Mark	Days 3,9,12,15,18,21,27	1	1%
	Total Hatchery	29	24%
	Total readable otoliths	121	
	Unreadable Otoliths**	7	
	Total	128	

*Includes poor grinds, marks which are present but cannot be specifically assigned, and otoliths with autofluoresence obscuring mark.

**Includes missing, broken and poorly ground oliths.

Table 2. Origin of adult American shad collected at Conowingo Dam Fish Lifts, based on otolith analysis.

	Sample:	Hatchery										
		Larvae										
	One in	Susquehanna		below Conowingo Dam		Fingerling		Unmarked**		Naturally reproduced		Total sample
Year	??	N	%	N	%*	N	%*	N	%*	N	%	size
1989	50	36	23	-	0	-	0	94	59	29	18	159
1990	100	49	40	1	1	-	0	42	34	32	26	124
1991	100	111	44	8	3	3	1	63	25	68	27	253
1992	100	154	65	8	3	2	1	19	8	54	23	237
1993	100	76	61	21	17	2	2	4	3	21	17	124
1994	100	217	76	22	8	3	1	17	6	28	10	287
1995	100	255	77	19	6	4	1	1	0	52	16	331
1996	100	180	47	22	6	4	1	1	0	172	45	379
1997	50	84	34	12	5	4	2	0	0	150	60	250
1998	50	29	22	7	5	2	2	0	0	92	71	130
1999	50	90	48	9	5	1	1	0	0	88	47	188
2000	50	78	40	11	6	0	0	0	0	104	54	193
2001	50	120	58	9	4	0	0	0	0	79	38	208
2002	50	118	65	2	1	0	0	0	0	62	34	182
2003	50	146	74	0	0	0	0	0	0	50	26	196
2004	50	113	72	0	0	0	0	0	0	45	28	158
2005	50	176	64	2	1	0	0	0	0	96	35	274
2006	50	89	50	0	0	0	0	0	0	88	50	177
2007	50	71	46	1	1	0	0	3	2	81	52	156
2008	50	76	43	0	0	0	0	0	0	100	57	176
2009	50	63	36	0	0	0	0	2	1	108	62	173
2010	50	58	32	0	0	0	0	5	3	116	65	179
2011	50	63	35	0	0	0	0	0	0	116	65	179
2012	50	24	20	0	0	0	0	5	4	92	76	121
Totals		2,476	51	154	3	25	1	256	5	1,923	40	4,834

**Distinguished from naturally-reproduced fish by otolith microstructure.

TABLE 3. LENGTH-FREQUENCY OF AMERICAN SHAD COLLECTED IN THE SUSQUEHANNA RIVER AT THE CONOWINGO WEST FISH LIFT, 1993-2012.

Males	TL - mm																	
	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	Total
1993			2	3	17	17	18	27	6										90
1994	no data																		
1995*				1	1	18	31	80	107	71	18	4	2						333
1996*					2	11	45	56	44	32	13	9	2			1			215
1997*						12	48	47	34	24	6	1							172
1998*						1	6	13	26	19	2	1							68
1999*					1	8	13	40	22	15	4	1							104
2000*							7	32	55	27	12	3							136
2001						1	4	5	20	34	20	1							85
2002						2	11	5	9	14	24	8	2						75
2003							8	12	27	24	12			2					85
2004	1				2	5	2	14	15	19	12	3	1						74
2005					2	2	18	26	33	31	11	4							127
2006						6	9	21	21	12	4	1							74
2007							11	20	11	7	5								54
2008					1	15	17	23	19	12	1								88
2009						10	35	39	17	3	3								107
2010						4	8	24	48	19	2								105
2011					1	1	3	12	27	20	7								71
2012					1	6	16	15	9	4	5	1							57
	1	0	2	4	28	119	310	511	550	387	161	37	7	2	0	1	0	0	
Females																			
	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	Total
1993						3	9	7	7	14	4	1							45
1994	no data																		
1995*					1	1		2	6	64	91	47	14	8	2	1			237
1996*						2	2	1	11	28	36	49	17	7					153
1997*							2	3	4	28	20	12	10	3					82
1998*									4	11	27	24	6						72
1999*						1		3	12	20	26	14	8	4		1			89
2000*									3	14	12	21	5	4					59
2001									3	16	36	39	18	2					114
2002									1	4	14	32	42	15	4				112
2003									5	11	14	19	21	23	7	1		1	101
2004								1	4	10	24	26	12	11					88
2005							2	1	6	19	44	34	29	11	2				148
2006								5	10	28	33	21	9						106
2007						1			6	25	36	23	9	4					104
2008							1	2	14	25	28	13	7	1					91
2009								3	12	25	20	6	1						67
2010								1	12	31	42	4	1	1				1	93
2011									4	13	29	19	2						67
2012								3	7	11	28	19	4						72
	0	0	0	0	1	8	16	32	131	397	564	423	215	94	15	3	0	2	

TABLE 3. (CONTINUED)

Sexes combined																			
	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625	650	675	Total
1993	0	0	2	3	17	20	27	34	13	14	4	1	0	0	0	0	0	0	135
1994	no data																		
1995*	0	0	0	1	2	19	31	82	113	135	109	51	16	8	2	1	0	0	570
1996*	0	0	0	0	2	13	47	57	55	60	49	58	19	7	0	1	0	0	368
1997*	0	0	0	0	0	12	50	50	38	52	26	13	10	3	0	0	0	0	254
1998*	0	0	0	0	0	1	6	13	30	30	29	25	6	0	0	0	0	0	140
1999*	0	0	0	0	1	9	13	43	34	35	30	15	8	4	0	1	0	0	193
2000*	0	0	0	0	0	0	7	32	58	41	24	24	5	4	0	0	0	0	195
2001	0	0	0	0	0	1	4	5	23	50	56	40	18	2	0	0	0	0	199
2002	0	0	0	0	0	2	11	5	10	18	38	40	44	15	4	0	0	0	187
2003	0	0	0	0	0	0	8	12	32	35	26	19	21	25	7	1	0	1	186
2004	1	0	0	0	2	5	2	15	19	29	36	29	13	11	0	0	0	0	161
2005	0	0	0	0	2	2	20	27	39	50	55	38	29	11	2	0	0	0	275
2006	0	0	0	0	0	6	9	26	31	40	37	22	9	0	0	0	0	0	180
2007	0	0	0	0	0	1	11	20	17	32	41	23	9	4	0	0	0	0	158
2008	0	0	0	0	1	15	18	25	33	37	29	13	7	1	0	0	0	0	179
2009	0	0	0	0	0	10	35	42	29	28	23	6	1	0	0	0	0	0	174
2010	0	0	0	0	0	4	8	25	60	50	44	4	1	1	0	0	0	1	198
2011	0	0	0	0	1	1	3	12	31	33	36	19	2	0	0	0	0	0	138
2012	0	0	0	0	1	6	16	18	16	15	33	20	4	0	0	0	0	0	129
	1	0	2	4	29	127	326	543	681	784	725	460	222	96	15	4	0	2	
*TL estimated from FL according to: TL= FL * 1.117 + 6.674																			

TABLE 4. AGE-FREQUENCY OF AMERICAN SHAD COLLECTED IN THE SUSQUEHANNA RIVER AT THE CONOWINGO WEST FISH LIFT, 1995-2012.

Males													
Otolith Age													Mean
	2	3	4	5	6	7	8	9	10	11	??	Total	Age
1995	0	11	75	82	14	2	0	0	0	0	7	**191**	**4.6**
1996	4	79	70	47	1	2	0	0	0	0	10	**213**	**3.8**
1997	0	61	82	17	5	0	0	0	0	0	2	**167**	**3.8**
1998	0	4	36	27	0	0	0	0	0	0	0	**67**	**4.3**
1999	0	19	62	16	2	0	1	0	0	0	1	**101**	**4.1**
2000	0	19	85	25	5	0	0	0	0	0	0	**134**	**4.1**
2001	0	4	29	42	7	0	0	0	0	0	0	**82**	**4.6**
2002	0	16	15	31	9	2	0	1	0	0	1	**75**	**4.6**
2003	0	4	49	17	17	2	1	0	0	0	2	**92**	**4.6**
2004	0	13	12	33	8	5	1	0	0	0	0	**72**	**4.8**
2005	0	7	62	28	22	3	1	0	0	0	1	**124**	**4.6**
2006	1	5	32	27	7	0	0	0	0	0	0	**72**	**4.5**
2007	0	1	25	16	9	0	0	0	0	0	0	**51**	**4.6**
2008	0	17	35	23	10	1	0	0	0	0	0	**86**	**4.3**
2009	0	0	74	26	6	0	0	0	0	0	0	**106**	**4.4**
2010	0	6	21	50	1	0	0	0	0	0	4	**82**	**4.6**
2011	0	1	15	38	17	0	0	0	0	0	0	**71**	**5.0**
2012	0	17	12	21	4	3	0	0	0	0	0	**57**	**4.4**
Total	**5**	**284**	**791**	**566**	**144**	**20**	**4**	**1**	**0**	**0**	**28**	**1843**	**4.4**

Females													
	Otolith Age												Mean
	2	3	4	5	6	7	8	9	10	11	??	Total	Age
1995	0	0	14	86	28	7	0	0	0	0	5	**140**	**5.2**
1996	0	3	44	74	16	5	0	0	0	0	12	**154**	**4.8**
1997	1	2	28	27	21	2	0	0	0	0	1	**82**	**4.9**
1998	0	0	12	34	14	1	0	0	0	0	0	**61**	**5.1**
1999	0	0	24	46	13	2	0	0	0	0	4	**89**	**4.9**
2000	0	1	13	27	14	2	0	0	0	0	0	**57**	**5.1**
2001	0	0	18	56	34	4	0	0	0	0	0	**112**	**5.2**
2002	0	0	13	43	42	9	3	0	0	0	2	**112**	**5.5**
2003	0	1	12	30	44	13	1	0	0	0	0	**101**	**5.6**
2004	0	0	5	43	16	18	2	0	0	0	0	**84**	**5.6**
2005	0	2	18	33	71	16	4	1	0	1	2	**148**	**5.7**
2006	0	0	14	66	14	8	1	1	0	0	0	**104**	**5.2**
2007	0	0	10	29	57	2	2	0	0	0	0	**100**	**5.6**
2008	0	0	10	31	40	8	1	0	0	0	0	**90**	**5.5**
2009	0	0	15	34	11	4	0	0	0	0	0	**64**	**5.1**
2010	0	0	7	57	10	1	1	0	0	0	4	**80**	**5.1**
2011	0	0	0	20	42	3	0	0	0	0	2	**67**	**5.7**
2012	0	0	5	21	35	15	0	0	0	0	0	**76**	**5.8**
Total	**1**	**9**	**262**	**757**	**522**	**120**	**15**	**2**	**0**	**1**	**32**	**1721**	**5.3**

TABLE 4. (CONTINUED)

Sexes Conbined													
	Otolith Age												Mean
	2	3	4	5	6	7	8	9	10	11	??	Total	Age
1995	0	11	89	168	42	9	0	0	0	0	12	331	4.8
1996	4	82	114	121	17	7	0	0	0	0	22	367	4.2
1997	1	63	110	44	26	2	0	0	0	0	3	249	4.2
1998	0	4	48	61	14	1	0	0	0	0	0	128	4.7
1999	0	19	86	62	15	2	1	0	0	0	5	190	4.4
2000	0	20	98	52	19	2	0	0	0	0	0	191	4.4
2001	0	4	47	98	41	4	0	0	0	0	0	194	5.0
2002	0	16	28	74	51	11	3	1	0	0	3	187	5.1
2003	0	5	61	47	61	15	2	0	0	0	2	193	5.1
2004	0	13	17	76	24	23	3	0	0	0	0	156	5.2
2005	0	9	80	61	93	19	5	1	0	1	3	272	5.2
2006	1	5	46	93	21	8	1	1	0	0	0	176	4.9
2007	0	1	35	45	66	2	2	0	0	0	0	151	5.3
2008	0	17	45	54	50	9	1	0	0	0	0	176	5.0
2009	0	0	89	60	17	4	0	0	0	0	0	170	4.6
2010	0	6	28	107	11	1	1	0	0	0	8	162	4.8
2011	0	1	15	58	59	3	0	0	0	0	2	138	5.4
2012	0	17	17	42	39	18	0	0	0	0	0	133	5.2
Total	6	293	1053	1323	666	140	19	3	0	1	60	3564	4.8

TABLE 5. MEAN TOTAL LENGTH AND WEIGHT OF ADULT AMERICAN SHAD COLLECTED AT THE CONOWINGO DAM WEST FISH LIFT, 1993-2012.

	Males						Females						Combined					
	N	Mean Total Length (mm)	SD	N	Mean Weight (g)	SD	N	Mean Total Length (mm)	SD	N	Mean Weight (g)	SD	N	Mean Total Length (mm)	SD	N	Mean Weight (g)	SD
1993	x	404	36				45	457	37				135	422	44			
1995*	333	456	33	333	889	205	237	513	32	237	1371	284	624	479	43	624	1090	342
1996*	215	452	41	208	808	227	156	507	79	150	1413	292	371	475	66	358	1062	394
1997*	172	441	32	172	797	187	82	509	38	82	1441	349	254	463	47	254	1005	392
1998*	68	461	26	68	783	149	62	519	27	62	1295	261	130	489	39	130	1027	331
1999*	104	445	32	104	739	145	89	478	40	89	1201	251	193	474	47	193	966	318
2000*	136	465	26	136	862	169	59	493	32	59	1346	292	195	483	39	195	1026	327
2001	85	479	28	86	912	180	114	524	25	114	1372	215	199	505	34	200	1174	304
2002	75	481	44	75	1041	303	112	550	27	112	1618	347	187	523	49	187	1387	434
2003	95	474	36	95	1032	293	102	547	44	101	1735	443	197	512	54	196	1394	516
2004	74	463	48	75	947	255	88	528	34	88	1474	315	163	498	52	164	1232	390
2005	127	458	35	127	907	228	148	526	35	148	1508	333	277	495	49	277	1229	416
2006	74	450	33	74	860	197	106	507	31	106	1311	307	180	483	42	180	1125	347
2007	54	451	31	54	859	205	106	514	31	106	1424	289	160	493	43	160	1233	376
2008	88	436	32	88	759	194	91	503	32	90	1242	311	179	470	46	178	1003	354
2009	107	432	25	107	754	153	67	492	25	67	1199	235	174	456	39	174	925	287
2010	105	454	24	103	900	179	93	500	29	92	1318	271	199	475	35	196	1095	308
2011	71	465	29	71	863	196	67	512	23	67	1269	206	138	488	35	138	1060	286
2012	57	440	39	56	757	209	74	511	32	74	1319	245	134	479	50	133	1075	363

*TL estimated from FL according to: TL= FL * 1.117 + 6.674

TABLE 6. MEAN TOTAL LENGTH (MM) AT AGE FOR AMERICAN SHAD COLLECTED AT THE CONOWINGO DAM WEST FISH LIFT, 1995-2012.

Otolith age										
Male	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1995*		410	445	466	477	529				
1996*	392	424	463	484	526	492				
1997*		416	447	488	481					
1998*		431	454	473						
1999*		420	443	472	482		509			
2000*		454	460	488	515					
2001		478	465	486	494	480				
2002		419	471	502	527	509		536		
2003		429	458	488	512	510	512			
2004		366	387	430	444	477	410			
2005		411	441	474	496	492	510			
2006	442	394	442	460	483					
2007		432	439	451	484					
2008		397	433	457	469	451				
2009			426	445	471					
2010		408	446	464	463					
2011		385	447	466	485					
2012		404	430	462	476	481				
Female	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1995*			492	511	515	566				
1996*			504	526	473	533				
1997*	426	442	486	515	538	560				
1998*			491	521	539	495				
1999*			499	508	521	540				
2000*			500	526	541	549				
2001			506	521	538	537				
2002			528	547	554	580	579			
2003		450	489	540	560	579	570			
2004			445	461	486	495	498			
2005		405	488	521	531	549	571	620		575
2006			494	501	522	535	537	573		
2007			498	509	521	528	443			
2008			471	490	514	525	601			
2009			478	493	505	524				
2010			485	497	509	590	682			
2011				504	515	524				
2012			457	508	515	522				

TABLE 7. MEAN WEIGHT (G) AT AGE FOR AMERICAN SHAD COLLECTED AT THE CONOWINGO DAM WEST FISH LIFT, 1995-2012.

Otolith age										
Male	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1995		610	840	936	1022	1293				
1996	546	662	869	967	1220	970				
1997		667	834	1022	1018					
1998		614	750	861						
1999		642	717	855	885		1130			
2000		838	828	983	1195					
2001		949	831	956	1009	795				
2002		669	986	1126	1413	1280		1380		
2003		740	919	1090	1336	1335	1180			
2004		590	834	1025	1094	1402	1020			
2005		608	797	982	1160	1237	1270			
2006	630	557	811	921	1047					
2007		780	777	885	1072					
2008		529	725	896	947	940				
2009			724	816	930					
2010		653	833	964	905					
2011		400	773	872	947					
2012		595	681	863	883	1020				
Female	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1995			1162	1343	1418	1826				
1996			1344	1440	1513	1321				
1997	1400	950	1233	1524	1647	1695				
1998			1012	1311	1474	1210				
1999			1154	1234	1382	1500				
2000			1227	1425	1495	1885				
2001			1247	1340	1496	1460				
2002			1383	1619	1657	1841	1675			
2003		1000	1216	1726	1817	1989	2080			
2004			1250	1345	1572	1739	1715			
2005		673	1242	1437	1555	1740	1613	2470		1900
2006			1253	1248	1468	1589	1605	2050		
2007			1212	1380	1494	1517	1195			
2008			996	1125	1367	1310	1770			
2009			1088	1198	1311	1473				
2010			1143	1307	1306	2000	2820			
2011				1169	1307	1487				
2012			976	1254	1357	1437				

TABLE 8. SEX RATIO OF AMERICAN SHAD COLLECTED AT THE CONOWINGO DAM WEST FISH LIFT, 1993-2012.

	Susquehanna		
	Males	**Females**	**M:F ratio**
1993	90	45	1: 0.5
1994	no sex data		
1995	333	237	1: 0.7
1996	215	153	1: 0.7
1997	172	82	1: 0.5
1998	68	72	1: 1.1
1999	104	89	1: 0.9
2000	136	59	1: 0.4
2001	85	114	1: 1.3
2002	75	112	1: 1.5
2003	85	101	1: 1.2
2004	74	88	1: 1.2
2005	127	148	1: 1.2
2006	74	106	1: 1.4
2007	54	104	1: 1.9
2008	88	91	1: 1.0
2009	107	67	1: 0.6
2010	105	93	1: 0.9
2011	71	67	1: 0.9
2012	57	72	1: 1.3

TABLE 9. OTOLITH AGE AND REPEAT SPAWNING FOR AMERICAN SHAD COLLECTED IN THE CONOWINGO DAM WEST FISH LIFT, 2000-2012.

Male	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		18	80	25	5						128	
Repeats	0		18	77	17	2						114	89%
	1			3	4	3						10	8%
	2				4							4	3%
2001	N		3	30	39	7	1					80	
Repeats	0		3	30	38	7	1					79	99%
	1				1							1	1%
2002	N		16	14	29	9	2	0	1			71	
Repeats	0		16	9	12	4						41	58%
	1			5	13	3						21	30%
	2				4	2	2		1			9	13%
2003	N		4	47	17	17	2	1				88	
Repeats	0		4	44	17	17	2					84	95%
	1			3				1				4	44%
2004	N		13	13	34	8	5	1				74	
Repeats	0		13	13	27	7	3	1				64	86%
	1				7	1	1					9	12%
	2						1					1	1%
2005	N		7	64	27	22	3	1				124	
Repeats	0		7	44	21	6	1					79	64%
	1			18	4	9	1	1				33	27%
	2			2	2	5						9	7%
	3					2	1					3	2%
2006	N	1	5	32	27	7	0	0				72	
Repeats	0	1	5	30	20	6						62	86%
	1			2	6							8	11%
	2				1	1						2	3%
	3											0	0%
2007	N	0	1	25	16	9	0	0				51	
Repeats	0		1	17	13	2						33	65%
	1			7	2	4						13	25%
	2			1	1	2						4	8%
	3					1						1	2%
2008	N	0	17	35	24	10	0	0				86	
Repeats	0		17	29	13	4						63	73%
	1			6	7	5						18	21%
	2				3	1						4	5%
	3				1							1	1%

TABLE 9. (CONTINUED)

Male	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2009	N			74	26	6						106	
Repeats	0			71	23	3						97	92%
	1			3	3	2						8	8%
	2					1						1	1%
	3											0	0%
2010	N		6	29	54	2						91	
Repeats	0		6	25	49	1						81	89%
	1			4	5	1						10	11%
	2											0	0%
	3											0	0%
2011	N		1	15	36	17						69	
Repeats	0		1	15	29	14						59	86%
	1				7	2						9	13%
	2					1						1	1%
	3											0	0%
2012	N		17	12	26	6						61	
Repeats	0		17	12	21	4	3					57	83%
	1				5	2	1					8	12%
	2											0	0%
	3											0	0%

TABLE 9. (CONTINUED)

Female	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		1	13	27	14	2					57	
Repeats	0		1	13	19	11	1					45	79%
	1				4							4	7%
	2				3	3						6	11%
	3						1					1	
	4				1							1	
2001	N			16	51	30	4					101	
Repeats	0			16	51	30	4					101	100%
2002	N			13	42	41	9	3				108	
Repeats	0			11	19	21	5	1				57	53%
	1			2	19	15	4	2				42	39%
	2				4	5						9	8%
2003	N		1	12	30	44	13	1				101	
Repeats	0		1	12	24	40	9	1				87	86%
	1				3	2	2					7	7%
	2				3	2	2					7	7%
2004	N			5	43	17	19	2				86	
Repeats	0			5	37	14	12					68	79%
	1				5	2	4					11	13%
	2				1	1		1				3	3%
	3						3					3	3%
	4							1				1	1%
2005	N		2	18	33	70	16	4	1	0	1	145	
Repeats	0		2	11	19	37	4	1				74	51%
	1			7	7	21	4	2				41	28%
	2				7	5	3	1	1		1	18	12%
	3					7	3					10	7%
	4						2					2	1%
2006	N		0	14	66	14	8	1	1	0	0	104	
Repeats	0			14	50	10	5					79	76%
	1				12	4	2	1				19	18%
	2				3		1					4	4%
	3				1							1	1%
	4								1			1	1%
2007	N		0	10	29	57	5	2	0	0	0	103	
Repeats	0			10	16	33	3	2				64	62%
	1				7	8						15	15%
	2				5	12	2					19	18%
	3				1	4						5	5%
	4											0	0%
2008	N		0	10	31	41	8	1	0	0	0	91	
Repeats	0			9	22	22	2					55	60%
	1			1	6	9	2					18	20%
	2				3	5	1					9	10%
	3					4	2	1				7	8%
	4					1	1					2	2%

Table 9. (continued)

Female	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2009	N		0	15	34	11	2	0	0	0	0	62	
Repeats	0			12	28	9						49	79%
	1			3	6	2	1					12	19%
	2						1					1	2%
	3											0	0%
	4											0	0%
2010	N		0	9	64	12	1	1	0	0	0	87	
Repeats	0			8	58	8		1				75	86%
	1				6	3						9	10%
	2			1		1	1					3	3%
	3											0	0%
	4											0	0%
2011	N		0	0	19	42	3	0	0	0	0	64	
Repeats	0				19	37	3					59	92%
	1					5						5	8%
	2											0	0%
	3											0	0%
	4											0	0%
2012	N		0	5	23	38	17	0	0	0	0	83	
Repeats	0			5	21	35	15					76	119%
	1				2	3	2					7	11%
	2											0	0%
	3											0	0%
	4											0	0%

Table 9. (continued)

Sexes Combi	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		19	93	52	19	2					185	
Repeats	0		19	90	36	13	1					159	86%
	1			3	8	3						14	8%
	2				7	3						10	5%
	3						1					1	1%
	4				1							1	1%
2001	N		3	46	90	37	5					181	
Repeats	0		3	46	89	37	5					180	99%
	1				1							1	1%
	2											0	0%
2002	N		16	27	71	50	11	3	1			179	
Repeats	0		16	20	31	25	5	1				98	55%
	1			7	32	18	4	2				63	35%
	2				8	7	2		1			18	10%
2003	N		5	59	47	61	15	2				189	
Repeats	0		5	56	41	57	11	1				171	90%
	1			3	3	2	2	1				11	6%
	2				3	2	2					7	4%
2004	N		13	18	77	25	24	3				160	
Repeats	0		13	18	64	21	15	1				132	83%
	1				12	3	5					20	13%
	2				1	1	1	1				4	3%
	3						3					3	2%
	4							1				1	1%
2005	N		9	80	60	92	19	5	1	0	1	267	
Repeats	0		9	55	40	43	5	1				153	57%
	1			25	11	30	5	3				74	28%
	2				9	10	3	1	1		1	25	9%
	3					9	4					13	5%
	4						2					2	1%
2006	N			16	73	15	8	1	1			114	
Repeats	0			16	56	10	5					87	76%
	1				13	5	2	1				21	18%
	2				3		1					4	4%
	3				1							1	1%
	4								1			1	1%
2007	N		1	35	45	66	5	2				154	
Repeats	0		1	27	29	35	3	2				97	63%
	1			7	9	12						28	18%
	2			1	6	14	2					23	15%
	3				1	5						6	4%
	4											0	0%
2008	N		17	45	55	53	8	1				179	
Repeats	0		17	38	35	26	2					118	66%
	1			7	13	14	2					36	20%
	2				6	6	1					13	7%
	3				1	4	2	1				8	4%
	4					3	1					4	2%

Table 9. (continued)

Sexes Combi	Otolith Age	2	3	4	5	6	7	8	9	10	11	Total	%
2009	N			89	60	17	2					168	
Repeats	0			83	51	12	0					146	87%
	1			6	9	4	1					20	12%
	2					1	1					2	1%
	3											0	0%
	4											0	0%
2010	N		6	38	118	14	1	1	0			178	
Repeats	0		6	33	107	9	0	1	0			156	88%
	1		0	4	11	4	0	0	0			19	11%
	2		0	1	0	1	1	0	0			3	2%
	3		0	0	0	0	0	0	0			0	0%
	4											0	0%
2011	N		1	15	55	59	3	0	0			133	
Repeats	0		1	15	48	51	3	0	0			118	89%
	1		0	0	7	7	0	0	0			14	11%
	2		0	0	0	1	0	0	0			1	1%
	3		0	0	0	0	0	0	0			0	0%
	4											0	0%
2012	N		17	17	49	44	21	0	0			148	
Repeats	0		17	17	42	39	18	0	0			133	100%
	1		0	0	7	5	3	0	0			15	11%
	2		0	0	0	0	0	0	0			0	0%
	3		0	0	0	0	0	0	0			0	0%
	4											0	0%

TABLE 10. AGE COMPOSITION AND ORIGIN OF SUSQUEHANNA RIVER AMERICAN SHAD COLLECTED AT THE CONOWINGO DAM FISH LIFTS.

		% Age composition										% Composition by Hatchery Release Site			
	Total											Above Dams		Below Dams	Wild
	Fish lift											larvae	fingerlings		
Year	catch	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	%	%	%	%
1988	5,146			0.0	0.0	4.0	31.7	38.1	21.2	4.7	0.4	71% *		6% *	23% *
1989	8,218			0.0	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719			0.0	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%		1%	26%
1991	27,227			0.0	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	2%	5%	27%
1992	25,721			0.0	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	1%	4%	23%
1993	13,546			0.0	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	2%	18%	17%
1994	32,330			0.0	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	1%	8%	10%
1995	61,650			0.0	0.0	3.2	12.4	51.9	28.5	4.0	0.0	77%	1%	6%	16%
1996	37,513			0.0	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%	1%	6%	45%
1997	103,945			0.0	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%	2%	5%	60%
1998	46,481			0.0	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370			0.0	0.5	1.1	8.1	33.5	46.5	10.3	0.0	48%	1%	5%	47%
2000	163,331			0.0	0.0	1.0	9.9	27.6	51.0	10.4	0.0	40%	0%	6%	54%
2001	203,776			0.0	0.0	2.0	21.4	50.5	24.0	2.0	0.0	56%	0%	4%	38%
2002	117,348			0.5	1.6	6.0	27.7	40.2	15.2	8.7	0.0	65%	0%	1%	34%
2003	134,937			0.0	1.0	7.2	31.4	25.8	32.0	2.6	0.0	74%	0%	0%	26%
2004	112,786			0.0	1.9	14.9	15.5	48.4	11.2	8.1	0.0	72%	0%	0%	28%
2005	72,822	0.4	0.0	0.4	1.8	6.6	34.4	22.3	30.8	3.3	0.0	64%	0%	1%	35%
2006	60,869			0.6	0.6	4.5	11.9	52.8	26.1	2.8	0.6	50%	0%	0%	50%
2007	25,464				1.3	2.0	43.4	29.6	23.0	0.7		48%	0%	0%	52%
2008	22,541				0.6	5.1	28.7	30.9	25.3	9.6		43%	0%	0%	57%
2009	35,806					2.3	9.9	32.0	55.8			37%	0%	0%	63%
2010	43,362				0.552	0.552	8.287	66.3	20.99	3.315		35%	0%	0%	65%
2011	23,645					2.174	42.8	42.0	10.87	0.725		38%	0%	0%	62%
2012	23,629					13.53	29.3	31.6	12.78	12.78		24%	0%	0%	76%

*No estimate of hatchery contribution available, used mean of 1989-1996.

Used scale ages for 1988-1996, otolith ages for 1997-2009.

TABLE 11 . PERCENT VIRGIN AMERICAN SHAD COLLECTED IN THE CONOWINGO DAM FISH LIFTS, SUSQUEHANNA RIVER.

			% Virgin*							
Year	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1988			100%	100%	91%	99%	96%	97%	100%	100%
1989			100%	100%	83%	92%	91%	97%	100%	100%
1990			100%	100%	87%	91%	93%	99%	100%	100%
1991			100%	50%	78%	88%	85%	93%	100%	100%
1992			100%	75%	78%	81%	87%	98%	100%	100%
1993			100%	100%	100%	82%	88%	100%	100%	100%
1994			100%	100%	100%	94%	94%	93%	100%	100%
1995			100%	100%	100%	86%	95%	100%	100%	100%
1996			100%	100%	88%	87%	89%	97%	100%	100%
1997			100%	100%	88%	87%	89%	97%	100%	100%
1998			100%	100%	88%	87%	89%	97%	100%	100%
1999			100%	100%	88%	87%	89%	97%	100%	100%
2000			100%	100%	50%	68%	69%	97%	100%	100%
2001			100%	100%	100%	100%	99%	100%	100%	100%
2002			0%	33%	45%	50%	44%	74%	100%	100%
2003			100%	50%	73%	93%	87%	95%	100%	100%
2004			100%	33%	63%	84%	83%	100%	100%	100%
2005				20%	26%	46%	66%	68%	100%	
2006			0%	0%	63%	76%	75%	96%	100%	100%
2007				100%	67%	53%	64%	77%	100%	
2008				0%	22%	51%	64%	84%	100%	
2009					50%	75%	80%	94%		
2010				100%	0%	64%	91%	87%	100%	
2011					100%	86%	87%	100%	100%	
2012			100%	100%	86%	89%	86%	100%	100%	

* 1996-1999- used the average of 1994,1995, 2000 and 2001

TABLE 12. RECRUITMENT OF VIRGIN HATCHERY LARVAE, STOCKED ABOVE DAMS, TO THE CONOWINGO FISH LIFTS, SUSQUEHANNA RIVER.

	Cohort										
Year	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
1988	13										
1989	373	16									
1990	1,690	166	0								
1991	5,909	2,098	307	0							
1992	5,419	5,966	2,139	545	0						
1993	277	1,530	4,014	1,867	69	0					
1994	0	859	5,534	13,395	4,682	0	0				
1995		0	1,517	5,069	23,425	13,570	1,916	0			
1996			0	133	2,505	6,619	5,854	1,365	51		
1997				0	0	3,196	5,668	15,275	9,191	141	
1998					0	70	978	4,439	3,755	322	0
1999						205	359	2,678	11,344	17,191	3,902
2000							0	344	4,469	12,615	32,605
2001								0	2,339	24,562	57,254
2002								0	413	2,067	10,544
2003									0	515	5,283
2004										0	501
2005											0
2006											
2007											
2008											
2009											
2010											
2011											
2012											
Total recruits to lifts:	**13,680**	**10,635**	**13,510**	**21,008**	**30,681**	**23,661**	**14,776**	**24,102**	**31,562**	**57,413**	**110,089**
Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00	7.47
Number of larvae to return 1 adult:	724	487	477	641	183	305	206	271	203	174	68
Survival	0.0014	0.0021	0.0021	0.0016	0.0055	0.0033	0.0049	0.0037	0.0049	0.0057	0.0147
Mean number of larvae to return 1 adult (1986-2006):				**404**							

TABLE 12. (CONTINUED).

		Cohort										
	Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
	1988											
	1989											
	1990											
	1991											
	1992											
	1993											
	1994											
	1995											
	1996											
	1997											
	1998											
	1999	0										
	2000	6,876	0									
	2001	27,486	2,339	0								
	2002	13,360	8,576	6,616	0							
	2003	29,330	22,444	30,281	2,573	0						
	2004	7,515	10,521	32,481	9,018	6,513	0					
	2005	171	812	7,447	6,854	9,766	1,542	0				
	2006	0	0	869	2,782	12,173	7,652	869	174			
	2007		0	162	162	2,838	2,352	2,190	81	0		
	2008			0	0	109	1,422	1,914	2,078	930	0	
	2009				0	0	154	980	3,399	6,933	0	0
	2010					0	84	0	813	9,176	2,783	506
	2011						0	0	193	3,286	3,261	966
	2012							0	0	657	1,471	1,533
		84,739	**44,692**	**77,857**	**21,389**	**31,400**	**13,205**	**5,953**	**6,739**	**20,325**	**6,044**	**1,472**
		8.02	11.70	13.50	9.46	5.51	2.59	10.69	4.73	3.57	4.35	1.38
		95	262	173	442	175	196	1,795	702	176	719	937
		0.0106	0.0038	0.0058	0.0023	0.0057	0.0051	0.0006	0.0014	0.0057	0.0014	0.0011

Table 13. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 2000.

			Cohort														
		Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
		1988	0	*													
		1989	0	0													
		1990	0	0	0												
		1991	160	57	8	0											
		1992	70	77	28	7	0										
		1993	7	40	106	49	2	0									
		1994	0	12	77	185	65	0	0								
		1995		0	24	80	368	213	30	0							
		1996			0	3	56	147	130	30	1						
		1997				0	0	152	269	724	436	7					
		1998					0	5	67	306	259	22	0				
		1999						2	4	30	126	191	43	0			
		2000							0	0	0	0	0	0	0		
		2001								0	0	0	0	0	0	0	
		2002								0	0	0	0	0	0	0	
		2003									0	0	0	0	0	0	
		2004										0	0	0	0	0	
		2005											0	0	0	0	0
		2006												0	0	0	0
		2007													0	0	0
		2008														0	0
		2009															0
		2010															
		2011															
		2012															
Total recruits to lifts:			238	186	242	324	490	519	501	1,091	822	220	43	0	0	0	0
Fingerlings stocked/10,000:			7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95	0.00	0.00	2.50	0.00	0.00	0.00
Number of fingerlings to return 1 adult:			305	437	264	186	184	105	44	73	170	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Mean number of fingerlings to return 1 adult (1986-1994):						196											

TABLE 14. RECRUITMENT OF NATURALLY REPRODUCED AMERICAN SHAD TO THE CONOWINGO FISH LIFTS, 1986- 2006.

	Cohort										
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	55										
1989	83	4									
1990	601	59	0								
1991	2,388	848	124	0							
1992	1,703	1,875	672	171	0						
1993	73	406	1,065	496	18	0					
1994	0	104	667	1,615	565	0	0				
1995	0	0	308	1,030	4,761	2,758	389	0			
1996		0	0	126	2,383	6,298	5,570	1,298	48		
1997			0	0	0	5,684	10,081	27,168	16,346	251	
1998				0	0	223	3,103	14,084	11,913	1,020	0
1999					0	201	351	2,619	11,092	16,809	3,816
2000						0	0	458	5,959	16,820	43,474
2001							0	0	1,580	16,585	38,658
2002								0	217	1,086	5,540
2003									0	181	1,858
2004										0	200
2005											0
2006											
2007											
2008											
2009											
2010											
2011											
2012											
Total recruits to lifts:	4,904	3,295	2,837	3,439	7,727	15,164	19,495	45,628	47,155	52,752	93,546
Adults transported/1000:	4.08	6.55	4.64	6.09	14.79	22.90	13.72	10.53	27.88	55.77	33.83
No. of adults transported to return 1 adult:	0.83	1.99	1.63	1.77	1.91	1.51	0.70	0.23	0.59	1.06	0.36
Mean number of adults transported to return 1 adult (1986-2003):					1.28						

TABLE 14. (CONTINUED).

	Cohort									
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1988										
1989										
1990										
1991										
1992										
1993										
1994										
1995										
1996										
1997										
1998										
1999	0									
2000	9,168	0								
2001	18,559	1,580	0							
2002	7,020	4,506	3,476	0						
2003	10,316	7,894	10,651	905	0					
2004	2,993	4,190	12,935	3,591	2,594	0				
2005	93	443	4,062	3,738	5,327	841	0			
2006	0	0	860	2,751	12,036	7,566	860	172		
2007		0	173	173	3,025	2,506	2,334	86	0	
2008			0	0	144	1,871	2,518	2,734	1,223	0
2009				0	0	263	1,674	5,805	11,840	0
2010					0	155	0	1,497	16,892	5,123
2011						0	0	321	5,453	5,412
2012							0	0	2,034	4,555
	48,149	18,612	32,156	11,159	23,126	13,202	7,386	10,615	35,408	10,535
	31.36	10.65	39.66	21.9	89.8	11.7	16.6	2.1	25.4	24.9
	0.65	0.57	1.23	1.96	3.88	0.89	2.25	0.20	0.72	2.37

TABLE 15. VIRTUAL SURVIVAL RATES OF MARKED AMERICAN SHAD, BY STOCKING SITE, RECAPTURED AS ADULTS AT THE CONOWINGO DAM WEST FISH LIFT. VIRTUAL SURVIVAL RATE = RECRUITMENT TO THE CONOWINGO FISH LIFTS X 10,000, DIVIDED BY THE NUMBER STOCKED.

Cohort	Number Stocked (M)	Stocking location	Egg source	Number Recaptured (R)	Recruitment to Conowingo Fish Lifts	Virtual Survival Rate	Cohort Virtual Survival Rate	Adult Relative Virtual Survival Rate	Juvenile Relative Survival Rate
1995	9,070,999	Juniata or middle Susq.	Hud./Del.	93	66,229	73		0.40	0.65
1995	220,000	Conodoguinet Cr.	Hudson	1	860	39		0.22	0.77
1995	230,000	Conodoguinet (mouth)	Hudson	7	4,175	182		1.00	0.90
1995	198,000	Conestoga R.	Hudson	1	429	22		0.12	1.00
1995	190,000	Conestoga (mouth)	Hudson	1	638	34		0.18	0.36
1995	93,000	Muddy Cr.	Hudson	1	860	92		0.51	0.00
1995	520,000	below Conowingo (mid-channel)	Hud./Del.	6	3,847	74		0.41	0.00
1995	411,000	below Conowingo (nearshore)	Hud./Del.	6	2,862	70	73	0.38	0.00
1996	5,730,000	Juniata or middle Susq.	Hud./Del.	117	96,643	169		0.68	0.31
1996	561,000	West Br. Susq. R.	Hud./Del.	5	4,337	77		0.31	0.28
1996	683,000	North Br. Susq. R.	Hudson	10	7,819	114		0.46	1.00
1996	172,000	Conodoguinet Cr.	Delaware	4	3,521	205		0.83	0.37
1996	277,000	Conestoga R.	Delaware	0	0	0		0.00	0.00
1996	43,000	Standing Stone Cr.	Delaware	2	1,067	248		1.00	0.00
1996	1,087,000	below Conowingo	Hud./Del./Susq.	13	11,563	106	146	0.43	0.00
1997	3,037,000	Juniata or middle Susq.	Hud./Del.	86	63,010	207		0.62	0.89
1997	2,270,000	Juniata	Hud./Del.	30	20,872	92		0.27	1.00
1997	486,000	Jun. R. (Huntingdon)	Hudson	6	3,740	77		0.23	0.72
1997	622,000	West Br. Susq. R.	Hudson	2	1,821	29		0.09	0.41
1997	1,199,000	North Br. Susq. R.	Hud./Del.	14	10,026	84		0.25	0.97
1997	174,000	Conodoguinet Cr.	Delaware	8	5,821	335		1.00	0.14
1997	231,000	Conestoga R.	Hudson	3	2,237	97	134	0.29	0.12
1998	8,925,000	Jun. & Susq. R.	Hud./Del.	69	41,486	46		0.32	0.72
1998	321,000	W. Conewago Cr.	Hudson	7	4,714	147		1.00	0.89
1998	565,000	Juniata R.	Susq.	3	1,599	28		0.19	0.49
1998	305,000	Conodoguinet Cr.	Hudson	2	1,276	42		0.28	0.25
1998	1,126,000	North Br. Susq. R.	Hudson	9	6,075	54		0.37	1.00
1998	229,000	Conestoga R.	Hudson	1	638	28		0.19	0.00
1998	230,000	Swatara Cr.	Hudson	0	0	0		0.00	0.96
1998	56,000	West Br. Susq. R.	Susq.	0	0	0	47	0.00	0.00
1999	10,229,000	Juniata R.	Hud./Del.	182	96,189	94		1.00	0.73
1999	373,000	Conodoguinet Cr.	Hudson	5	3,085	83		0.88	0.59
1999	984,000	W. Br. Susq. R.	Hudson	0	0	0		0.00	0.00
1999	236,000	Conestoga R.	Hudson	2	1,428	60		0.64	1.00
1999	219,000	W. Conewago Cr.	Hudson	1	164	8		0.08	0.20
1999	249,000	Swatara Cr.	Hudson	1	696	28		0.30	0.80
1999	1,211,000	N. Br. Susq. R.	Hudson	8	4,665	39	79	0.41	0.21

TABLE 15. (CONTINUED)

2000	7,369,000	Juniata & Susq. R.	Hudson	57	20,522	28		0.43	1.00
2000	111,000	Conodoguinet Cr.	Hudson	0	0	0		0.00	0.74
2000	109,000	W. Conewago Cr.	Hudson	1	714	65		1.00	0.84
2000	961,000	W. Br. Susq. R.	Hud/Susq.	0	0	0		0.00	0.23
2000	231,000	Conestoga R.	Hudson	5	1,329	58		0.88	0.18
2000	33,000	Swatara Cr.	Hudson	0	0	0		0.00	0.00
2000	975,000	N. Br. Susq. R.	Hudson	6	2,641	27	26	0.41	0.56
2001	1,940,860	Juniata & Susq. R.	Hudson	51	14,420	74		0.49	1.00
2001	1,859,345	Juniata & Susq. R.	Susq.	60	15,245	82		0.55	0.64
2001	22,450	W. Br. Susq. R.	Susq.	0	0	0		0.00	0.00
2001	306,860	W. Br. Susq. R.	Susq.	2	505	16		0.11	0.05
2001	140,821	Conodoguinet Cr.	Susq.	1	266	19		0.13	0.03
2001	169,545	W. Conewago Cr.	Susq.	1	128	8		0.05	0.09
2001	210,831	Conestoga R.	Susq.	11	3,171	150		1.00	0.11
2001	182,490	Swatara Cr.	Susq.	2	508	28		0.19	0.56
2001	676,982	N. Br. Susq. R.	Hudson	4	1,586	23	65	0.16	0.51
2002	1,906,173	Juniata R.	Hud/Susq.	26	5,447	29		0.11	0.15
2002	216,560	Juniata R.	Susq.	25	5,528	255		0.94	0.37
2002	101,350	W. Br. Susq. R.	Hud/Susq.	5	1,351	133		0.49	0.54
2002	2,000	Conodoguinet Cr.	Susq.	0	0	0		0.00	0.00
2002	18,924	Conestoga R.	Susq.	1	341	180		0.66	0.00
2002	15,000	Swatara Cr.	Susq.	2	407	271		1.00	0.00
2002	21,000	N. Br. Susq. R.(PA)	Hudson	0	0	0		0.00	0.00
2002	158,790	N. Br. Susq. R.(NY)	Susq.	3	384	24		0.09	0.62
2002	2,000	Chemung R. (NY)	Hudson	0	0	0		0.00	0.00
2002	198,351	Chemung R. (NY)	Hudson	1	128	6	51	0.02	1.00
2003	5,712,662	Juniata/Susq. R.	Hudson	17	3,191	6		0.30	0.29
2003	1,947,223	Juniata/Susq. R.	Susquehanna	22	3,636	19		1.00	0.73
2003	591,558	W. Br. Susq. R.	Hudson	3	542	9		0.49	0.36
2003	167,774	Conodoguinet Cr.	Hudson	0	0	0		0.00	0.32
2003	158,146	Conestoga R.	Hudson	0	0	0		0.00	0.00
2003	293,183	W. Conewago Cr.	Hudson	1	207	7		0.38	0.55
2003	107,867	Swatara Cr.	Hudson	1	128	12		0.64	1.00
2003	800,129	N. Br. Susq. R.(PA)	Hudson	1	128	2		0.09	0.47
2003	491,988	N. Br. Susq. R.(NY)	Hudson	3	499	10		0.54	0.22
2003	414,721	Chemung R. (NY)	Hudson	1	128	3	8	0.17	0.00
2004	2,043,369	Juniata/Susq. R.	Hudson	26	5,032	25		0.38	0.00
2004	840,575	Juniata/Susq. R.	Susquehanna	19	2,990	36		0.54	0.00
2004	282,143	W. Br. Susq. R.	Hudson	11	1,843	65		1.00	0.00
2004	200	Conodoguinet Cr.	Hudson	0	0	0		0.00	0.00
2004	60,273	Conestoga R.	Hudson	1	207	34		0.53	0.00
2004	142,155	W. Conewago Cr.	Hudson	0	0	0		0.00	0.00
2004	53,261	Swatara Cr.	Hudson	0	0	0		0.00	0.00
2004	479,805	N. Br. Susq. R.(PA)	Hudson	0	0	0		0.00	0.00
2004	484,933	N. Br. Susq. R.(NY)	Hudson	1	128	3		0.04	0.00
2004	343,253	Chemung R. (NY)	Hudson	4	705	21	23	0.31	0.00
2005	1,394,634	Juniata/Susq. R.	Susquehanna	57	11,105	80		0.68	0.19
2005	335,083	W. Br. Susq. R.	Hudson	20	3,933	117		1.00	1.00
2005	20,000	Juniata/Susq. R.	Delaware	0	0	0		0.00	0.31
2005	1,820,958	Juniata/Susq. R.	Hudson	7	1,407	8	46	0.07	0.16
2006	1,336,518	Juniata/Susq. R.	Hudson	9	1,502	11		0.31	0.71
2006	1,423,294	Juniata/Susq. R.	Susquehanna	30	5,168	36		1.00	0.42
2006	315,388	W. Br. Susq. R.	Hudson	5	1,019	32		0.89	1.00
2006	164,235	Conodoguinet Cr.	Hudson	0	0	0		0.00	0.85
2006	159,920	Conestoga R.	Hudson	0	0	0		0.00	0.22
2006	135,258	W. Conewago Cr.	Hudson	0	0	0		0.00	0.00
2006	135,166	Swatara Cr.	Hudson	0	0	0		0.00	0.78
2006	273,594	N. Br. Susq. R.(PA)	Hudson	1	242	9		0.24	0.00
2006	230,362	N. Br. Susq. R.(NY)	Hudson	0	0	0		0.00	0.00
2006	171,826	Chemung R. (NY)	Hudson	0	0	0	18	0.00	0.20
2007	1,165,059	Juniata/Susq. R.	Potomac	3	396	3		0.16	0.64
2007	62,673	W. Br. Susq. R.	Susquehanna	1	132	21		1.00	0.80
2007	68,783	Conodoguinet Cr.	Susquehanna	0	0	0		0.00	0.73
2007	50,000	W. Conewago Cr.	Susquehanna	0	0	0		0.00	1.00
2007	28,949	N. Br. Susq. R.(PA)	Susquehanna	0	0	0	4	0.00	0.00

Table 15. (continued)

Cohort	Number Stocked (M)	Stocking location	Egg source	Number Recaptured (R)	Recruitment to Conowingo Fish Lifts	Virtual Survival Rate	Cohort Virtual Survival Rate	Adult Relative Virtual Survival Rate	Juvenile Relative Survival Rate
2008	1,597,821	W. Br. Susq. R.	Potomac	1	178	1		0.04	0.29
2008	135,493	W. Br. Susq. R.	Susquehanna	0	0	0		0.00	1.00
2008	82,958	Juniata/Susq. R.	Susq./Del.	0	0	0		0.00	0.00
2008	140,463	Juniata/Susq. R.	Susq./Pot.	2	357	25		1.00	0.83
2008	75,699	Conodoguinet Cr.	Susquehanna	0	0	0		0.00	0.00
2008	115,529	Conestoga R.	Potomac	0	0	0		0.00	0.00
2008	45,507	W. Conewago Cr.	Potomac	0	0	0		0.00	0.00
2008	124,031	Swatara Cr.	Susquehanna	0	0	0		0.00	0.47
2008	172,581	N. Br. Susq. R.(PA)	Potomac	0	0	0	2	0.00	0.67
2009	499,485	W. Br. Susq. R.	Potomac	1	178	4		0.34	0.26
2009	103,169	W. Br. Susq. R.	Potomac	0	0	0		0.00	0.00
2009	653,424	W. Br. Susq. R.	Susquehanna	3	535	8		0.78	1.00
2009	169,985	Conodoguinet Cr.	Potomac	1	178	10		1.00	0.00
2009	111,284	Conodoguinet Cr.	Potomac	0	0	0		0.00	0.00
2009	203,635	Conodoguinet Cr.	Potomac	1	178	9		0.83	0.00
2009	504,542	doguinet Cr. (mouth)/Conoy cr. (m	Potomac	1	178	4		0.34	0.00
2009	455,432	N. Br. Susq. R.(PA)	Potomac	0	0	0	5	0.00	0.00

AMERICAN EEL SAMPLING AT CONOWINGO DAM – 2012

Steve Minkkinen

Ian Park

USFWS, Maryland Fishery Resources Office

BACKGROUND

Eels are a catadromous species that ascend freshwater environments as juveniles then reside in riverine habitats until reaching maturity at which time they migrate to the Sargasso Sea where they spawn once and die. Larval eels are transported by ocean currents to rivers along the eastern seaboard of the continent. Unlike anadromous shad and herring, they have no particular homing instinct. Historically, American eels were abundant in East Coast streams, comprising more than 25 percent of the total fish biomass in many locations. However, Atlantic coast commercial landings have been declining since the 1970’s.

The Atlantic States Marine Fisheries Commission Fishery Management Plan for American Eel lists access to freshwater habitat as a priority for protecting the population. Although the Chesapeake Bay and tributaries support a large portion of the coastal eel population, eels have been essentially extirpated from the largest Chesapeake tributary, the Susquehanna River. The Susquehanna River basin encompasses 43% of the Chesapeake Bay watershed. Construction of Conowingo Dam in 1928 effectively closed the river to upstream migration of elvers at river mile ten (Figure 1).

Mainstem Susquehanna fish passage facilities (lifts and ladder) were designed and sized to pass adult shad and herring and are not effective (due to attraction flow velocities and operating schedules) in passing juvenile eels (elvers) upriver. Specialized passages designed to accommodate elvers are needed to allow them access to the watershed above dams.

SURVEY METHODS AND EQUIPMENT PLACEMENT

To determine the best method to reintroduce eels into the Susquehanna River above Conowingo Dam, we have collected baseline information on eel abundance, migration timing, catch efficiency, and attraction parameters at the base of the Conowingo Dam since the spring of 2005. Information from the study will assist in determining the potential for reintroducing eels into the Susquehanna watershed above Conowingo Dam.

The 2012 American eel sampling below Conowingo took place on the west side of the dam adjacent to the West Fish Lift. This sampling served as an attempt to further survey the population of juvenile eels (elvers) at the base of Conowingo Dam. In 2007, elvers were observed climbing up the rip rap where water was spilling over from pumps operated to supply water for the West fish lift operations. From 2008 through 2012 we used this excess water as attraction flow for our elver trap, constructed from industrial cable tray with landscape fabric attached to the bottom (Figure 2). Elvers that found this attraction flow would crawl up the rip rap to the trap and then climb into the trap. The top of the cable tray emptied into a covered collection tanks (Figure 3). Aerated water was supplied to the collection and holding tank using a 1/8 HP Sweetwater™ Blower. In 2009 and 2010 we made an attempt to attract elvers directly from the Susquehanna River at the base of the riprap as well. In 2011 we discontinued the experimental trap going down to the river's edge. Elvers were sedated with, Finquel Tricane Methanesulfonate (MS-222), individually counted and a subsample were measured for total length (TL). Large numbers of eels were counted volumetrically. The collection of substantial numbers of eels allowed for the experimental stocking of elvers into several tributaries to the Susquehanna River as well as the Susquehanna River mainstem (Table 1). Stockings in Buffalo Creek and Pine Creek is part of a compensatory mitigation for the Sunbury Riverfront Stabilization Project for the City of Sunbury (DA Permit Application Number: NAB 2005-02860-PO5).

All of the elvers stocked were marked with a 6 hour immersion in buffered oxytetracycline (OTC) at a concentration of 550 ppm prior to release. Subsamples of elvers were sent to the Lamar Fish Health Center (Lamar, PA) for disease testing before any stocking occurred.

In 2012, our yellow eel collection continued using a double throated rectangular trap with a 25 mm by 13 mm mesh that is consistent with local commercial gear. Yellow eels captured in eel pots were sedated with a concentrated solution of MS-222 (450g/L), measured, and had a Passive Integrated Transponder (PIT) tag inserted in the dorsal musculature and released.

In 2012, young-of-year (glass eels) were collected by Maryland Department of Natural Resources (Maryland DNR) in Turville Creek, MD. These eels were then transported to the United State Geological Survey lab in Wellsboro, Pennsylvania. The glass eels were held in the lab until May, and then released in Buffalo and Pine Creek (Table 1).

RESULTS

Eels were sampled between 16 May and 27 August 2012 and elvers were collected throughout the entire sampling period (Table 2). A total of 127,000 elvers were collected during 2012 with the majority collected in five pulses. The first pulse occurred at the end of May and then about every two weeks after. The seasonal pattern of migration in 2012 was similar to that observed in previous years with a majority of the eels collected from mid June through mid August. In 2008, 2010, 2011 and 2012 we saw multiple pulses of elvers throughout our sampling efforts; where as in 2009 there did not appear to be peaks in collections, but more of a steady level of migration through the sampling period. In 2011 we saw a large peak in elver collection at the end of August through the beginning of September during high flows associated with hurricane Irene and tropical storm Lee (Figure 4).

Juvenile eel lengths ranged from 71 to 208 mm TL (Figure 5), similar to previous years sampling. In 2012, 95% of elvers measured were between 90 and 149 mm, and from 2005-2011 90% of elvers measured were between 90 and 149 mm.

Yellow and silver eel collections in eel pots have taken place from 2007 through 2012. In 2012, we captured 187 yellow and silver eels that ranged from 352 to 578 mm TL. Of the 187 captures, 66 eels had new PIT tags inserted, 22 were recaptures from tagging done in 2012 or in previous years, the remainder were released without being tagged or were sacrificed for studies. In 2012 we had fewer captures and recaptures compared to 2011 (224 captures and 55 recaptures, Table 3). The addition of the 66 eels PIT-tagged eels this year brings the total number of PIT-tagged yellow eels in the study to 355. We are tracking annual growth rates of the 36 PIT tagged eels that have been recaptured after at least one year after tagging (Table 4).

Nine stockings from elvers captured at Conowingo Dam were completed, with an estimated total of 96,000 elvers being stocked in Susquehanna Watershed (Table 1).

To evaluate stocking success at Buffalo and Pine Creek, we conducted electrofishing surveys using 3 backpack electrofishers and a barge electrofisher in July and August 2012. We duplicated methods used by the Maryland Biological Stream Survey (2007) to quantify the catch per unit effort (CPUE) and the biomass of eels. Two sites, bracketing the eel stocking sites, in each creek were surveyed (Table 1). At each site, 75 meters of stream were blocked off using ¼" mesh block net. In order to quantify the fauna in the stream, two passes with the electrofishing units were conducted and all species of fish collected were enumerated. Captured eels were measured to assess growth and a subsample of the eels collected was brought back to confirm previous marking of otoliths by OTC. In August of 2012, 163 elvers were recaptured in Buffalo Creek. We recaptured 64 elvers at the Strawbridge Rd site and 100 were at the foot bridge on Rte. 1003. Sampling in Pine Creek in 2012 provided 235 recaptured elvers, 21 of which were recaptured at the Darling Run site, and 214 were caught at the Ansonia Bridge site. The average TL of stocked elvers from Conowingo was 125 mm, and the average TL of glass eels stocked was 76 mm, while the average TL of recaptured eels in Buffalo Creek was 196 mm. The average TL of recaptured eels in Pine Creek was 128 mm. In addition to eels, 3,348 individuals of 33 fish species were collected in Buffalo Creek and 4,717 individuals of 24 fish species were collected in Pine Creek during electrofishing surveys. (Minkkinen et al. 2012)

In addition to the electrofishing surveys at the stocking locations in Buffalo Creek, we sampled upstream and downstream within the watersheds of our stocking locations. We used two backpack shockers and sampled the creek 2.4 kilometers upstream and 2 kilometers downstream from the stocking locations and previously surveyed areas. We collected a total of 210 eels, the upstream CPUE was 38.2 eels per hour, and the downstream CPUE was 26.7 eels per hour. The recaptured eels were sedated with MS-222 and measured, total length ranged from 138 mm to 551 mm (Figure 6). We inserted PIT tags into the dorsal musculature of eels that were over 200 mm prior to being released (174).

A subsample of elvers and yellow eels were sacrificed to evaluate the presence of the swim bladder parasite *Anguillicola crassus*. A total of 144 elvers were euthanized using MS-222, then examined for the presence of *Anguillicola crassus*. The elver samples were collected in 2010, 2011 and 2012. *Anguillicola crassus* was found in 66 of the samples (46%), with the highest infection rate of 7 nematodes found in one eel. An additional 28 yellow eel samples were collected in 2012 and *Anguillicola crassus* was found in nine eels (32%), with the highest infection rate of 22 nematodes being found in one eel. There does not appear to be any relationship between the length of an eel and the infection rate (Figure 7), or an increase in infection rate from one year to the next.

DISCUSSION

The sampling above and below the stocking site in Buffalo Creek has shown that at least some of the elvers that we have stocked have the ability to grow much faster than the yellow eels that we have caught below the Conowingo dam. The yellow eels captured below the dam had an average growth rate of 44 mm per year with a standard deviation of 25. The maximum growth in one year for a yellow eel captured below Conowingo dam is 129 mm per year. We found four eels in Buffalo Creek that were over 525mm, assuming that they were elvers stocked in 2010 and were the average size of stocked eels (125 mm), they have grown an average of over 200mm a year.

Samplings conducted by other agencies have captured eels that had migrated away from the stocking locations. Biologists from the Pennsylvania Fish and Boat Commission collected two eels in Rapid Run (a tributary to Buffalo Creek). The eel’s lengths were estimated to be 280-330 mm and were found about 19 kilometers upstream from the stocking locations (personal communication). Biologists from the Susquehanna River Basin Commission have found several eels upriver and downriver from our stocking location in Pine Creek. The most upriver eel found is approximately 19 kilometers from the stocking location, and the most downriver location is about 82 kilometers downstream (personal communication). The Pine Creek recaptures ranged from 130 mm to 500 mm. Eels could be in other locations in the basin and additional sampling will likely provide more information about their dispersal throughout the watershed.

We attempted to evaluate the relationship between elver migrations in relation to environmental uces. The factors we considered were lunar fraction, river flow, barometric pressure, air temperature, daily precipitation levels, and the average daily values of dissolved oxygen, salinity, water temperature, pH, turbidity, and chlorophyll. In years past we have not been able to determine what environmental factors control the timing of the elver migration below Conowingo Dam. Typically elvers reach the dam between the first week of May through the end of June and peak captures usually occur in June and July. In 2011 using Pearson correlation it appeared that turbidity, river flow and precipitation have the largest correlation value and these three values are directly related to one another. However in 2012 we did not see a correlation between environmental factors and elver collection.

Interruptions in power supply to our pumps have impacted elver catch on several occasions. We have implemented several sampling design changes in an attempt to ensure that we would have an uninterrupted supply of water throughout the sample period. We have also increased the size of our collection and holding tanks in an effort to increase survival and decrease stress while holding the elvers for stocking. These measures have improved our ability to capture and hold larger numbers of elvers for stocking above the dam.

FUTURE PLANS

In 2013 we will release a majority of the elvers captured at Conowingo Dam into the Susquehanna River above the York Haven dam. A smaller quantity of elvers will also be released into Buffalo Creek. The Maryland Fishery Resources Office will survey Buffalo Creek for PIT tagged eels in an attempt to continue growth analysis of stocked eels.

REFERENCES

Maryland Department of Natural Resources. 2007. Maryland Biological Stream Survey: Sampling Manual Field Protocols. 65 pp.

Minkkinen S.P., Devers J.L. & Galbraith H. 2012. Experimental Stocking of American Eels in the Susquehanna River Watershed. City of Sunbury, Riverbank Stabilization Project DA Permit Application Number: NAB2005-02860-POS

FIGURES AND TABLES

Figure 1. Map of the Maryland Biological Stream Survey (MBSS) sampling sites of tributaries to the Susquehanna River in Maryland. The numbers in boxes indicates eel counts at each sampling site. Note the difference in densities of eels in tributaries below Conowingo Dam compared to above the Dam.

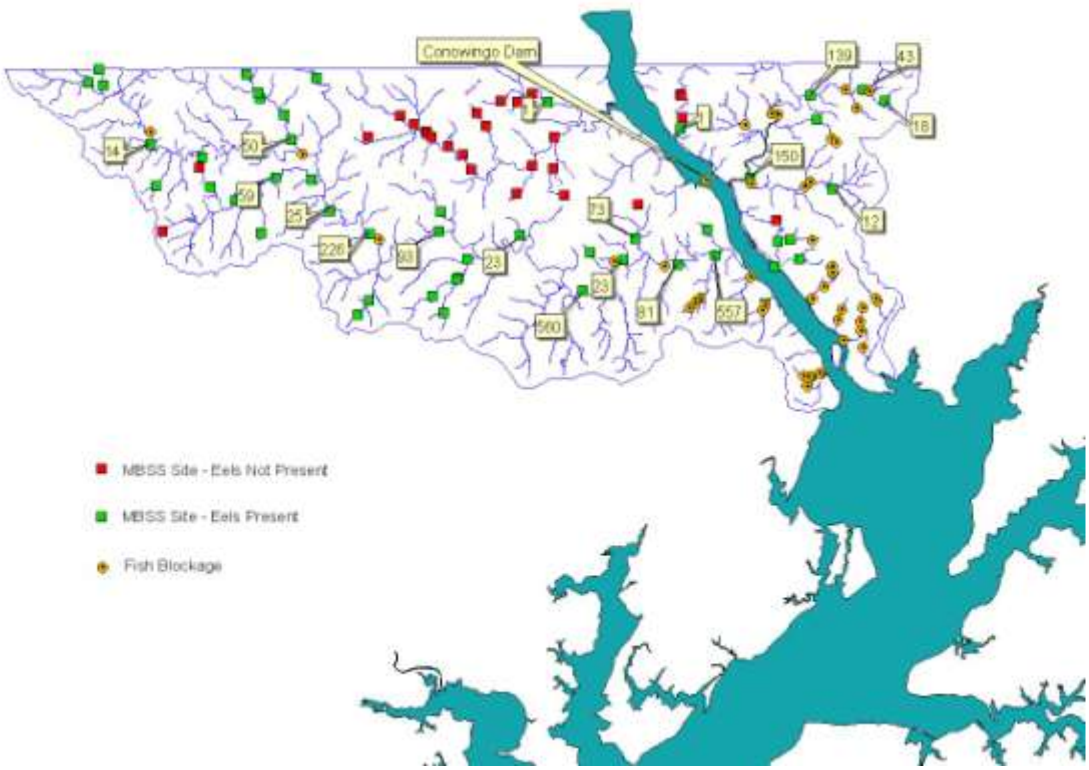


Figure 2. Eel trap constructed of industrial cable tray and landscape fabric.

Figure 3. The cable tray emptying into a collection tank.

Figure 4. Weekly elver captures at Conowingo Dam, 2008 – 2012.

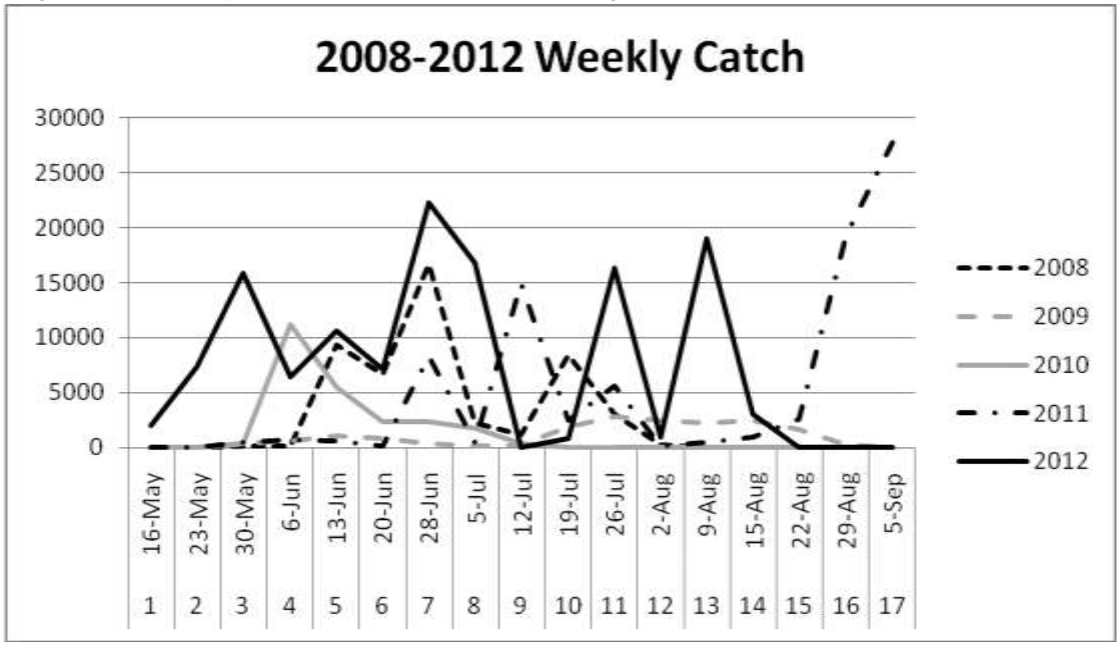


Figure 5. Length frequency of elvers captured below Conowingo Dam 2005-2012.

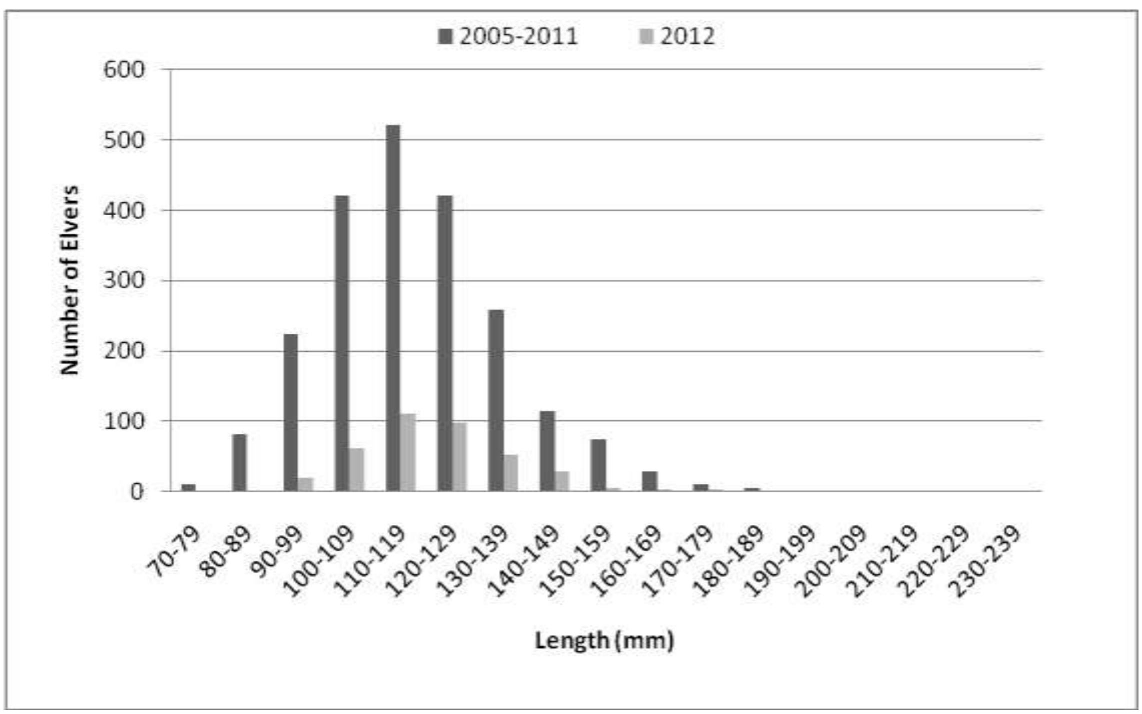


Figure 6. Length frequency of yellow eels captured in Buffalo Creek

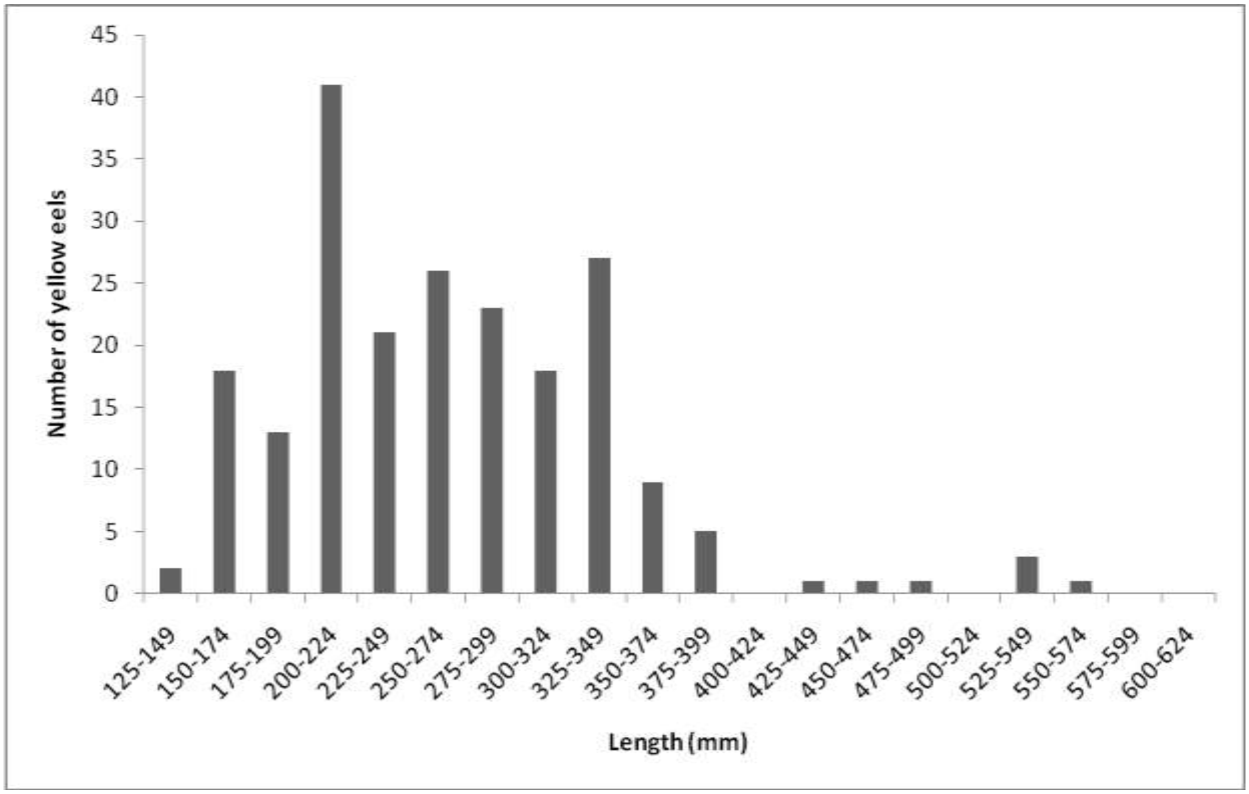


Figure 7. The number of *Anguillicola crassus* present in different lengths of elvers collected from Conowingo Dam.

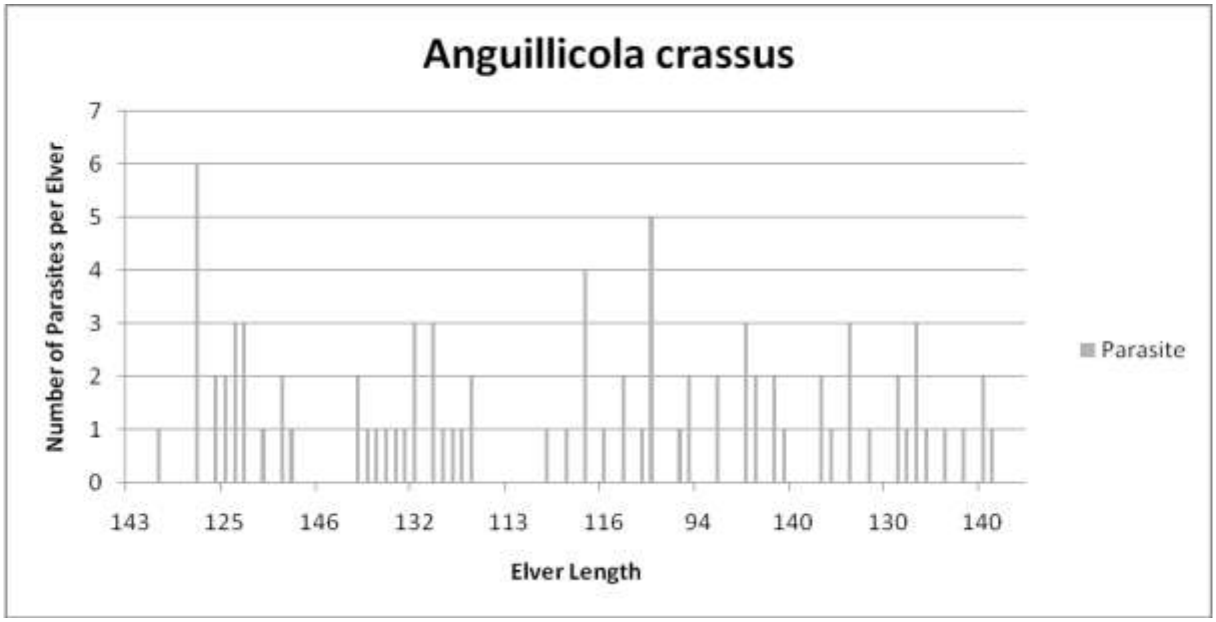

Anguillicola crassus
Number of Parasites per Elver
0
1
2
3
4
5
6
7
143
125
146
132
113
116
94
140
130
140
Elver Length
Parasite

Table 1. Date, location, and number of elvers stocked in 2012

Date	# stocked	Latitude	Longitude	Site	Source
5/24/2012	15237	41 44.203' N	77 25.822' W	Darling Run Acces, Pine Creek, PA	Glass
5/24/2012	8426	40 59.139' N	76 55.930' W	Strawbridge Rd, Buffalo Creek, PA	Glass
5/31/2012	7122	40 59.139' N	76 55.930' W	Strawbridge Rd, Buffalo Creek, PA	Conowingo
6/6/2012	16241	41 44.633' N	77 26.031' W	Anasonia Bridge, Pine Creek, PA	Conowingo
6/20/2012	11592	41 44.633' N	77 26.031' W	Anasonia Bridge, Pine Creek, PA	Conowingo
6/27/2012	5000	39 36.873' N	76 12.382' W	Glenville Rd Dam, Deer Creek, MD	Conowingo
6/28/2012	8827	39 40.794' N	76 16.847' W	Robinson Mill Rd Bridge, Broad Creek, MD	Conowingo
7/5/2012	11401	39 41.702' N	76 14.460' W	Flintville Rd Boat Ramp, Broad Creek, MD	Conowingo
7/26/2012	15536	40 09.900' N	76 44. 850'W	Etters Boat Ramp, Susquehanna River PA	Conowingo
8/7/2012	1068	40 59.139' N	76 55.930' W	Strawbridge Rd, Buffalo Creek, PA	Conowingo
8/13/2012	19865	40 09.755' N	76 44. 953'W	Etters Boat Ramp, Susquehanna River PA	Conowingo

Table 2. Number of elvers caught at the base of Conowingo Dam on the West side of the dam during 2012.

Date	# of Elvers		Date (con't)	# of Elvers
5/16/2012	100		6/29/2012	1421
5/18/2012	613		7/2/2012	3520
5/21/2012	1330		7/5/2012	16822
5/23/2012	277		7/17/2012	0
5/24/2012	108		7/23/2012	829
5/29/2012	7029		7/25/2012	14513
5/30/2012	2067		7/26/2012	722
5/31/2012	2652		7/27/2012	402
6/1/2012	5354		7/30/2012	737
6/4/2012	5820		8/1/2012	110
6/6/2012	5238		8/3/2012	387
6/8/2012	487		8/6/2012	438
6/11/2012	667		8/10/2012	8002
6/13/2012	1795		8/11/2012	3316
6/15/2012	3379		8/13/2012	7697
6/18/2012	3508		8/15/2012	2080
6/20/2012	1956		8/17/2012	840
6/22/2012	849		8/20/2012	164
6/25/2012	4327		8/24/2012	0
6/27/2012	13950		8/27/2012	71
6/28/2012	3436			

Table 3. Number of Passive Integrated Transponder Tags (PIT) applied to yellow eels below Conowingo Dam by year.

Year	# of Tags Applied
2007	51
2008	32
2009	68
2010	11
2011	127
2012	66

Table 4. Growth of yellow eels caught and recaptured in pots at the base of Conowingo dam by year.

	Average Length (mm)						*Average Annual Growth Increase (mm)*
Eel ID	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
1	594	617	*	*	*	*	23.0
2	733	770	*	*	*	*	37.0
3	463	474	*	*	*	*	11.0
4	404	510	521	*	*	*	58.5
5	426	445	*	*	*	*	19.0
6	338	390	505	*	*	*	83.5
7	551	589	*	*	*	*	38.0
8	475	511	*	*	*	*	36.0
9	405	471	510	*	*	*	55.0
10	377	405	440	*	*	*	31.5
11	466	490	*	*	*	*	24.0
12	391	520	*	557	*	*	55.3
13	386	428	*	*	*	*	21.0
14	458	*	565	*	*	*	53.5
15	484	*	624	*	*	*	70.0
16	457	*	590	*	*	*	66.5
17	386	*	478	*	*	*	46.0
18	447	*	580	*	*	*	66.5
19	*	419	433	*	*	*	14.0
20	*	364	383	395	449	*	28.3
21	*	393	516	*	*	*	123.0
22	*	479	543	*	*	*	64.0
23	*	497	575	*	*	*	78.0
24	*	454	*	550	*	*	48.0
25	*	*	612	626	*	*	14.0
26	*	*	495	578	*	*	83.0
27	*	*	432	462	470	*	19.0
28	*	335	*	*	446	*	37.0
29	*	321	*	*	377	*	18.6
30	*	*	476	*	508	*	16.0
31	*	*	368	*	465	*	48.5
32	*	*	*	*	446	482	36.0
33	*	*	*	*	390	422	32.0
34	*	*	405	*	*	465	30.0
35	*	*	*	*	418	458	40.0

36	*	*	*	*	464	513	49.0

POPULATION ASSESSMENT OF ADULT AMERICAN AND HICKORY SHAD IN THE UPPER CHESAPEAKE BAY

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INTRODUCTION

The Maryland Department of Natural Resources has conducted annual surveys targeting adult American shad and hickory shad in the upper Chesapeake Bay (Susquehanna River) since 1980 and 1998, respectively. The purpose of these surveys is to define stock characterizations, including sex and age composition, spawning history, relative abundance and mortality.

After closure of the American shad recreational and commercial fisheries in 1980, stocks increased significantly in the lower Susquehanna River until 2001; after this year, American shad abundance generally decreased. Hickory shad abundance appears to be high and stable within the lower Susquehanna River. The Maryland Department of Natural Resources (MDNR) is committed to restoring these species to sustainable, self-producing populations in the Susquehanna River Basin.

METHODS

Data Collection

Adult American shad were angled from the Conowingo Dam tailrace on the Susquehanna River two times per week from 4 April through 30 May 2012 (Figure 1). Two rods were fished simultaneously; each rod was rigged with two shad darts and lead weight was added when required to achieve proper depth. All American shad were sexed (by expression of gonadal products), total length (TL) and fork length (FL) were measured and scales were removed below the insertion of the dorsal fin for ageing and spawning history analysis. Fish in good physical condition (including unspent or ripe females) were tagged with Floy tags (color-coded to identify the year tagged) and released. A MDNR hat was given to fishers as a reward for returned tags.

Normandeau Associates, Inc. was responsible for observing and/or collecting American shad at the Conowingo Dam fish lifts. American shad collected in the East Fish Lift (EFL) at the Conowingo Dam were deposited into a trough, directed past a 4' x 10' counting window, identified to species and counted by experienced technicians. American shad recaptured from the West Fish Lift (WFL) at the Conowingo Dam were counted and either used for experiments (e.g., hatchery brood stock, oxytetracycline analysis, sacrificed for otolith extraction) or returned to the tailrace. For both lifts, tags were used to identify returning American shad.

Recreational data from a non-random roving creel survey were collected from anglers in the Conowingo Dam tailrace during the spring. In this survey, stream bank anglers were interviewed about American and hickory shad catch and hours spent fishing. A voluntary logbook survey also provided location, catch and hours spent fishing for American and hickory shad in the Susquehanna River for each participating angler.

MDNR's Susquehanna Restoration and Enhancement Program provided additional hickory shad data (2004-2012) from their brood stock collection in the Susquehanna River. Hickory shad were collected in Deer Creek (a Susquehanna River tributary) for hatchery brood stock and were subsampled for age, repeat spawning marks, sex, length and weight. In 2004 and 2005, fish were collected using hook and line fishing; fish have been collected using electrofishing gear from 2006 to the present.

Data Analysis

Sex and Age Composition

Male-female ratios were derived for American shad angled at the Conowingo Dam in the Susquehanna River. Hickory shad male-female ratios were derived from data provided by the Restoration and Enhancement Program's brood stock collection on the Susquehanna River.

Age determination from scales was attempted for American shad scales collected from the Conowingo Dam. American shad scales were aged using Cating's method (Cating 1953). A minimum of four scales per sample were cleaned, mounted between two glass slides and read for age and spawning history using a Bell and Howell MT-609 microfiche reader. The scale edge was counted as a year-mark due to the assumption that each fish had completed a full year's growth at the time of capture. Ages were not assigned to regenerated scales or to scales that were difficult to read. Hickory shad scales from the Susquehanna River were aged by the Restoration and Enhancement Program. Repeat spawning marks were counted on all alosine scales during ageing, and the percentages of repeat spawners by species and system (sexes combined) were arcsine-transformed (in degrees) before looking for linear trends over time. For all statistics, significance was determined at $\alpha = 0.05$.

Relative Abundance

Catch-per-unit-effort (CPUE) in the Conowingo Dam tailrace was calculated as the number of adult fish captured per boat hour. Data for both the EFL and the WFL were used to calculate a combined lift CPUE, which was the total number of adult fish lifted per hour of lifting. The geometric mean (GM) of adult American shad CPUE for both the tailrace area and the lifts was then calculated as the average LN (CPUE + 1) for each fishing/lifting day, transformed back to the original scale. Catch-per-angler-hour (CPAH) for American shad and hickory shad in the Susquehanna River were also calculated from both the roving creel survey and shad logbooks.

Chapman's modification of the Petersen statistic was used to estimate abundance of American shad in the Conowingo Dam tailrace (Chapman 1951):

$$N = (C+1)(M+1)/(R+1)$$

where N is the relative population estimate, C is the number of fish examined for tags at the EFL and WFL, M is the number of fish tagged and R is the number of tagged fish recaptured.

Overestimation of abundance by the Petersen statistic (due to low recapture rates) necessitated the additional use of a biomass surplus production model (SPM; Macall 2002, Weinrich et al. 2008):

$$N_t = N_{t-1} [r\ N_{t-1}(1\text{-}N_{t-1}) / K)]\text{-}\ C_{t-1}$$

where N_t is the population (numbers) in year t, N_{t-1} is the population (numbers) in the previous year, r is the intrinsic rate of population increase, K is the maximum population size, and C_{t-1} is losses associated with upstream and downstream fish passage and bycatch mortality in the Atlantic herring fishery in the previous year (equivalent to catch in a surplus production model). The dynamics of this population are governed by the logistic growth curve. Model parameters were estimated using a non-equilibrium approach that follows an observation-error fitting method (i.e., assumes that all errors occur in the relationship between true stock size and the index used to measure it). Assumptions include proportional bycatch of American shad in the Atlantic herring fishery and correct adult American shad turbine mortality estimates. The SPM required an initial population estimate in 1985, which was set as the 1985 Petersen statistic (calculation described above).

Mortality

Catch curve analysis was used to estimate total instantaneous mortality (Z) for American and hickory shad in the Susquehanna River. The number of repeat spawning marks was used in this estimation instead of age because ageing techniques for American shad scales are tenuous (McBride et al. 2005). Therefore, the Z calculated for these fish represents mortality associated with repeat spawning. Assuming that consecutive spawning occurred, the ln-transformed spawning group frequency was plotted against the corresponding number of times spawned:

$$\ln(S_{fx} + 1) = a + \mathrm{Z} * W_{fx}$$

where S_{fx} is number of fish with 1,2,...*f* spawning marks in year *x*, *a* is the y-intercept, and W_{fx} is frequency of spawning marks (1,2,...*f*) in year *x*. Using Z, annual mortality was obtained from a table of exponential functions and derivatives (Ricker 1975).

RESULTS

American shad

Sex and Age Composition

The male-female ratio of adult American shad captured by hook and line from the Conowingo tailrace was 1:0.72. Of the 191 fish sampled by this gear, 177 were successfully scale-aged (Table 1). Males were present in age groups 3-6 and females were found in age groups 3-8. The 2007 year-class (age 5) and the 2006 year-class (age 6) were the most abundant for males and females, respectively, accounting for 45% of males and 46% of females (Table 1). Thirty-four percent of males and 73% of females were repeat spawners. The arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2012; r^2 = 0.45, P < 0.001; Figure 2).

Relative Abundance

Sampling at the Conowingo Dam occurred for 18 days in 2012. A total of 226 adult American shad were encountered by the gear; 217 of these fish were captured by MDNR staff from a boat and the remaining 9 were captured by shore anglers. MDNR staff tagged 190 (84%) of the sampled fish. To remain consistent with historical calculations, only the 217 fish captured from the boat were used to calculate the hook and line CPUE. No tagged American shad recaptures were reported from either commercial fishermen or recreational anglers

The EFL operated for 62 days between 2 April and 5 June. The 2012 season was the third longest season of EFL operation and had the highest number of lifts since the EFL became operational in 1991. Of the 22,143 American shad that passed at the EFL, 39% (8,665 fish) passed between 22 April and 11 May. Peak passage was on 24 April; 1,710 American shad were recorded on this date. Twenty-four of the American shad counted at the EFL counting windows were identified as being tagged in 2012; only 2 fish passed that were tagged in 2011 (Table 2).

The Conowingo WFL operated for 37 days. The 1,486 captured American shad were retained for hatchery operations, sacrificed for characterization data collection, or returned alive to the tailrace. Peak capture from the WFL was on 5 May. The four tagged American shad recaptured by the WFL in 2012 were fish tagged in 2012 (Table 2).

The Petersen statistic estimated 150,743 American shad in the Conowingo Dam tailrace in 2012, and the SPM estimated a population of 111,500 fish. Despite differences in yearly estimates, the overall population trends derived from each method are similar (Figure 3). Specifically, SPM estimates declined from 2001 to 2007 and increased from 2008 to 2012. Petersen estimates follow a similar pattern if the high levels of uncertainty in 2004 and 2008 (due to low recapture rates) are considered.

Estimates of hook and line GM CPUE vary without trend over the time series (1984-2012; $r^2 = 0.11$, $P = 0.07$). Abundance is particularly variable from 2007-2012 and remains below the high indices observed from 1999 to 2002 (Figure 4). WFL data have not yet been released by Normandeau Associates, Inc., to calculate the combined lift GM CPUE. As of 2011, the combined lift GM CPUE significantly increased over the time series (1980-2011; $r^2 = 0.38$, $P < 0.001$); however, the GM CPUE decreased steadily from 2002 to 2008 before increasing slightly from 2009 through 2011 (Figure 5).

The creel survey conducted 58 interviews were conducted over five days during creel survey at the Conowingo Dam Tailrace. The CPAH in 2012 was the third lowest since the start of the survey in 2001 (Table 3), and CPAH has decreased over the time series (2001-2012; $r^2 = 0.46$, $P = 0.02$). Three anglers returned logbooks in 2012. Although American shad CPAH calculated from shad logbook data decreased significantly over the time series (1999-2012; $r^2 = 0.35$, $P = 0.03$), CPAH has steadily increased since 2009 (Table 4).

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in $Z = 0.61$.

Hickory Shad

Sex and Age Composition

A total of 1,014 hickory shad were sampled in 2012 by the brood stock collection survey in Deer Creek. The male-female ratio was 2.06:1. Of the total fish captured by this survey, 200 were successfully aged. Males were present in age groups 3-6 and females were found in age groups 3-7. The most abundant year-classes by sex were the 2008 year-class (age 4) for both males (42.6%) and females (33.8%; Table 5). Hickory shad sampled from 2004 to 2012 ranged from 2 to 9 years of age, with ages 3 through 8 present every year except for 2012 (Table 6). In

2012, the oldest fish were age 7. The arcsine-transformed proportion of these repeat spawners (sexes combined) has not changed significantly over the time series (2004-2012; r^2 = 0.028, P = 0.67; Figure 6). However, the total percent of repeat spawners in 2012 (64.0%) is the lowest total percent of repeat spawners of the time series (2004-2012; Table 7).

Relative Abundance

Shad logbook data indicated that hickory shad CPAH did not vary significantly over the time series (1998-2012; r^2 = 0.13, P = 0.19); however, hickory shad CPAH decreased in 2012 (Table 8).

Mortality

Total instantaneous mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.68.

DISCUSSION

American Shad

American shad are historically one of the most important exploited fish species in North America. However, the stock has drastically declined due to the loss of habitat, overfishing, ocean bycatch, stream blockages and pollution. Restoration of American shad in the upper Chesapeake Bay began in the 1970s with the building of fish lifts and the stocking of juvenile American shad. Maryland closed the commercial and recreational American shad fisheries in 1980, and the ocean intercept fishery closed in 2005. The American shad adult stock has shown some improvement since the inception of restoration efforts, although the 2007 ASMFC stock assessment indicated that stocks were still declining in most river systems along the east coast (ASMFC 2007).

The population size of American shad appears to be increasing in the lower Susquehanna, particularly since 2007 (SPM estimate). This follows a period (2002 to 2007) when calculated indices of abundance generally decreased (including the hook and line CPUE, logbook CPAH and creel CPAH). Despite this increase in population size, the 2012 hook and line CPUE was the lowest it has been since 1986 and there is no significant trend in CPUE over time. Gizzard shad are increasing in abundance in the Susquehanna drainage and may reduce the number of lifted American shad by using the lifts themselves, thus affecting lift CPUE. The Potomac River CPUE is increasing (1996-2012); however, the CPUE in the Nanticoke River shows no significant trend (1988-2011), which suggests uneven area-wide recovery.

Both the Petersen estimate and the SPM are useful techniques for providing estimates of American shad abundance at the Conowingo Dam. The SPM likely underestimates American shad abundance. For example, the Conowingo Dam lift efficiency (defined as annual number of American shad lifted at Conowingo Dam divided by population estimate) was as high as 98.7 % in 2004, and it is unlikely that the dam passed nearly 100% of the fish in the Conowingo Dam tailrace. Conversely, the Petersen statistic likely overestimates the population, especially in years of low recapture of tagged fish. However, the trends (rather than the actual numbers) produced by the estimate/model should be emphasized when assessing the population at the Conowingo Dam in the Susquehanna River.

Scales are the only validated ageing structures for determining the age of American shad (Judy 1960, McBride et al. 2005). However, Cating's method of using transverse grooves is no longer recommended: comparisons of American shad scales from different populations show different groove frequencies to the freshwater zone and first three annuli (Duffy et al. 2011). Until alternative ageing structures are investigated, we will remain consistent with historical ageing methods; however, we discarded scales that were difficult to interpret and continue to use repeat spawning marks to calculate mortality rates.

The percent of repeat spawning American shad has increased over time. The percent of repeat spawners was generally less than 10% in the early 1980s in the Conowingo Dam tailrace (Weinrich et al. 1982). In contrast, 50% of aged American shad at the Conowingo Dam were repeat spawners in 2012. This increase in repeat spawners may be related to the end of truck and transport methods in 1997. During truck and transport, American shad were transported above dams where turbine mortality was nearly ensured for all fish returning downstream. However, the population size did decrease after truck and transport ended in 1997, confirming that multiple factors contribute to the recovery of American shad in the lower Susquehanna River (i.e., spawning habitat, juvenile success, percent of repeat spawners).

The total instantaneous mortality rate for American shad captured in the Conowingo Dam tailrace in 2012 is below the benchmark Z_{30} assigned to rivers in neighboring states (ASMFC 2007). The mortality estimate may be a maximum rate because repeat spawning marks are assessed during the spawning season after fish have returned to freshwater but before developing a new spawning mark.

Hickory Shad

Hickory shad stocks have drastically declined due to the loss of habitat, overfishing, stream blockages and pollution. A statewide moratorium on the harvest of hickory shad in Maryland waters was implemented in 1981 and is still in effect today.

Adult hickory shad are difficult to capture due to their aversion to fishery independent (fish lifts) and dependent (pound and fyke net) gears. In the Susquehanna River, very few hickory shad are historically observed using the EFL. A notable exception was 2011: 20 hickory shad were counted at the EFL counting window, which is more than three times the previous high in 2002. Despite the traditionally low number of hickory shad observed passing the Conowingo Dam, Deer Creek (a tributary to the Susquehanna River) has the greatest densities of hickory shad in Maryland (Richardson et al. 2009). According to shad logbook data collected from Deer Creek anglers (1998-2012), catch rates exceed four fish per hour for all years except 2009 and 2010. Hickory shad are sensitive to light and generally strike artificial lures more frequently when flows are somewhat elevated and the water is slightly turbid. Consequently, the low CPAH for hickory shad in 2009 may be directly related to the low flow and clear water conditions encountered by Deer Creek anglers and observed by Maryland DNR staff during that spring season.

Hickory shad age structure has remained relatively consistent, with a wide range of ages and a high percentage of older fish. Ninety percent of hickory shad from the Susquehanna spawned by age four, and this stock generally consists of few virgin fish (Richardson et. al 2004). Repeat spawning has remained relatively consistent over the 2004-2012 time series, with the percent of repeat spawners ranging between 64-89%.

Because only a catch and release fishery exists for hickory shad in Maryland, estimates of Z are attributable solely to natural mortality. The high percent of repeat spawners is also indicative of very low bycatch mortality. Hickory shad ocean bycatch is minimized compared to the other alosines because both mature adults and immature sub-adults migrate and overwinter closer to the coast (ASMFC 2009). This is confirmed by the fact that few hickory shad are observed portside as bycatch in the ocean small-mesh fisheries (Matthew Cieri, Maine Dep. Marine Res., pers. comm.).

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TABLES

Table 1. Number of adult American shad and repeat spawners by sex and age sampled from the Conowingo Dam tailrace in 2012.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	4	0	1	0	5	0
4	31	5	1	0	32	5
5	46	15	14	5	60	20
6	22	15	34	25	56	40
7	0	0	23	23	23	23
8	0	0	1	1	1	1
Totals	103	35	74	54	177	89
Percent Repeats	34.0%		73.0%		50.3%	

Table 2. Number of recaptured American shad in 2012 at the Conowingo Dam East and West Fish Lifts by tag color and year.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Orange	2012	24
Green	2011	2
West Lift		
Tag Color	Year Tagged	Number Recaptured
Orange	2012	4

Table 3. American shad recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2012. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Hours Fished for American Shad	American Shad Catch	American Shad CPAH
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34
2007	30	107.5	128	1.19
2008	16	32.5	24	0.74
2009	40	85	120	1.41
2010	36	64	114	1.78
2011				
2012	58	189	146	0.77

Table 4. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for American shad, 1999-2012.

Year	Total Reported Angler Hours	Total Number of American Shad	Catch Per Angler Hour
1999	160.5	463	2.88
2000	404	3,137	7.76
2001	272.5	1,647	6.04
2002	331.5	1,799	5.43
2003	530	1,222	2.31
2004	291	1035	3.56
2005	258.5	533	2.06
2006	639	747	1.17
2007	242	873	3.61
2008	559.5	1,269	2.27
2009	378	967	2.56
2010	429.5	857	2.00
2011	174	413	2.37
2012	171.5	486	2.83

Table 5. Numbers of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in Deer Creek in 2012.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	40	0	13	0	53	0
4	55	42	24	18	79	60
5	28	28	21	21	49	49
6	6	6	9	9	15	15
7	0	0	4	4	4	4
8	0	0	2	2	0	0
Totals	129	76	87	66	200	128
Percent Repeats	58.9%		73.2%		64.0%	

Table 6. Percent of hickory shad by age and number sampled from the brood stock collection survey in Deer Creek by year, 2004-2012.

Year	N	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9
2004	80		7.5	23.8	27.5	18.8	18.8	3.8	
2005	80		6.3	17.5	28.8	33.8	11.3	1.3	1.3
2006	178	0.6	9	31.5	29.8	20.2	7.3	1.7	
2007	139		6.5	23.7	33.8	20.9	12.2	2.2	0.7
2008	149		9.4	29.5	33.6	20.1	5.4	2	
2009	118		7.6	16.9	44.9	19.5	10.2	0.8	
2010	240		12.5	37.9	31.3	11.3	6.7	0.4	
2011	216		30.1	30.1	27.3	8.8	2.78	0.93	
2012	200		49.3	76.4	51.3	17.3	5.6		

Table 7. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek, 2004-2012.

Year	N	Percent Repeats
2004	80	68.8
2005	80	82.5
2006	178	67.4
2007	139	79.1
2008	149	83.9
2009	118	89.0
2010	240	75.4
2011	216	68.5
2012	200	64.0

Table 8. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for hickory shad, 1998-2012.

Year	Total Reported Angler Hours	Total Number of Hickory Shad	Catch Per Angler Hour
1998	600.0	4,980	8.30
1999	817.0	5,115	6.26
2000	655.0	3,171	14.8
2001	533.0	2,515	4.72
2002	476.0	2,433	5.11
2003	635.0	3,143	4.95
2004	750.0	3,225	4.30
2005	474.0	2,094	4.42
2006	766.0	4,902	6.40
2007	401.0	3,357	8.37
2008	942.0	5,465	5.80
2009	561.0	2,022	3.60
2010	552.0	1,956	3.54
2011	224.3	1,802	8.03
2012	184.0	857	4.66

FIGURES

Figure 1. Conowingo Dam (Susquehanna River) hook and line sampling location for American shad in 2012.

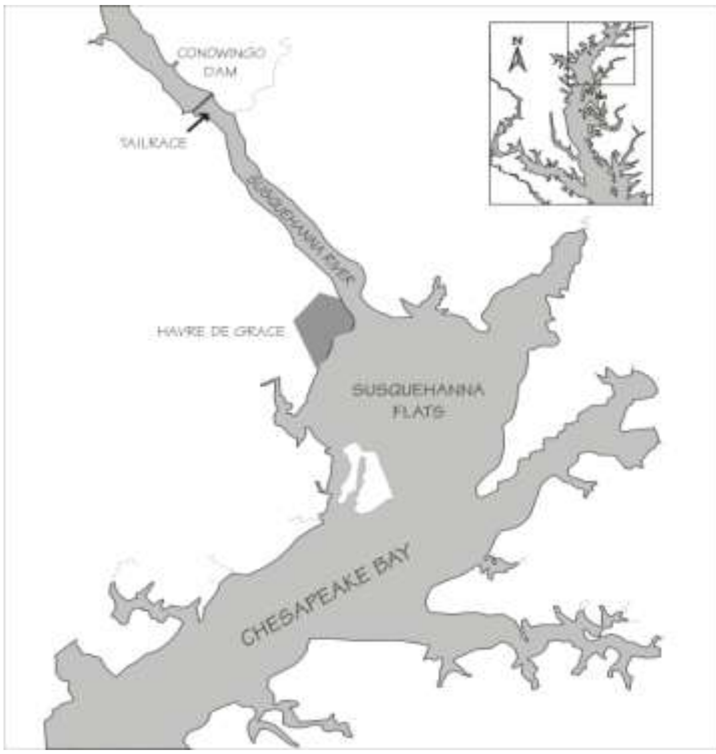

Figure 2. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2012.

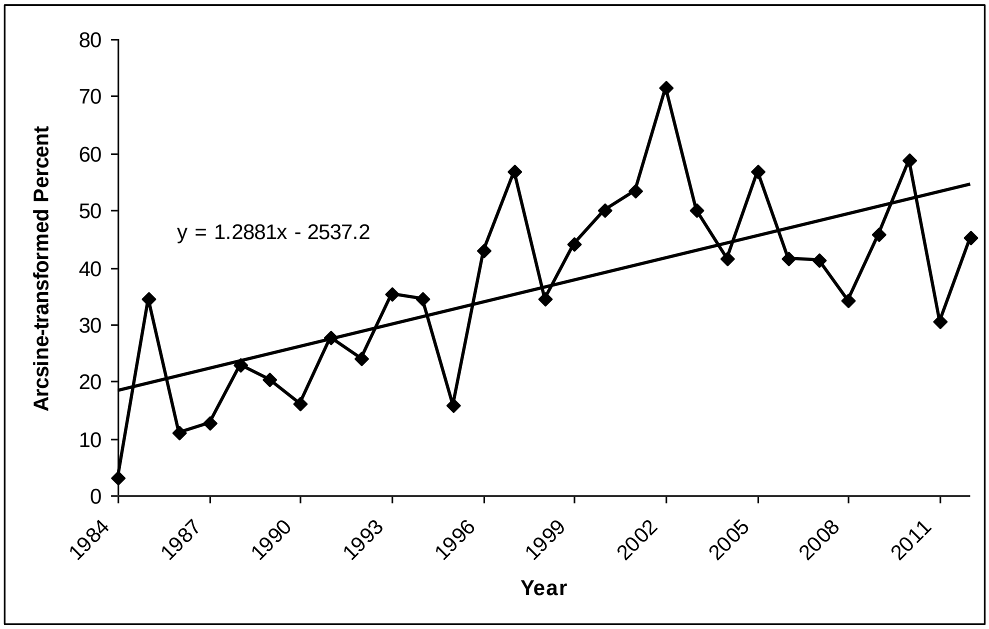

Figure 3. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic and the surplus production model (SPM), 1986-2012.

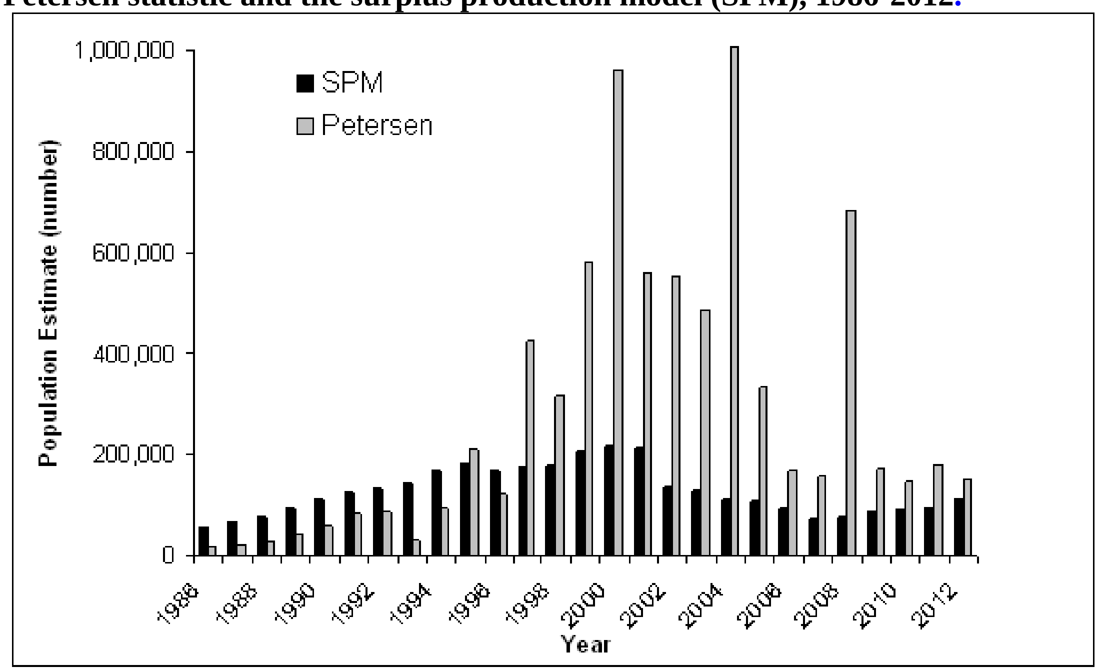

Figure 4. American shad geometric mean CPUE (fish per boat hour) from the Conowingo Dam tailrace hook and line sampling, 1984-2012.

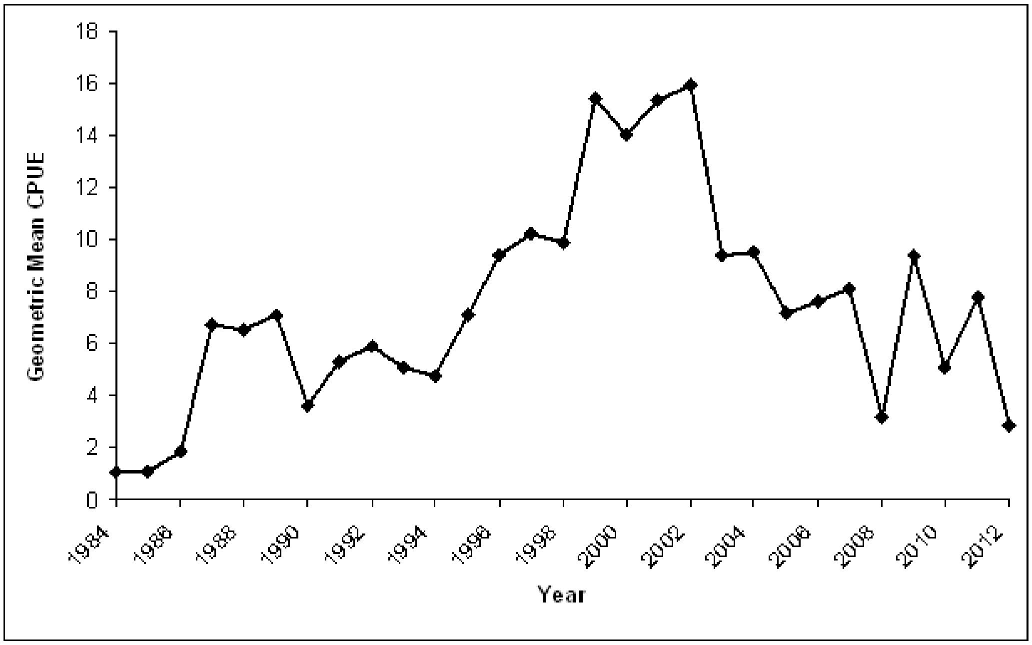

Figure 5. American shad geometric mean CPUE (fish per lift hour) from the East and West Fish Lifts at the Conowingo Dam, 1980-2011. Data for 2012 have not yet been released.

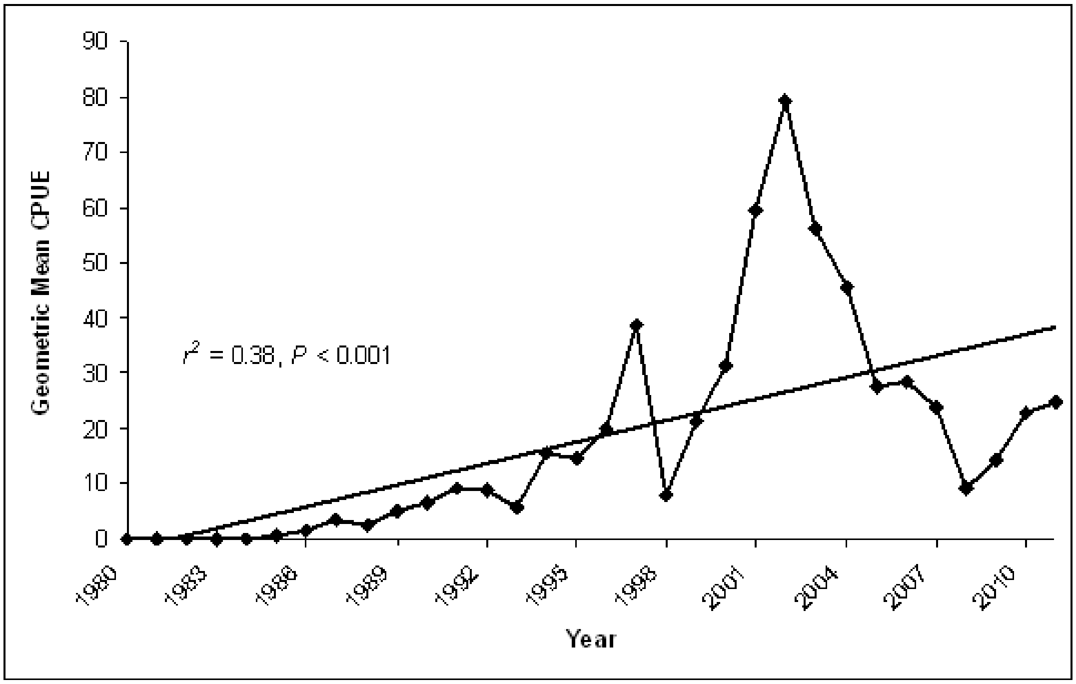

Figure 6. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River), 2004-2011.