RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER

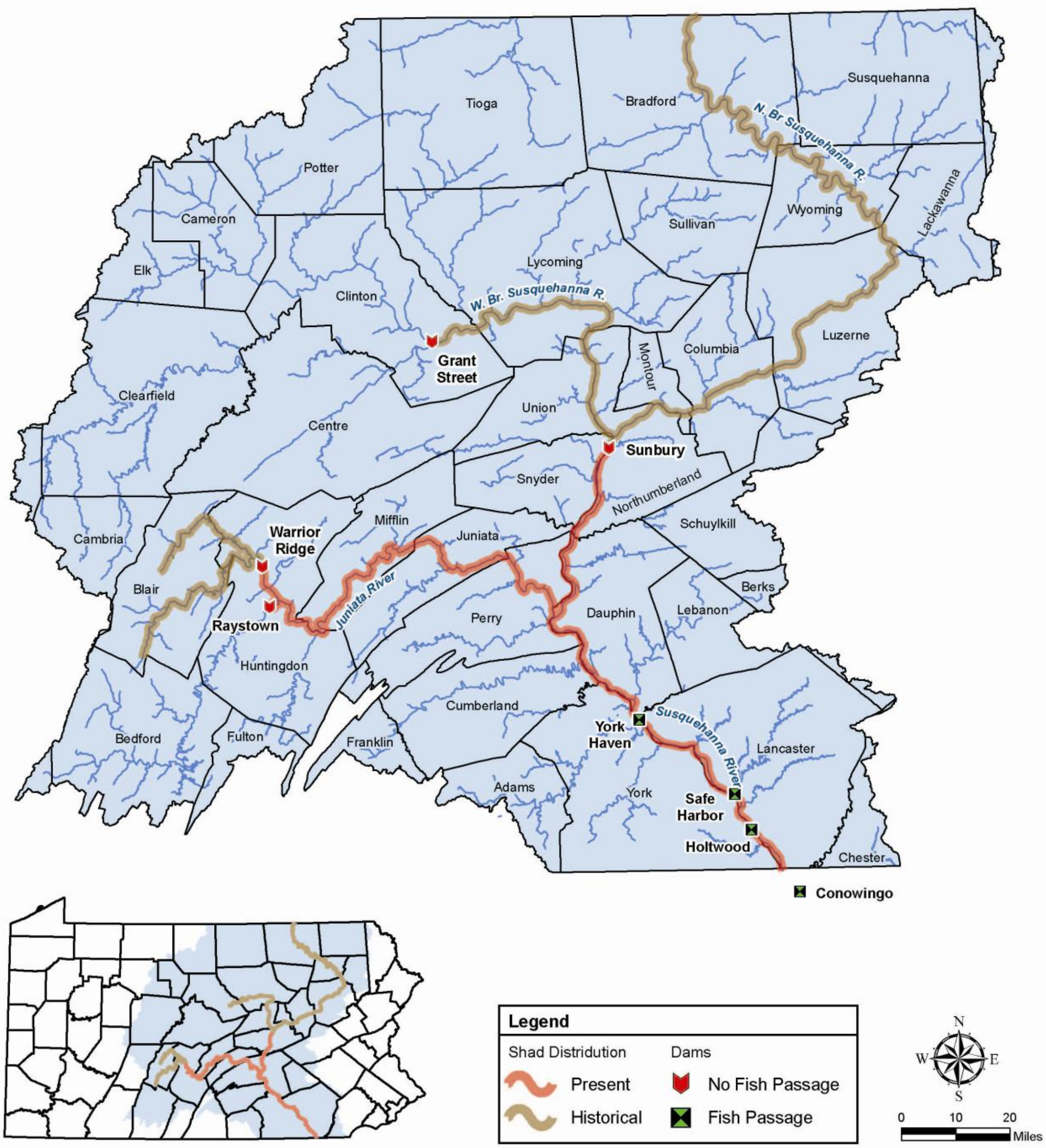
ANNUAL PROGRESS REPORT
2011

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

March 2012

American Shad
Habitat and Distribution
Susquehanna River Basin



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EXECUTIVE SUMMARY

This 2011 Annual Report of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) presents results from activities and studies directed at restoring American shad to the Susquehanna River. Rebuilding anadromous American shad and river herring stocks is based on hatchery releases and natural reproduction of adult fish passed directly through fish lifts at Conowingo, Holtwood, Safe Harbor dams and a fish ladder at York Haven dam. The restoration program represents a continuing commitment among all of the SRAFRC parties and its partners to return migratory fishes to historic spawning and nursery habitat upstream of dams in the Susquehanna River.

Operation of the Conowingo East Fish Lift (EFL) was delayed for most of April, 2011 due to river water temperatures less than 50.0°F (1 to 11 April) and the onset of high river flows in excess of 100,000 cfs on 7 April. The Conowingo East lift began operations on April 25, but shad did not appear in abundance on May 11. The lift operated every day thereafter through May 19 when SRAFRC partners agreed to cease shad passage because few shad were using the Holtwood Fish Lift. SRAFRC partners agreed that there was no point in passing shad into Conowingo Pool since they could not get above Holtwood. For the season, the East lift operated 15 days, made 259 lifts and passed 289,453 fish. Gizzard shad (257,522) and American shad (20,571) comprised 96% of all fish passed. Other alosines included only 20 hickory shad, 2 alewives and 17 blueback herring. American shad were collected at water temperatures of 58.8 to 66.9°F and at natural river flows of 43,500 to 145,200 cfs. The natural river flow and water temperature during the three highest days of shad passage, (14, 15, and 16 May), ranged from 43,500 cfs to 46,700 cfs and 64.5°F to 65.0°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 51,171 cfs. The average daily river flow during the operational season was 78,047 cfs.

During the 2006 season, the East fish lift passed a total of 24 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the MDDNR. Of these floy-tagged fish, 20 tags were green (2011 hook and line), and 4 pink (2010 hook and line).

Average daily river flow at Conowingo suffered 4 peaks between April 1 and May 6 which delayed operation of the west lift until May 13. The West Fish Lift operated until June5, fishing 85.4 hours and 144 lifts. Total catch amounted to 100,070 fish of 32 taxa. Gizzard shad comprised 79% of the total catch and the next two most numerous species, channel catfish and American shad comprised 19% of the total. No other Alosines were caught. Catch of American shad averaged 205 per operating day with a peak day catch of 1,185 shad on May 16.

Every 50th shad collected throughout the season was killed for otolith analysis and scale samples, yielding 61 specimens. An additional 76 shad were processed from tank-spawn trials. Of the 137 shad sacrificed for hatchery vs. wild analysis by PFBC, 37% were shown to be of hatchery origin. A total of 378 American shad were used for tank spawning on-site at Conowingo Dam.

High river flow events in March and April, 2011 delayed the start of fish lift operations at the Conowingo East fish lift (EFL) until 25 April, 2011. The passage of over one-thousand American shad at the Conowingo EFL on 11 May would have normally triggered the start of fish lift operations at Holtwood. However, the high river flows deposited large amounts of rock debris in the tailrace hopper pit and crowder channel that had to be removed prior to the commencement of Holtwood lift operations. A specialized work crew utilizing divers was needed to remove the debris before the Holtwood Fish Lift commenced operations on 20 May, 2011. The tailrace lift was operated on 9 days while the spillway lift operated on 3 days. Lift operations were terminated for the season, with agency concurrence, on 5 June. The lifts passed 5,052 fish of 15 taxa. Gizzard shad (4,535), channel catfish (229), and walleye (122), dominated the catch, and comprised nearly 97% of the total fish collected and passed. American shad represented the sole *Alosa* species collected and passed at Holtwood in 2011. A total of 18 American shad (nearly 86% of total shad catch) was passed in the tailrace lift while the spillway lift accounted for 3 American shad (14% of total shad catch). The highest daily shad catch occurred on 25 May when 5 shad moved upstream during 9.4 hours of operation. The 2011 American shad passage rate at Holtwood versus Conowingo (less than 1% of fish passing Conowingo passed Holtwood) was the lowest observed since operations commenced in 1997. The passage rate may have been the product of high river flows, equipment malfunctions, and the debris in the fish lift. This provides more evidence that maintenance problems can severely impact fish passage at technical fishways.

Safe Harbor fishway operation normally commences soon after passage of approximately 500 American shad via the Holtwood fishway. Due to high river flow events, Holtwood did not begin operation after the Conowingo East Fish Lift passed 1,000 American shad. Safe Harbor Fish Lift operations commenced on 26 May, 2011, one day after Holtwood passed 5 American shad into Lake Aldred. The Safe Harbor fishway ended operations on 6 June. Lift operations ended, with agency concurrence, due to the sub-par passage of American shad and abnormally high river flows. The Safe Harbor fish lift operated for 56 hours during 9 days between May 26 and June 6 and made 61 lifts. A total of 8,059 fish of 10 species passed upstream into Lake Clarke. Gizzard shad (3,216) was the dominant species passed and comprised 40% of the catch. Eight American shad were passed upstream through the fish way and comprised less than 1% of the catch. Other predominant fishes passed included quillback (2,037) and channel catfish (2,323). Peak passage occurred on 27 May, when 1,305 fish were passed. Passage of other alosines, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2011. Safe Harbor passed about 38% of the American shad counted at Holtwood.

The York Haven fish ladder was opened on 1 April (allowing volitional, unmanned passage) and closed on 5 June. Due to low American shad passage at Safe Harbor, the fish ladder at York Haven was not manned and counts are not available.

The Maryland Department of Natural Resources (MDNR) conducts annual surveys targeting adult American shad and hickory shad in the upper Chesapeake Bay (Susquehanna River). American shad are angled from the Conowingo Dam tailrace, measured, sexed, tagged and released. Indices of abundance are derived from this hook and line data and from combined lift data. Recreational creel and logbook surveys also provide information on American and hickory shad abundance. MDNR's Susquehanna Restoration and Enhancement Program provides additional hickory shad data from brood stock collection in the Susquehanna River. Both the Petersen estimate and the surplus production model exhibited an increasing trend in American shad abundance in the Susquehanna River over the time series (1986-2011), and American shad indices of abundance (hook and line, and combined lift) increased in 2011. The 2011 male-female ratio for Conowingo tailrace adult American shad was 1:2,28. From hook and line sampling, male American shad were present in age groups 4-6 and females in age groups 4-7. The trend in the arcsine-transformed percent of American shad repeat spawners is increasing, despite a decrease in 2011. Hickory shad age structure remains consistent, with a wide range of ages and a high percentage of older fish. Males were present in age groups 3-7 and females in age groups 3-8. In 2011, an unusually large number of hickory shad were passed at the East Fish Lift, and CPAH in Deer Creek was the fourth highest in the 14 year time series.

A total of 137 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2011. Based on tetracycline marking and otolith microstructure, 63% of the 134 readable otoliths were identified as wild and 37% 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 1986-2006 year classes, stocking of approximately 388 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.

The U.S. Fish and Wildlife Service (USFWS) was contracted by Pennsylvania Fish and Boat Commission (PFBC) to collect American shad eggs from the Potomac River. The purpose of the collection was to supply viable eggs to the Van Dyke American Shad Hatchery in support of ongoing Susquehanna River American shad restoration efforts. Sampling took place over a total of 19 days and supplied a total of 137 L of American shad eggs (6.2 million) with a 44% fertilization rate resulting in 2.7 million viable eggs. The U.S. Fish and Wildlife Service's sixth attempt to deliver eggs for Susquehanna River American shad restoration resulted in a similar number of viable eggs as in previous years with the exception of 2010.

The PFBC also collected shad eggs from the Delaware River at Smithfield Beach, PA. Fishing occurred from 15 May through 2 June 2011. Eggs were collected and shipped on 13 of the 13 nights of fishing. A total of 1,010 adult shad were captured and 171.9 liters of eggs were shipped for a hatchery count of more than 9.9 million eggs. Overall, the viability for Delaware River American shad eggs was 14.7%.

This was the 8th year of hickory shad spawning tests and the 11th year of hormone induced American shad spawning tests at the Conowingo West Fish Lift. Hickory shad continued to outperform the American shad in these tests without the benefit of hormone injections. A total of 378 hickory shad were used for tank-spawning at a 1:0.06 male-female ratio. A total of 12.2 million hickory shad eggs were produced with a viability of 78.9%, the second highest in the eight year program. A total of 936 American shad were used for tank-spawning at a 3:2 male-female ratio. A total of 1.2 million eggs were produced with a viability of 15.7%, near the ten year average of 18.7%. The late start of the American shad tests due to river conditions raised some doubts that a full complement of 15± tests with 936 injected fish could be completed before the end of the American shad runs that typically end in early June. The elimination of control tests and a steady supply of pre-spawn brood stock from the West Lift helped speed up the testing schedule. During the first week of June, river temperature reached 24.0°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 three spawning tests.

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A total of 5 shipments of hickory shad eggs (12.1 million eggs) were received and processed at Van Dyke in 2011. Overall egg viability was 78.9% resulting in the production of some 3.6 million larvae. Hickory shad larvae were stocked in Octoraro Creek (500 thousand), a tributary to the Susquehanna River, while Pennypack and Ridley creeks (tributaries to the Delaware River) received 1.9 and 1.2 million hickory shad larvae, respectively.

A total of 31 shipments of American shad eggs (23.5 million eggs) were received at Van Dyke in 2011. Total egg viability was 22.6% and survival of viable eggs to stocking was 78%, resulting in production of 4.1 million larvae. Larvae were stocked in the Juniata River (1.3 million), the West Branch Susquehanna River (1.4 million), Bald Eagle Creek (191 thousand), and the North Branch Susquehanna River in Pennsylvania (83 thousand). Delaware River source American shad larvae were stocked in the Lehigh (473 thousand) and the Schuylkill (643 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.

As was the case since 2002, juvenile shad collections continued to be weak in 2011. Juvenile American shad were collected by haul seine at City Island and Columbia, in strainers at Conowingo Dam and by electrofishing in Lake Aldred and Conowingo pond. Haul seine GM CPUE at Columbia (combined daily lifts) of 0.06 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 100% hatchery origin. Production of hatchery larvae from the Van Dyke Hatchery was 3.1 million. Adult shad passage was the worst recorded due to high flows and maintenance issues at Holtwood. Based on haul seine CPUE at Columbia, survival of hatchery-reared American shad larvae was 106 times lower during 2008 to 2011 than during 1993 to 2001 indicating that survival of hatchery-reared larvae has plummeted in recent years. The cause of this is not known.

USFWS staff from Maryland Fishery Resources Office in Annapolis sampled for American eels immediately downstream for Conowingo Dam from May 23 through September 8, 2011. Sampling ended abruptly due to flooding subsequently caused by tropical storm Lee. The 2011 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 2008, 2010 and 2011, multiple waves of elvers were collected, where as in 2009 there did not appear to be spikes in collections, but more of a steady level of migration through the sampling period. Juvenile eel lengths ranged from 84 to 225 mm TL (Figure 5), slightly larger than previous years sampling. Yellow and silver eel collections in eel pots have taken place from 2007 - 2011. In 2011, we caught 224 yellow and silver eels that ranged from 333 to 659 mm TL. Of the 224 captures, 127 eels had new PIT tags inserted, 55 were recaptures from tagging done in 2011 or in previous year, and the rest were released without being tagged. This year we caught significantly more yellow and silver eels than in previous years.

A total of ten stockings from elvers captured at Conowingo Dam were conducted, with an estimated total of 62,000 elvers being stocked in Buffalo, Pine and Conowingo Creek. 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. Electrofishing surveys were conducted in August to evaluate stocking success at Buffalo and Pine Creek. A total of 441 elvers were recaptured in Buffalo Creek and 20 in Pine Creek.

Fish passage facility maintenance, operations, fish counting and reporting were paid by each of the affected utility companies in accordance with guidelines established by separate fish passage advisory committees. American shad egg collections from the Potomac River, Van Dyke hatchery culture and marking, juvenile shad netting and other surveys above Conowingo Dam, and otolith mark analysis were funded by the PA Fish and Boat Commission. Maryland DNR funded the adult shad population assessment, stock analysis, and juvenile shad seining in the upper Chesapeake Bay. USFWS covered costs associated with the eel survey at Conowingo. Costs related to Conowingo West fish lift operations including tank spawning and hormones were paid from a SRAFRC contributed funds account administered by USFWS. Contributions to the special account in 2011 came from Maryland DNR and PFBC. Additional information on activities discussed in this Annual Report can be obtained from individual Job authors or by contacting the PFBC Anadromous Fish Restoration Unit Leader at:

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SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY, SPRING 2011

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October 2011

EXECUTIVE SUMMARY

Operation of the Conowingo East Fish Lift (EFL) was delayed for most of April, 2011 due to river water temperatures less than 50.0°F (1 to 11 April) and the onset of high river flows in excess of 100,000 cfs on 7 April, (Figure 1). The EFL operated for 15 days in 2011. EFL operations were terminated on 19 May per request of the resource agencies. The resource agencies requested that Exelon cease EFL operations until a significant number of American shad previously passed by the EFL into Conowingo Pond successfully pass upstream of the Holtwood facility. The 2011 fish passage season marks the twenty-first season of overall operation and the fifteenth year of volitional passage operation at the Conowingo EFL.

The EFL passed 289,453 fish of 24 species. Gizzard shad (257,522), American shad (20,571), channel catfish (10,087), walleye (360) and carp (253), dominated the catch, and comprised nearly 100% of the total fish collected and passed.

A total of 20,571 American shad were passed. The highest daily shad catch occurred on 14 May when 5,013 shad were passed upstream. On 7 of the 15 days of operation, American shad passage exceeded 1,000 fish. On a daily basis, overall shad passage was strongest through the fishway between 1000 hrs and 1659 hrs.

Fishway operations were conducted at water temperatures ranging from 53.1°F to 65.4°F and river flows between 43,500 and 145,200 cfs. Spillage occurred on 5 of the 15 days of operation, (one third of the season). River flows were high throughout the passage season.

The 2011 fish passage season marks the first time operations under spill conditions were documented with photographs. 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 put into effect because of very low American shad and other fish passage counts during spill conditions.

For most of the season, water clarity was adequate, which did allow the viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at the Conowingo EFL in 2011 was 24.

Future operations of the EFL will build on the past fifteen 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 2011 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 (as previously noted) was maintained for the period 1 to 31 May. A minimum flow of 5,000 cfs or natural river (as previously noted) is maintained when fish lift operations occur in June.

Fishway Operation

The start of operation for the EFL in 2011 began on 25 April. EFL operations were limited in April, 2011due to water temperatures less than 50.0°F (1 to 11 April) and river flows that exceeded 100,000 cfs from 7 April through 8 May, (Figure 1). The first four American shad were passed on 8 May. Everyday operation began on 8 May, and continued through19 May. On 19 May, the Agencies requested that Exelon cease operations of the EFL until a significant number of shad passed by the EFL into Conowingo Pond successfully passed upstream of the Holtwood facility. EFL operations did not resume due to the lack of successful shad passage at Holtwood in 2011. The EFL operated a total of 15 days during the 2011 season.

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, and daily/hourly fish passage numbers. 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 2011 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 hourly throughout the day. 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.

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, B, or C was utilized throughout the 2011 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 1. A total of 289,453 fish of 24 species passed upstream into Conowingo Pond. Gizzard shad (257,522), American shad (20,571), channel catfish (10,087), walleye (360), and carp (253) were the dominant species passed. Gizzard shad and American shad comprised 89% and 7% respectively of the season total; the two species together accounted for 96% of the total fish passed. Other common fishes included shorthead redhorse (184), quillback (167), and smallmouth bass (146). Alosids, (American shad and river herring) comprised about 7% of the total catch. Peak passage occurred on 11 May when 66,490 fish, (95% gizzard shad), were passed.

American Shad Passage

The East lift collected and passed 20,571 American shad (Table 1). The first four American shad passed on 8 May. Collection and passage of shad varied daily with 1.9% (383) of the shad passed from 25 April to 10 May, 87% (17,900) passed from 11 May to 16 May, and 11% (2,288) passed from 17 May to 19 May (Figures 2 and 3). On 7 of the 15 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on 14 May when 5,013 American shad were passed.

American shad were collected at water temperatures of 53.1 to 65.4°F and at natural river flows of 43,500 to 145,200 cfs (Table 2 and Figure 2). The natural river flow and water temperature during the three highest days of shad passage, (14, 15, and 16 May), ranged from 43,500 cfs to 46,700 cfs and 64.5°F to 65.0°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 51,171 cfs. The average daily river flow during the operational season was 78,047 cfs.

The hourly passage of American shad at the EFL is given in Table 3. Generally, 66% (13,584) of all American shad passed between 1000 and 1659 hours. The highest hourly passage rate occurred from 1100 to 1159 hours.

Alosids

A small number of river herring, (2 alewife and 17 blueback herring) were passed during the 2011 season. Twenty hickory shad were also passed in spring 2011.

Maryland tag-recapture

During the 2011 season, the EFL passed a total of 24 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the MDDNR. Of these floy-tagged fish, 4 tags were pink (2010 hook and line) and 20 were green (2011 hook and line).

SUMMARY

EFL operation was initiated on 25 April with the first four American shad passed on 8 May. EFL operations were limited in April, 2011 due to cold water temperatures (< 50.0°F) and river flows above 100,000 cfs. The EFL passed 20,571 American shad from 8 May through 19 May. The total number of American shad passed during the 2011 season was lower than passage values recorded in 2009 and 2010, (Tables 4 and 5), due possibly to the cessation of EFL operations on 19 May at the request of the resource agencies. It is also the fifth consecutive year in which the EFL passed less than 50,000 American shad.

The 2011 fish passage season marks the first time operations under spill conditions were documented with photographs (Appendix A). 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 put into effect because of very low American shad and other fish passage counts during spill conditions. Photo 1 portrays the EFL in operation with 2 spill gates open. Photo 2 portrays the EFL operating with 4 spill gates open. Photo 3 displays entrance gate A in the "full closed" position with water pouring out of the gate. Spill conditions have a direct, negative effect on the EFL's ability to generate a strong and efficient attraction flow.

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 exit area. 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 119 American shad lift mortalities, (0.6% of the total shad passed), was observed in 2011, similar to lift mortalities observed in recent years (0.2% to 1.0%) and 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.

LITERATURE CITED

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

Normandeau Associates, Inc. 1999. Summary of the operations at the Conowingo Dam East fish passage facility in spring, 1998. Prepared for Susquehanna Electric Company, Darlington, MD.

TABLES AND FIGURES

Table 1. Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2011.

Date:	*4/25*	*4/27*	*5/4*	*5/8*	*5/9*	*5/10*	*5/11*	*5/12*
Start Fishing Time:	*9:00*	*8:00*	*8:00*	*9:00*	*8:00*	*8:15*	*7:30*	*7:30*
End Fishing Time:	*15:00*	*14:00*	*13:00*	*13:00*	*15:00*	*17:30*	*19:15*	*19:20*
Hours of Operation:	*6.0*	*6.0*	*5.0*	*4.0*	*7.0*	*9.3*	*11.8*	*11.8*
Number of Lifts:	*12*	*11*	*5*	*6*	*8*	*19*	*23*	*23*
Water Temperature (°F):	*55*	*58*	*58.1*	*58.8*	*58.3*	*60.8*	*61.7*	*61.9*
American Shad	0	0	0	4	7	372	1,337	2,435
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	2	0	0
Gizzard shad	5,764	4,654	355	1,750	10,196	29,992	63,176	50,480
Hickory shad	0	0	0	0	0	1	0	19
Striped bass	0	1	0	0	1	0	8	0
White perch	0	0	0	0	0	0	0	1
Sea lamprey	0	0	0	0	0	0	2	4
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
Carp	0	2	2	2	1	6	7	25
Quillback	4	2	1	0	3	1	3	5
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	3	16	0	4	3	0	0	1
Brown bullhead	0	0	1	0	0	0	0	0
Channel catfish	291	515	284	369	841	982	1,899	26
Rock bass	0	0	0	0	0	0	0	1
Bluegill	0	0	2	2	0	5	2	0
Smallmouth bass	0	2	0	0	0	13	20	25
Largemouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	2	0	0	3	9	36	11
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	6,062	5,194	645	2,131	11,055	31,383	66,490	53,033

Table 1. (continued)

Date:	*5/13*	*5/14*	*5/15*	*5/16*	*5/17*	*5/18*	*5/19*	***Season***
Start Fishing Time:	*7:30*	*6:45*	*7:00*	*7:30*	*7:30*	*7:30*	*7:30*	***Total***
End Fishing Time:	*19:30*	*19:30*	*19:15*	*19:45*	*19:15*	*19:15*	*16:00*	
Hours of Operation:	*12.0*	*12.8*	*12.3*	*12.3*	*11.8*	*11.8*	*8.5*	***142.4***
Number of Lifts:	*22*	*21*	*24*	*24*	*23*	*22*	*16*	***259.0***
Water Temperature (°F):	*63.5*	*64.1*	*65.3*	*66.1*	*66.9*	*66.7*	*66.9*	
American Shad	2,182	5,013	3,326	3,607	1,188	713	387	**20,571**
Blueback herring	0	5	5	1	0	6	0	**17**
Alewife	0	0	0	0	0	0	0	**2**
Gizzard shad	28,859	4,772	14,800	15,617	10,267	7,984	8,856	**257,522**
Hickory shad	0	0	0	0	0	0	0	**20**
Striped bass	3	0	0	2	0	1	5	**21**
White perch	0	0	1	0	2	0	2	**6**
Sea lamprey	0	9	1	2	1	0	1	**20**
Rainbow trout	0	0	0	1	0	1	0	**2**
Brown trout	0	1	0	0	1	0	0	**2**
Muskellunge	0	0	1	0	0	0	0	**1**
Carp	13	7	70	79	11	15	13	**253**
Quillback	13	1	59	32	23	15	5	**167**
White sucker	0	1	1	2	0	0	0	**4**
Shorthead redhorse	0	0	53	83	2	9	10	**184**
Brown bullhead	0	0	3	1	0	0	0	**5**
Channel catfish	59	459	446	661	1,609	1,067	579	**10,087**
Rock bass	0	0	7	5	0	1	1	**15**
Bluegill	1	1	9	5	3	1	0	**31**
Smallmouth bass	5	0	28	27	13	3	10	**146**
Largemouth bass	0	1	3	0	0	0	0	**4**
Yellow perch	0	0	4	3	0	0	0	**7**
Walleye	9	3	123	51	56	28	29	**360**
Atlantic Needlefish	0	0	0	6	0	0	0	**6**
TOTAL	31,144	10,273	18,940	20,185	13,176	9,844	9,898	**289,453**

Table 2. 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 2011.

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)	Crest Gates
4/25	0	*0*	111,700	53.1	18	11	C/B	310	25.4	108.5	3
4/27	0	*0*	145,200	57.9	18	11	C/B	310	25.2	108.3	6
5/4	0	*0*	132,300	59.0	4	11	C/B	310	24.6	108.6	3
5/8	4	*0*	109,200	57.2	8	11	C	310	24.3	108.5	11
5/9	7	*0*	90,700	58.4	10	11	C	310	24.5	108.3	11
5/10	372	*0*	74,800	60.1	22	11	C	310	23.3	108.2	0
5/11	1337	*0*	64,900	61.6	18	11	C	310	23.4	106.7	0
5/12	2435	*1*	58,200	63.1	24	11	C	310	22.5	106.5	0
5/13	2182	*1*	51,500	64.7	24	11	A/C	310	23.0	106.3	0
5/14	5013	*6*	46,700	65.0	24	5	A	310	19.3	105.8	0
5/15	3326	*2*	43,500	64.6	24	7	C	310	22.0	106.2	0
5/16	3607	*10*	45,100	64.5	26	11	C	310	22.8	107.2	0
5/17	1188	*1*	48,300	65.3	20	8	C	310	22.8	106.8	0
5/18	713	*2*	55,500	65.4	12	11	C	310	23.0	105.8	0
5/19	387	*1*	93,100	64.3	20	11	C	310	23.3	107.7	0

Table 3. Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2011.

Date:	*4/25*	*4/27*	*5/4*	*5/8*	*5/9*	*5/10*	*5/11*	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*
Observation Time-Start:	*9:00*	*8:00*	*8:10*	*8:30*	*8:10*	*8:15*	*8:15*	*7:30*	*7:45*	*7:20*	*7:40*	*8:00*
Observation Time-End:	*15:15*	*14:15*	*13:10*	*13:15*	*15:10*	*18:00*	*19:35*	*19:45*	*19:45*	*19:50*	*19:30*	*20:00*
Military Time (hrs)												
0700 to 0759	--	--	--	--	--	--	--	25	--	21	38	--
0800 to 0859	--	--	--	--	--	3	64	68	186	8	247	191
0900 to 0959	--	--	--	1	2	2	20	212	135	127	271	466
1000 to 1059	--	--	--	--	--	2	30	147	229	515	474	537
1100 to 1159	--	--	--	1	2	16	53	302	287	543	359	515
1200 to 1259	--	--	--	1	--	16	76	230	194	442	255	318
1300 to 1359	--	--	--	1	--	44	93	269	120	583	292	373
1400 to 1459	--	--	--	--	1	32	105	251	224	546	319	282
1500 to 1559	--	--	--	--	2	80	100	211	199	495	211	189
1600 to 1659	--	--	--	--	--	75	211	121	108	603	375	158
1700 to 1759	--	--	--	--	--	102	282	143	182	495	217	168
1800 to 1859	--	--	--	--	--	--	205	212	190	467	178	226
1900 to 1959	--	--	--	--	--	--	98	244	128	168	90	184
Total	0	0	0	4	7	372	1,337	2,435	2,182	5,013	3,326	3,607

Table 3. (continued)

Date:	*5/17*	*5/18*	*5/19*	*Season*
Observation Time-Start:	*7:40*	*7:40*	*7:45*	*Total*
Observation Time-End:	*19:30*	*19:30*	*16:45*	
Military Time (hrs)				
0700 to 0759	63	12	2	**161**
0800 to 0859	118	39	67	**991**
0900 to 0959	90	116	70	**1,512**
1000 to 1059	117	58	71	**2,180**
1100 to 1159	130	82	18	**2,308**
1200 to 1259	108	67	20	**1,727**
1300 to 1359	57	25	28	**1,885**
1400 to 1459	84	25	22	**1,891**
1500 to 1559	107	60	46	**1,700**
1600 to 1659	114	85	43	**1,893**
1700 to 1759	90	82	--	**1,761**
1800 to 1859	68	50	--	**1,596**
1900 to 1959	42	12	--	**966**
Total	1,188	713	387	**20,571**

Table 4. Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2011.

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	0.53	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	496	0.915	30	29,272	71	160	0
2010	59	685	526	0.857	38	37,757	4	1	0
2011	**15**	**259**	**142.4**	**0.021**	**24**	**20,571**	**17**	**2**	**20**

Table 5. Summary of American shad passage counts and percent passage at Susquehanna River dams, 1997-2011.

	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%**

Figure 1. Plot of River Flow (as measured at Holtwood Dam) March through June, 2011.

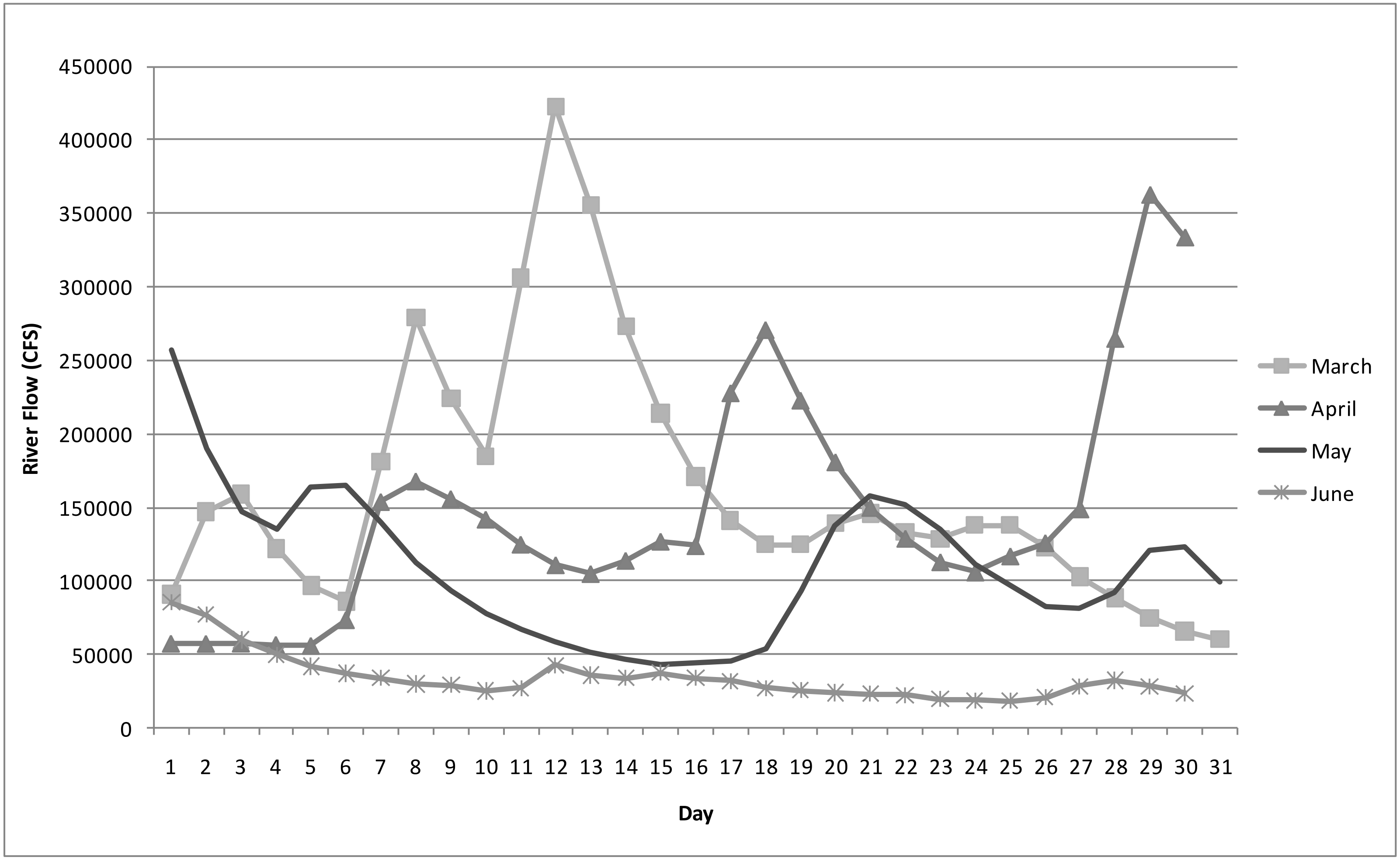


Figure 2. A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the daily American shad catch at the Conowingo East Fish Lift, spring 2011.

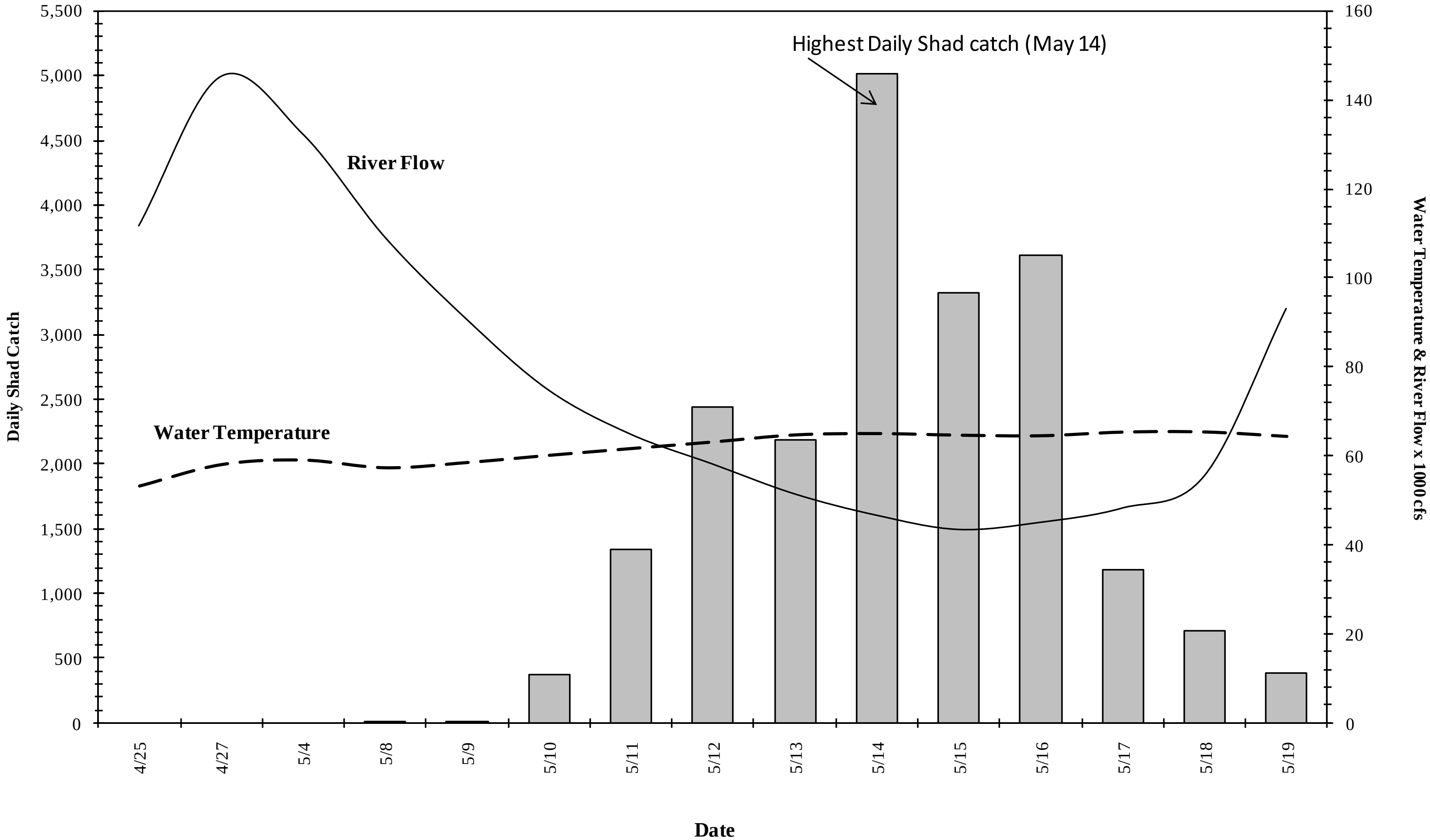
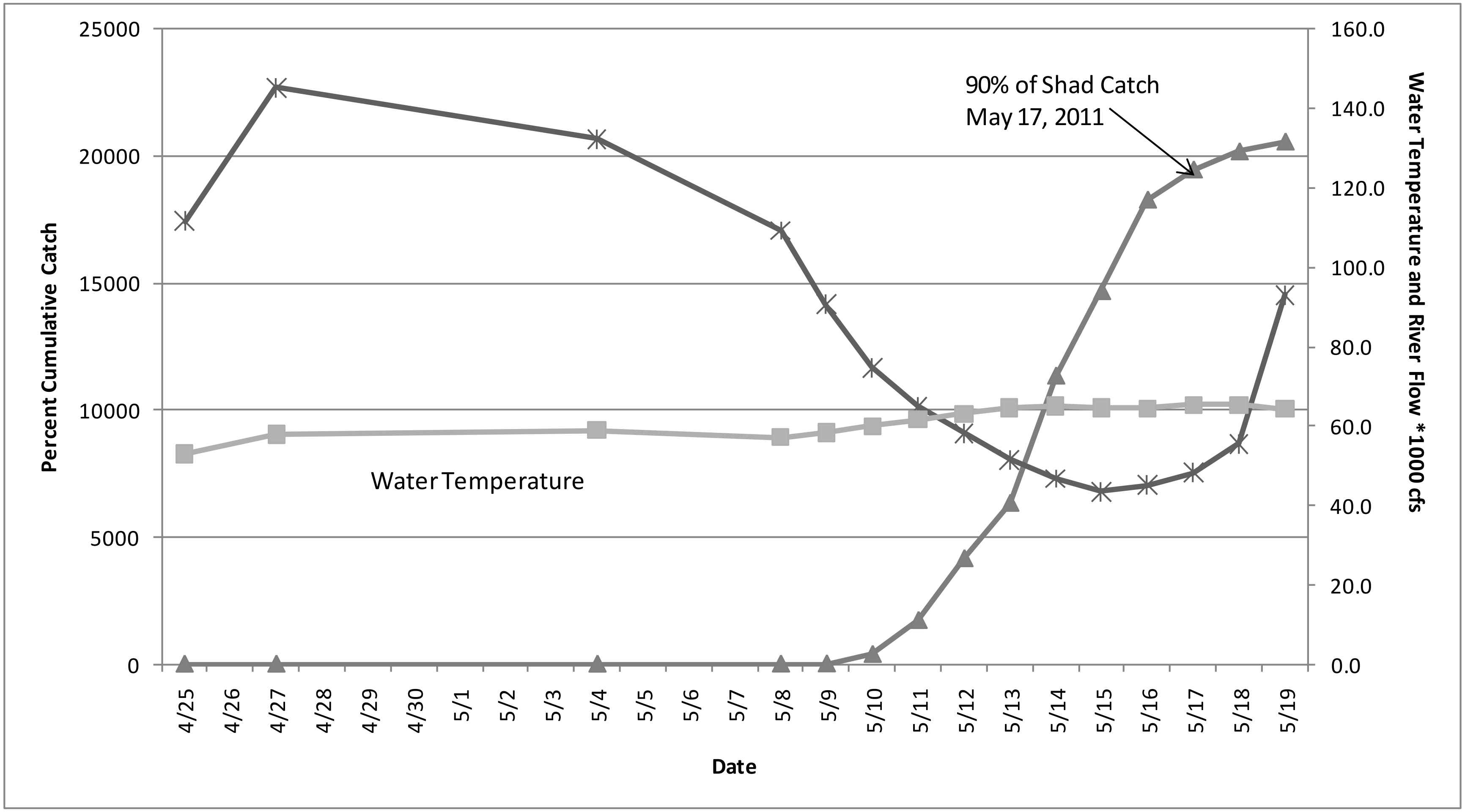
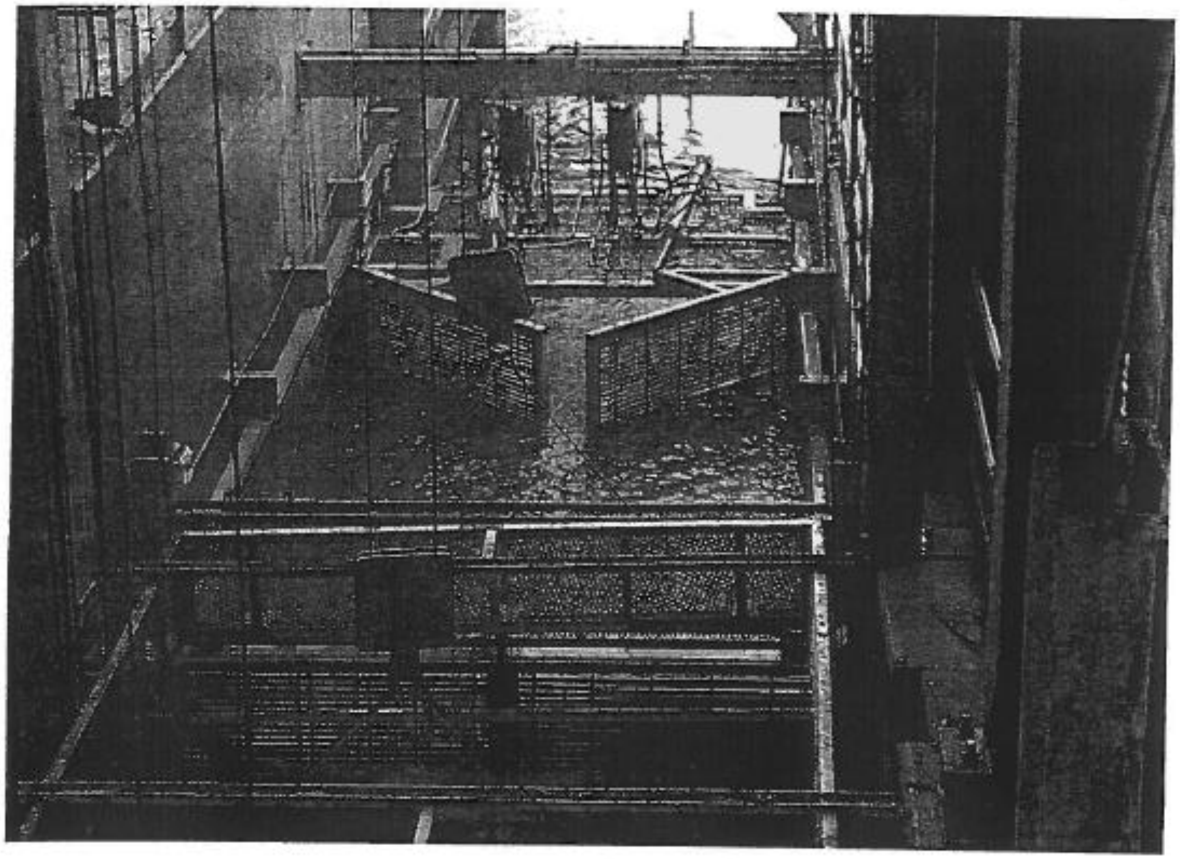


Figure 3. A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the percent cumulative American shad catch at the Conowingo East Fish Lift, spring 2011.

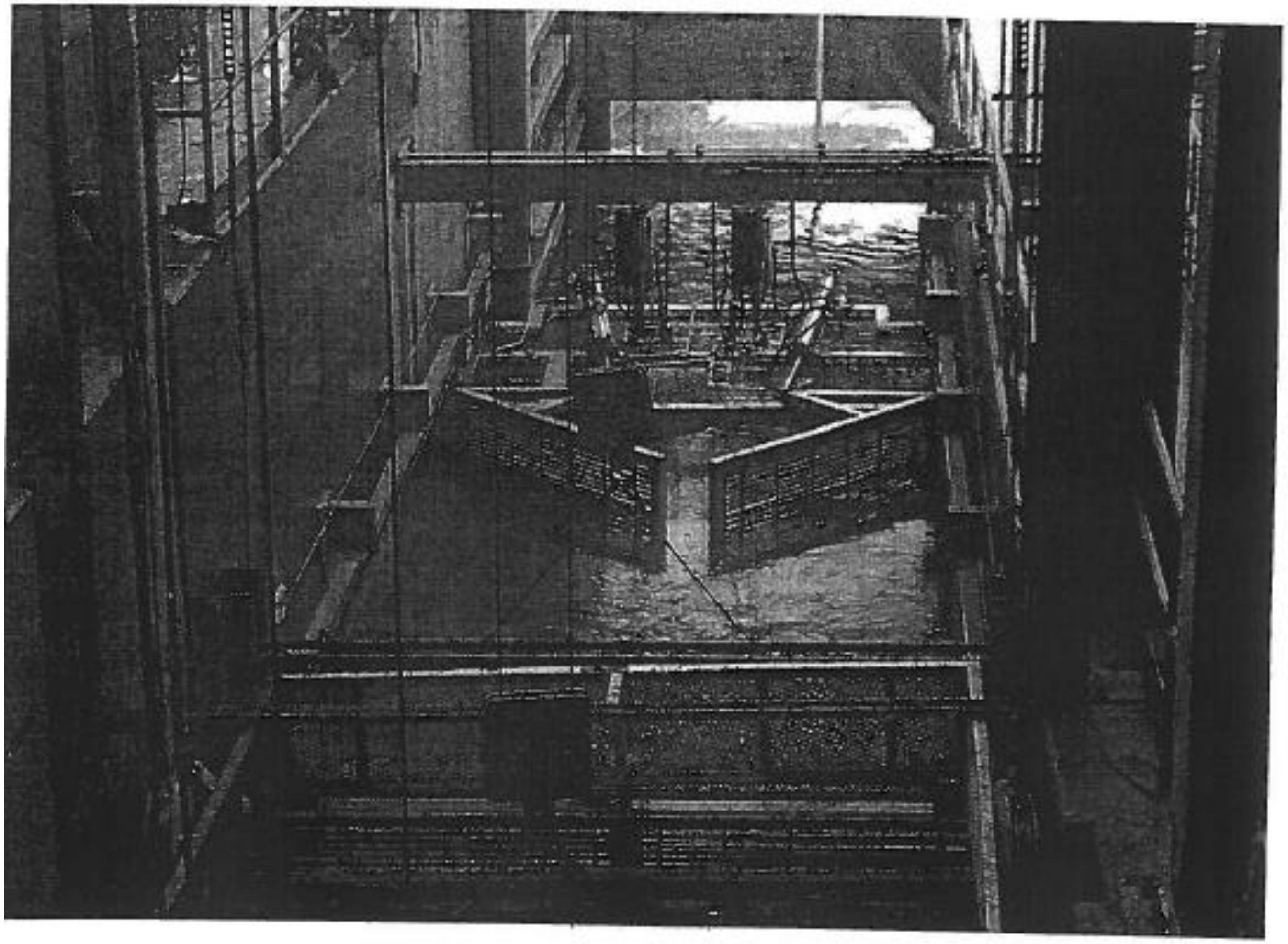


APPENDIX A



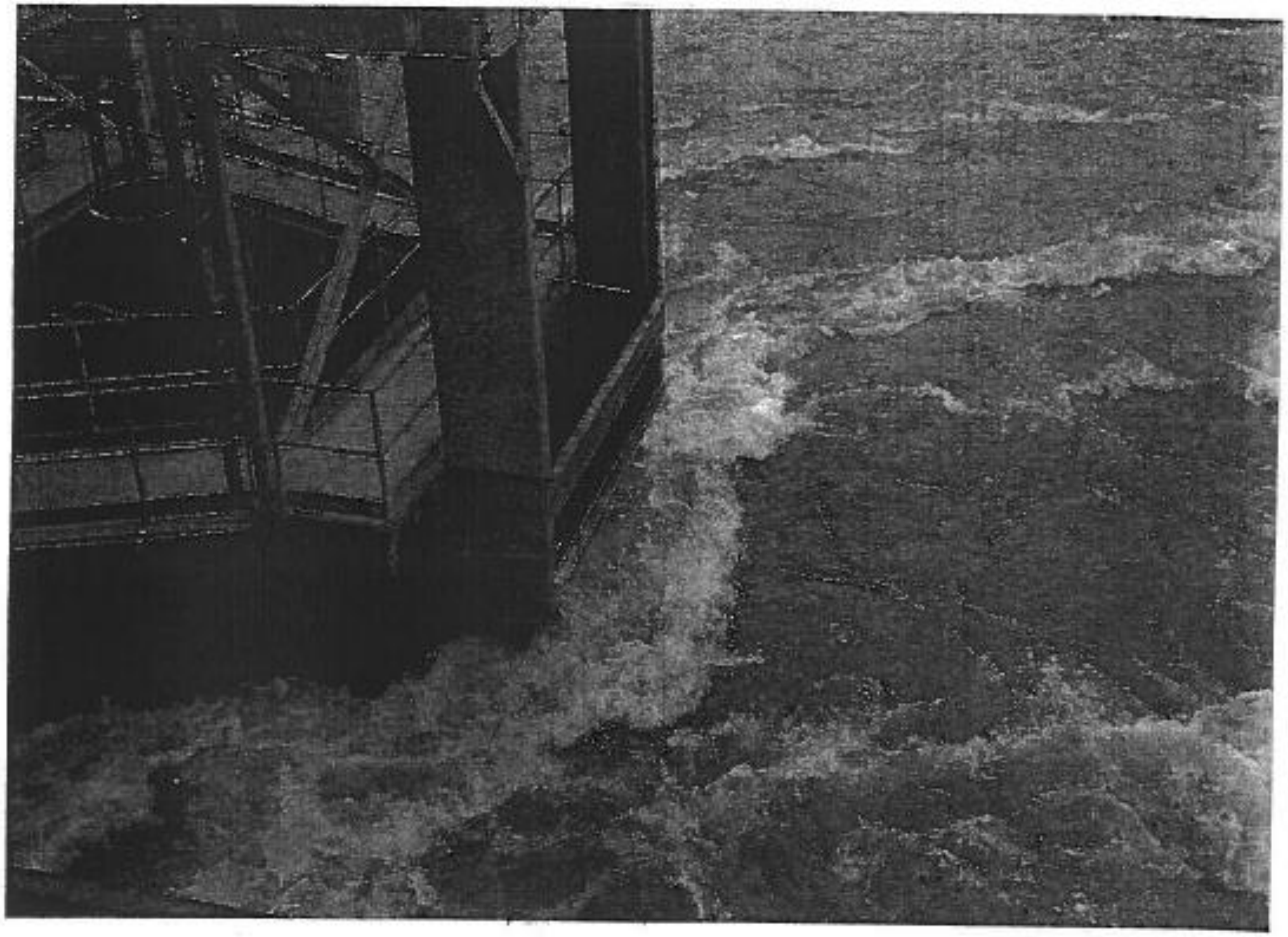
Photograph 1

EFL crowder area with 2 spill gates open, Spring 2011



Photograph 2

EFL crowder area with 4 spill gates open, Spring 2011



Photograph 3

EFL gate A closed: water pouring over top: 6 spill gates open, Spring 2011

JOB 1, PART 2. SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS – 2011

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INTRODUCTION

The shore-based trapping device at Conowingo Dam known as the West Fish Lift 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 in spring 2011 (see Part 1). Upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam but Susquehanna Electric Company (SECO) has agreed to keep the West Fish Lift operational, and to administer an annual contract for West Fish Lift trapping operations. Project details are coordinated with the resource agencies through the Susquehanna River Technical Committee (SRTC). Funding to reimburse SECO for contractor expenses for these operations, as well as shad tank spawning trials in 2011 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, and annual contributions by the PA Fish and Boat Commission and Maryland DNR. These contributed funds have been administered by the USFWS Susquehanna Coordinator.

The objectives of Conowingo West Fish Lift operations in 2011 included: collection and enumeration of shad, river herring, and other migratory and resident fishes; and obtaining 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. No fish were trucked upstream in 2011.

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 by SECO 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 peaks between April 1 and May 6 which delayed operation of the west lift until May 13. Average daily flow encountered two additional peaks during West Fish Lift operation, varying between 52,000 cfs on May 13 to 158,000 cfs on May 21, back to 81,000 cfs on May 27, to 123,000 on May 30, and back down to 43,000 cfs on June 5, the last day of operation (Figure 1). Water temperature during the same period increased more or less gradually from 63 to 74° F. Lift operations began on May 13 and occurred on 15 days through June 5. Total fishing effort over this period amounted to 144 lifts and a fishing time of 85.4 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 2011. 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 100,070 fish of 32 taxa (Table 1). Gizzard shad comprised 79% of the total catch and the next two most numerous species, channel catfish and American shad comprised 19% of the total. Some 3,074 American shad were caught, representing 3.1% of the total catch (Table 2). No other Alosines were caught. Catch of American shad averaged 205 per operating day with a peak day catch of 1,185 shad on May 16.

Normandeau Associates used 378 American shad at the lift site for tank spawning (Job II, Part 3). Of the 134 shad sacrificed for hatchery vs. wild analysis by PFBC, 37% were shown to be of hatchery origin. Males averaged 465 mm in total length and 1,060 g while females averaged 512 mm and 1,269 g. Four shad tagged by Maryland DNR in 2011 and two tagged in 2010 were recaptured at the West Fish Lift. Overall male to female sex ratio of shad in the West Fish Lift in 2011 was 1.0 to 1.4 (Table 3).

DISCUSSION

River flows were high in 2011 causing a late start for the West Fish Lift operation. Peak catch occurred on May 16 with a catch of 1,185 American shad. West Fish Lift catch per effort of 35.9 shad per fishing hour, 21 shad per lift, and 205 shad per day were above the long term averages of 30 shad per fishing hour, 14 shad per lift, and 202 shad per day (Table 4). Operations and fish catch at the West Fish Lift during 1985-2011 are summarized in Table 5.

Table 1. Catch of fishes at the Conowingo Dam West Fish Lift, 2011.

Number of Days	**15**
Number of Lifts	**144**
Fishing Time (hours : minutes)	**83:47**
Number of Taxa	**32**
AMERICAN SHAD	3,074
HICKORY SHAD	0
BLUEBACK HERRING	0
ALEWIFE	0
GIZZARD SHAD	79,044
STRIPED BASS	28
HYBRID STRIPED BASS	0
CARP	424
White Perch	47
American Eel	21
Brook Trout	3
Brown Trout	4
Rainbow Trout	1
Muskellunge	1
Goldfish	1
Comely Shiner	15
Spotfin Shiner	10
Quillback	30
White Sucker	2
Shorthead Redhorse	30
Brown Bullhead	21
Channel Catfish	15,953
Flathead Catfish	738
White Catfish	3
Rock Bass	34
Redbreast Sunfish	3
Green Sunfish	1
Pumpkinseed	27
Bluegill	22
Smallmouth Bass	68
Largemouth Bass	28
White Crappie	2
Yellow Perch	16
Walleye	298
Atlantic Needlefish	117
Sea Lamprey	4
Total	**100,070**

Table 2. Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 13 May- 5 June, 2011.

Date:	13-May	14-May	15-May	16-May	17-May	18-May	19-May	26-May
Day:	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	THURSDAY
Number of Lifts:	12	10	7	10	2	9	3	22
Time of First Lift:	11:00	11:15	11:50	9:35	13:05	9:20	12:15	9:23
Time of Last lift:	16:45	15:30	16:00	16:00	15:25	15:20	13:00	17:13
Operating time (hours):	5:45	4:15	4:10	6:25	2:20	6:00	0:45	7:50
Average Water Temperature (°F):	63.4	63.9	65.9	67.0	66.5	66.1	67.5	66.7
American shad	172	253	186	1185	29	311	114	28
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	13550	10150	3850	4900	1500	3100	330	16050
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	0	0	0	1	0	5	4	1
Carp	3	8	4	5	3	18	38	115
Other species	305	1264	611	715	433	786	121	4647
Total	14,030	11,675	4,651	6,806	1,965	4,220	607	20,841
Date:	27-May	28-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	**Total**
Day:	FRIDAY	SATURDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	**for the Year**
Number of Lifts:	15	12	10	8	8	8	8	**144**
Time of First Lift:	8:30	8:27	8:50	8:50	9:00	8:45	8:05	
Time of Last lift:	16:14	15:05	15:30	15:00	15:30	15:45	13:40	
Operating time (hours):	7:44	6:38	6:40	6:10	6:30	7:00	5:35	**85:35**
Average Water Temperature (°F):	68.8	70.6	74.0	75.1	74.8	74.0	73.8	
American shad	108	156	11	33	49	40	399	**3,074**
Blueback herring	0	0	0	0	0	0	0	**0**
Alewife	0	0	0	0	0	0	0	**0**
Gizzard shad	6350	5640	9600	2250	1330	84	360	**79,044**
Hickory shad	0	0	0	0	0	0	0	**0**
Striped bass	5	1	3	2	2	4	0	**28**
Carp	127	25	20	40	16	2	0	**424**
Other species	2468	1585	1250	1346	1078	609	282	**17,500**
Total	9,058	7,407	10,884	3,671	2,475	739	1,041	**100,070**

Table 3. American shad sex ratio information, Conowingo West Fish Lift, 2011. No operation on 20-25 and 29-31 May.

Date	Sample size	Males	Females	Male:Female Ratio
13-May	103	51	52	1: 1.0
14-May	103	50	53	1: 1.1
15-May	62	31	31	1: 1.0
16-May	108	37	71	1: 1.9
17-May	29	12	17	1: 1.4
18-May	124	65	59	1: 0.9
19-May	114	54	60	1: 1.1
26-May	17	9	8	1: 0.9
27-May	103	43	60	1: 1.4
28-May	155	58	97	1: 1.7
1-Jun	11	5	6	1: 1.2
2-Jun	33	14	19	1: 1.4
3-Jun	49	16	33	1: 2.1
4-Jun	40	12	28	1: 2.3
5-Jun	201	78	123	1: 1.6
Totals	**1,252**	**535**	**717**	**1: 1.4**

Table 4. Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods,* 1985-2011.

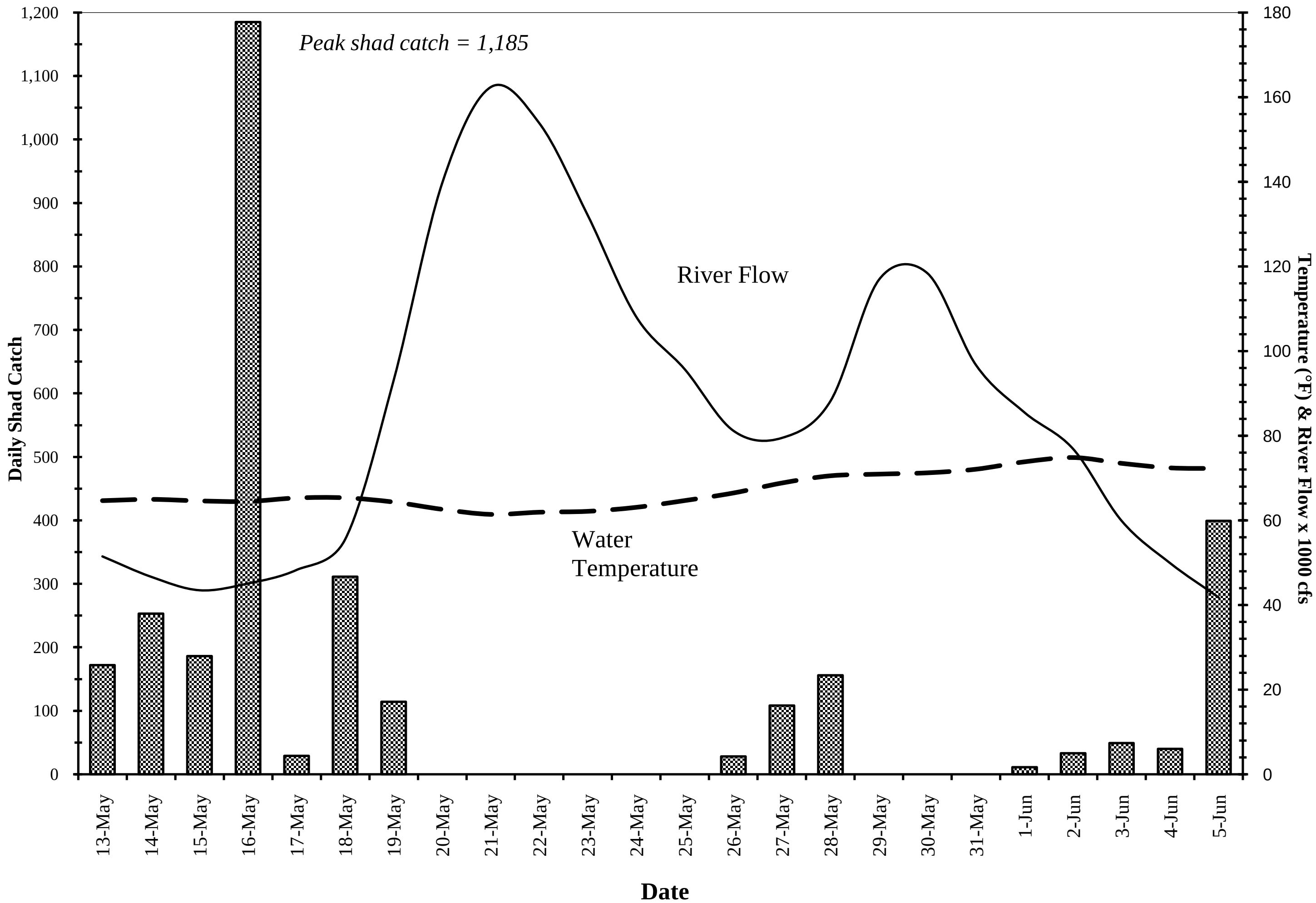
Year	Number Days	Number Lifts	Fishing Hours	Total Catch	Catch Per Day	Catch Per Lift	Catch Per Hour
1985	37	839	328.6	1,518	41	2	4.6
1986	53	737	431.5	5,136	97	7	11.9
1987	49	1,295	506.5	7,659	156	6	15.1
1988	54	1,166	471.7	5,137	95	4	10.9
1989	46	1,034	447.2	8,216	179	8	18.4
1990	62	1,247	541.0	15,958	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**

*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 - 2011.

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**

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 2011. The West Lift was not operated from 20 to 25 and 29 to 31 May.



SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY, SPRING 2011

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January 2012

EXECUTIVE SUMMARY

High river flow events in March and April, 2011 delayed the start of fish lift operations at the Conowingo East fish lift (EFL) until 25 April, 2011. The passage of over one-thousand American shad at the Conowingo EFL on 11 May would have normally triggered the start of fish lift operations at Holtwood. However, the high river flows deposited large amounts of rock debris in the tailrace hopper pit and crowder channel that had to be removed prior to the commencement of Holtwood lift operations. Fishway operations at Holtwood Dam began on 20 May, 2011. The tailrace lift was operated on 9 days while the spillway lift operated on 3 days. Lift operations were terminated for the season, with agency concurrence, on 5 June. During late May, fish lift operations were suspended for six days due to high river flows and a tailrace hopper mechanical problem. The 2011 fish passage season marks the fifteenth year of operation at Holtwood.

The lifts passed 5,052 fish of 15 taxa. Gizzard shad (4,535), channel catfish (229), and walleye (122), dominated the catch, and comprised nearly 97% of the total fish collected and passed. American shad represented the sole *Alosa* species collected and passed at Holtwood in 2011.

A total of 18 American shad (nearly 86% of total shad catch) was passed in the tailrace lift while the spillway lift accounted for 3 American shad (14% of total shad catch). The highest daily shad catch occurred on 25 May when 5 shad moved upstream during 9.4 hours of operation. On a daily basis, American shad passed through the fishway between 0900 hrs and 1659 hrs with 71% (15 of 21 shad) passed between 1100 and 1659 hrs.

Fishway operations were conducted at water temperatures ranging from 62.7°F to 74.6°F and river flows between 139,700 and 41,800 cfs. Spillage occurred on all 10 days of operation. River water temperatures were within the observed historic range, but river flows were uncommonly high throughout the passage season, (Figure 1).

For most of the season, water clarity was poor, making it difficult 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 2011 was 0.

The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of fish passing Conowingo passed Holtwood) was below the historical average of 33.2% (1997-2010).

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 2011, only the last two days of the season (4 and 5 June) occurred at river flows less than 60,000 cfs but above 40,000 cfs with no shad passage. The fifteen day period from 20 May through 3 June occurred at river flows greater than 60,000 cfs and all 21 American shad were passed during this time. It should be noted that in 2011, unfavorably high river flows did not allow flashboard repairs to be completed prior to or during the fish passage season. Future operations of the fishway will build on the past fifteen 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 2011. This year marked the fifteenth operational season.

Objectives of 2011 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 2011, 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. However, in March and April 2011, the flashboards were severely damaged due to several high flow events and repairs could not be conducted until after cessation of fish lift operations because of consistent high river flows. Due to heavy accumulations of sediment and rock debris in the tailrace hopper pit and crowder channel deposited by the high river flows, fish lift operations at Holtwood did not begin immediately after the passage of one-thousand shad at Conowingo Dam on 11 May. Since river flows were greater than station capacity, spill occurred on all days of fish lift operation, (Table 2). In 2011, station capacity was limited to eight units (approximately 26,000 cfs) due to redevelopment activities. Passage operations ended on 5 June, with agency concurrence, due to high river flows, and extremely poor American shad passage.

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 flows, in, through, and from the lifts, are 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.

During fish lift operations in 2011flashboards were unable to be installed due to persistent, high river flows.

Design guidelines for fishway operation include four entrance combinations. These are: (1) entrance A, B, and C; (2) entrance A and B; (3) entrance A and C; and (4) Entrance C. 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 2011, the following gate combinations were utilized: Entrances B and C (2 days); Entrance C (1day); Entrance B (7 days). Entrance A was found to be inoperable during pre-season inspections and attempts to repair it could not be completed prior to the termination of lift operations in 2011. The spillway lift, (Entrance gate C), is used less frequently when river flows are greater than 40,000 cfs or flashboard sections are damaged/missing as spillage may mask or interfere with the attraction flow from the spillway entrance gate.

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. Pre-season equipment preparations began in March 2011, after a high river flow event that peaked at 423,000 cfs, and all equipment functioned properly. In April 2011, a 363,000 cfs river flow event occurred and additional equipment checks were performed. During these checks, it was discovered that large amounts of rock debris and sediment had been deposited in the tailrace hopper pit and crowder channel, which prohibited the startup of operations until it could be cleared out by a construction crew and dive team. The rock debris originated from the temporary access pads and roads placed as part of expansion project activities and the material was dislodged during the high river flow events.

This year, Holtwood operations did not start two days after the passage of one-thousand American shad at Conowingo Dam due to an extensive clean-up operation required to remove large amounts of sediment and rock debris in the tailrace hopper pit and crowder channel deposited by high river flow events. Fish lift operations began on 20 May. This year we recorded 10 days of operation. The tailrace lift was operated 9 days during this year's fish passage operation and encountered one major mechanical problem. On 20 May, as the tailrace hopper was being lowered after completing the fifth lift, the hopper jumped out of the guide channels and cocked. Maintenance personnel were dispatched to investigate the cause of the failure and make repairs. During further inspections, it became clear that a main hoist cable was damaged during this incident and had to be replaced. Tailrace fish lift operations resumed on 25 May and continued with one other notable mechanical problem. The festoon power cable which travels with the tailrace crowder had to be replaced after it jammed and tore apart. The spillway lift was operated on 3 days this season and encountered no mechanical problems.

The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of fish passing Conowingo passed Holtwood) was below the historical average of 33.2% (1997-2010). Several high river flow events this spring significantly hampered American shad passage at Holtwood and other fish passage facilities located on the Susquehanna River, (Table 6 and Figure 1). 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 fishways 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 co-operators.

RESULTS

Relative Abundance

The diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2011 operational period is presented in Table 1. A total of 5,052 fish of 15 taxa passed upstream into Lake Aldred. Gizzard shad (4,535), channel catfish (229), and walleye (122) comprised nearly 97% of the fishes passed. The 2011 American shad passage total was the lowest observed based on actual numbers of fish, and based on Conowingo results, this was the lowest passage percentage rate recorded in the fifteen years of fish lift operations at Holtwood, (Tables 1, 5, and 6). Other abundant fishes passed included carp (82), quillback (30) and American shad (21). The high passage day for all species combined occurred on 27 May, when 1,018 fish were passed, comprised mostly of gizzard shad (947), and channel catfish (21).

For most of the season, water clarity ranged from 5 to 15 inches of visibility, which made it difficult for viewing technicians to identify American shad with attached Maryland DNR floy tags. The number of floy tags observed at Holtwood in 2011 was 0.

American Shad Passage

A total of 21 American shad were passed at Holtwood during 2011; 18 American shad passed in the tailrace lift while the spillway lift accounted for 3 American shad (Table 4). The highest daily shad catch occurred on 25 May when 5 shad moved upstream during 9.4 hours of operation. On a daily basis, overall shad passage occurred through the fishway between 0900 hrs and 1659 hrs (Table 3). Fishway operations were conducted at water temperatures ranging from 62.7°F to 74.6°F and river flows between 41,800 cfs and 139,700 cfs, (as measured at Holtwood Dam), (Table 2). Spillage occurred on all ten days of operation. River water temperatures were within the observed historic range, but river flows were uncommonly high throughout the passage season.

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 119 ft., (a tailrace elevation of 119 ft. occurred on 5 of the10 days of operation). Tailrace elevations correspond to unit operation, which varies from 0 to 10 units. In 2011, Units 1 and 2 remained offline due to redevelopment activities. During spring 2011, 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 high river flow events and mechanical difficulties led to limited use of the spillway lift during spill events. Simultaneous operation of both the spillway and tailrace fish lifts did not occur this year because the flashboards were not in place during the entire fish passage season.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 167 ft to 170 ft (Table 2). Forebay elevations during passage operations ranged from 168 ft to 169.9 ft for approximately 40% of the 2011 season.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Nearly 71% (15 of 21 American shad) passed through the fishway between 1100hr and 1659hrs. American shad passage was low each day of operation, 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 three 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, 18 and 3 shad were captured in the tailrace and spillway lifts over the total operating period in 2011, respectively (Table 4).

Passage Evaluation

In spring 2011, 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 2011, spill events occurred during all 10 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 2011, only the last two days of the season, (June 4 and 5), occurred at river flows less than 60,000 cfs but above 40,000 cfs with no shad passage. Fifteen days during the season (May 20-June 3) occurred at river flows greater than 60,000 cfs and passage of all 21 shad occurred during this time (Table 5 and Figure 2). During fish lift operations in 2011, river flows ranged from 41,800 cfs to139,700 cfs. The 2011 American shad passage rate at Holtwood versus Conowingo (0.10% of American shad passed at Conowingo were passed by Holtwood), was below the historical average of 33.2% observed at Holtwood from 1997 to 2010. In 2011, unfavorably high river flows did not allow flashboard repairs to be conducted prior to or during the fish passage season, which inhibited efforts to maintain forebay water levels that provide an ample volume of water to feed the entire fish lift water supply system and allow for the simultaneous operation of the tailrace and spillway fish lifts.

We hope to optimize future fishway operations by utilizing knowledge gained through these fifteen 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 2011 American shad passage season.

RECOMMENDATIONS

1. 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.
2. 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.
3. 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.
4. 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

TABLES AND FIGURES

Table 1. Summary of the daily number of fish passed by the Holtwood fish passage facility in 2011.

Date:	*20 May*	*25 May*	*26 May*	*27 May*	*28 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*Total*
Hours of Operation - Tailrace:	*3.0*	*9.4*	*9.4*	*10.3*	*10.0*	*8.2*	*1.0*	*0.0*	*5.2*	*7.7*	*64.2*
Number of Lifts - Tailrace:	*5*	*14*	*16*	*17*	*16*	*13*	*1*	*0*	*8*	*11*	*101.0*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*7.1*	*8.8*	*3.2*	*0.0*	*19.1*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*10*	*10*	*5*	*0*	*25.0*
Water Temperature (°F):	*62.7*	*64.2*	*66.3*	*68.0*	*69.8*	*73.5*	*74.6*	*73.3*	*71.9*	*72.0*	
American shad	0	5	3	4	4	1	1	3	0	0	21
Gizzard shad	30	402	760	947	398	184	312	790	576	136	4,535
Brown trout	0	0	0	0	0	0	0	1	0	0	1
Muskellunge	0	0	0	0	0	0	0	1	0	0	1
Carp	0	6	11	14	8	1	1	22	17	2	82
Quillback	0	0	8	13	5	0	2	0	2	0	30
Shorthead redhorse	0	0	0	1	1	0	0	0	0	0	2
Channel catfish	4	5	5	21	36	13	43	63	27	12	229
Flathead catfish	0	0	0	1	0	4	0	0	0	0	5
Rock bass	0	1	1	1	3	0	0	1	1	0	8
Green sunfish	0	0	0	0	0	0	0	0	1	0	1
Bluegill	2	1	0	0	0	0	0	0	2	0	5
Smallmouth bass	0	0	1	4	0	0	1	2	0	0	8
Largemouth bass	0	0	0	2	0	0	0	0	0	0	2
Walleye	0	3	16	10	10	0	3	38	40	2	122
Total	***36***	***423***	***805***	***1,018***	***465***	***203***	***363***	***921***	***666***	***152***	**5,052**

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 2011.

	River Flow	Ave.Water	Secchi	Number	Weir Gate Operation			Elevation (ft)		
Date	(cfs)	Temp. (°F)	(in)	of Units	A	B	C*	Tailrace	Spillway	Forebay
20 May	139,700	62.70	3	8*		X		119.6	Spill	170.7
25 May	95,700	64.20	5	8*		X		119.7	Spill	171
26 May	81,200	66.30	15	8*		X		119.3	Spill	170.1
27 May	79,500	68.00	22	8*		X		118.7	Spill	169
28 May	88,200	69.80	22	8*		X		119.1	Spill	169.9
1 Jun	85,500	73.50	5	8*		X		119.3	Spill	170
2 Jun	76,900	74.60	8	8*		X	X	115	Spill	169.3
3 Jun	59,900	73.30	10	8*			X	118.1	Spill	168.7
4 Jun	49,900	71.90	15	8*		X	X	118	Spill	167
5 Jun	41,800	72.00	15	8*		X		118	Spill	167

*For 2011, Units 1 and 2 not operating due to redevelopment activities; Spillway entrance gate C damaged by flooding prior to 2005 seas

Table 3. Hourly summary of American shad passage at the Holtwood fish passage facility in 2011.

Date:	*20 May*	*25 May*	*26 May*	*27 May*	*28 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	
Observation Time (Start):	*9:10*	*8:50*	*8:10*	*8:00*	*8:10*	*9:00*	*8:50*	*8:08*	*8:40*	*8:40*	
Observation Time (End):	*11:30*	*17:45*	*17:50*	*18:00*	*17:45*	*17:06*	*16:50*	*16:50*	*16:50*	*15:50*	***Total***
Military Time (hrs)											
0700 to 0759	--	--	--	--	--	--	--	--	--	--	0
0800 to 0859	--	--	--	--	--	--	--	--	--	--	0
0900 to 0959	--	2	--	--	1	--	--	--	--	--	3
1000 to 1059	--	--	--	--	1	1	1	--	--	--	3
1100 to 1159	--	--	--	1	--	--	--	--	--	--	1
1200 to 1259	--	--	--	--	1	--	--	--	--	--	1
1300 to 1359	--	--	1	--	--	--	--	1	--	--	2
1400 to 1459	--	--	1	1	--	--	--	--	--	--	2
1500 to 1559	--	1	1	2	--	--	--	1	--	--	5
1600 to 1659	--	2	--	--	1	--	--	1	--	--	4
1700 to 1759	--	--	--	--	--	--	--	--	--	--	0
1800 to 1859	--	--	--	--	--	--	--	--	--	--	0
1900 to 1959	--	--	--	--	--	--	--	--	--	--	0
2000 to 2059	--	--	--	--	--	--	--	--	--	--	0
Total	**0**	**5**	**3**	**4**	**4**	**1**	**1**	**3**	**0**	**0**	**21**

Table 4. Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood power Station, 2011

	Shad	Number Collected		Percent Collected	
Date	Catch	Tailrace	Spillway	Tailrace	Spillway
20-May	0	--	--	0%	--
25-May	5	5	--	100%	--
26-May	3	3	--	100%	--
27-May	4	4	--	100%	--
28-May	4	4	--	100%	--
1-Jun	1	1	--	100%	--
2-Jun	1	1	--	100%	--
3-Jun	3	--	3	--	100%
4-Jun	0	--	--	100%	--
5-Jun	0	--	--	100%	--
Total	21	18	3	86%	14%

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

	1997	1998*	1999	2000*	2001	2002*	2003*	2004*
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr	26 Apr
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun	03 Jun
Season duration (days)	58	47	40	40	43	55	36	39
Number of days of operation	55	41	40	36	42	35	34	39
Am. shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135	109,360
Am. shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254	3,428
River flow ≤40,000 cfs								
Number of days	48	22	34	19	40	19	15	2
Percent of season	87%	54%	85%	53%	95%	54%	44%	5%
No. of Am. shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229	2
Daily ave. of Am. shad passed	546	341	1,002	1,037	2,733	543	1,348	1
Percent of total passage	93%	91%	98%	67%	99%	59%	80%	0%
River flow 40,001 to 60,000 cfs								
Number of days	7	2	6	12	2	14	18	20
Percent of season	13%	5%	15%	33%	5%	40%	53%	51.3%
No. of Am. shad passed	1,862	230	633	9,536	634	7,029	5,019	1,943
Daily ave. of Am. shad passed	266	115	106	795	317	502	279	97
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.8%	56.7%
River flow >60,000 cfs								
Number of days	0	17	0	5	0	2	1	17
Percent of season	0%	41%	0%	14%	0%	6%	3%	43.6%
No. of Am. shad passed	0	493	0	173	0	171	6	1,483
Daily ave. of Am. shad passed	0	29	0	35	0	86	6	87
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%	43.3%

* Denotes seasons of high river flow or frequent spillage.

Table 5. (continued)

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

* Denotes seasons of high river flow or frequent spillage.

Table 6. Summary of American shad passage counts and percent passage at Susquehanna River dams.

	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**	**0.10%**	**8**	**38.10%**	**0**	**0.00%**

Figure 1. Plot of River Flow as measured at Holtwood Dam for the period March through June, 2011

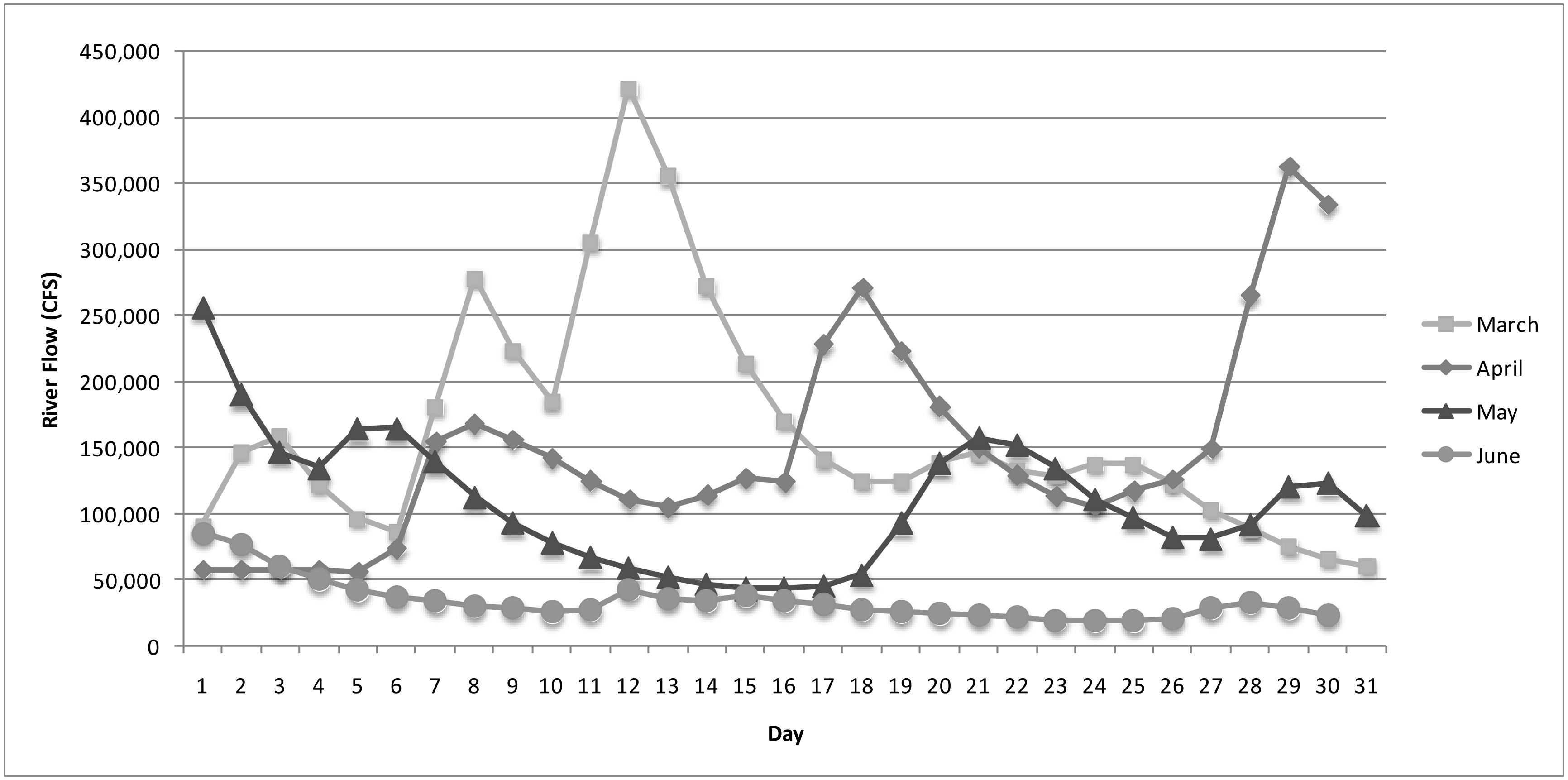
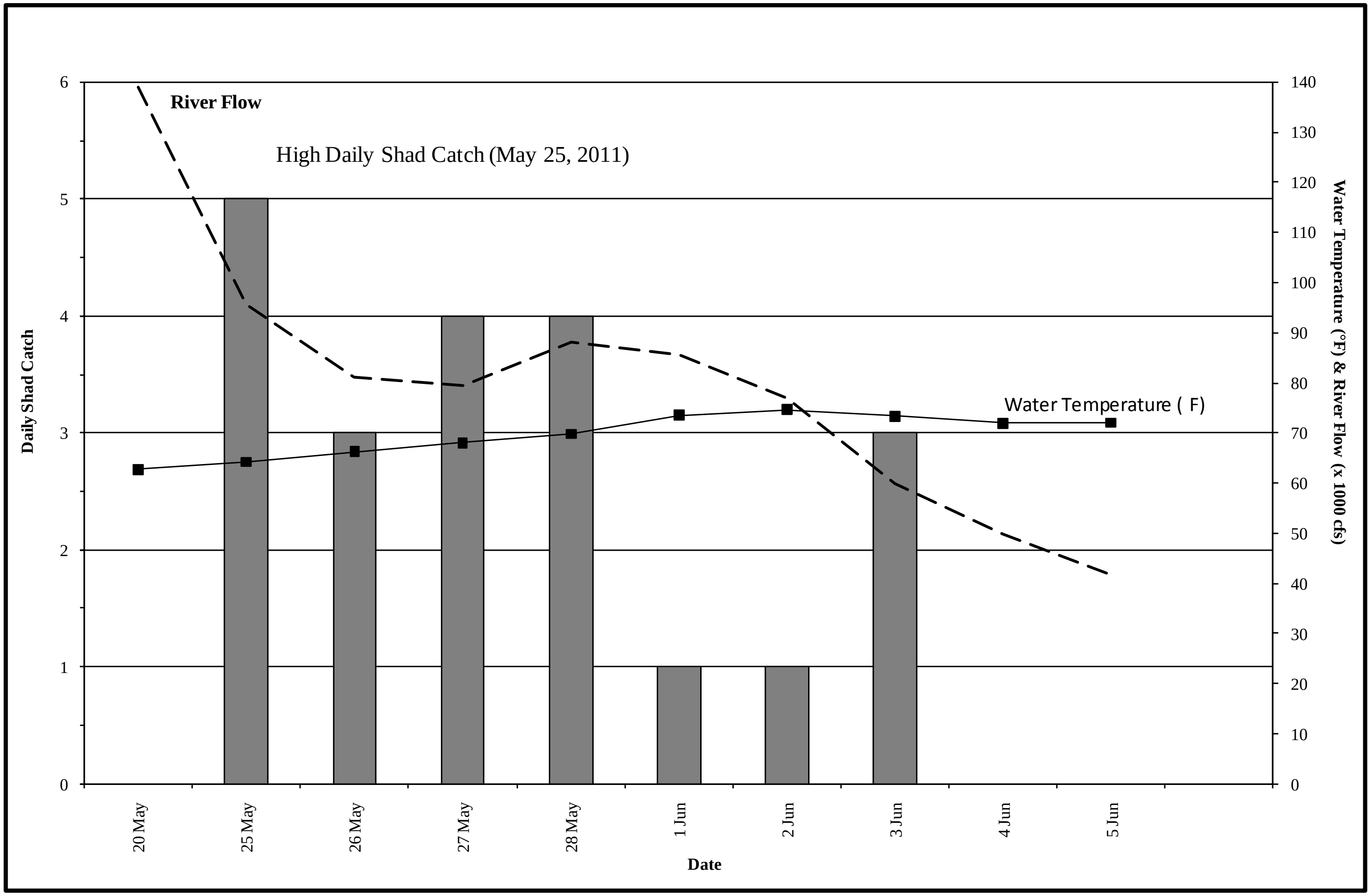


Figure 2. A plot of river flow (x 1000) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2011.



SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY, SPRING, 2011

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October 2011

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 2011 operation were to (1) monitor passage of migratory and resident fishes through the fishway; (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

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 (capacity: 4,725 gallons), 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 2011 season utilized a combination of entrances A and C (Table 2).

Fishway Operation

Safe Harbor fishway operation normally commences soon after passage of approximately 500 American shad via the Holtwood fishway. Due to high river flow events, Holtwood did not begin operation after the Conowingo East Fish Lift passed 1,000 American shad (Figure 1). These flow events deposited large amounts of rock debris and mud into the Holtwood Fish Lift's crowder channel and hopper pit. A specialized work crew utilizing divers was needed to remove the debris before the Holtwood Fish Lift commenced operations on 20 May, 2011. Safe Harbor Fish Lift operations commenced on 26 May, 2011, one day after Holtwood passed 5 American shad into Lake Aldred. The Safe Harbor fishway ended operations on 6 June. Lift operations ended, with agency concurrence, due to the sub-par passage of American shad and abnormally high river flows.

Throughout the 2011 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons and guidelines approved by the Safe Harbor Fish Passage Technical Advisory Committee (SHFPTAC). A detailed description of the fishways 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 2011 by the Safe Harbor fishway is presented in Table 1. A total of 8,059 fish of 10 species passed upstream into Lake Clarke. Gizzard shad (3,216) was the dominant species passed and comprised 40% of the catch. Eight American shad were passed upstream through the fishway and comprised less than one percent of the catch. Other predominant fishes passed included channel catfish (2,323) and quillback (2,037). The highest day of fish passage occurred on 27 May, when 1,305 fish, (31% quillback and 28% channel catfish), were passed.

American Shad Passage

The Safe Harbor fishway passed 8 American shad during 9 days of operation in 2011 (Table 1). This year's operating season was approximately 5 weeks shorter than last season, resulting in the lowest number of American shad passed since operations commenced in1997 (Table 4). Safe Harbor managed to pass 38% of the American shad passed at Holtwood Dam and less than one percent of the American shad passed by Conowingo Dam, (Table 4). In the 2011 season, there was no peak passage of American shad. Four of the nine days of operation resulted in the passage of two American shad, which comprised the season total of eight American shad.

American shad were passed at water temperatures of 64.5°F to 73.5°F and river flows of 37,500 to 85,000 cfs (Table 2 and Figure 2). Water temperatures were within the historically observed range during the 2011 season.

The number of American shad observed passing through the trough by hour is shown in Table 3. Due to the lack of American shad available for passage, no significant patterns of fish passage were observed. Passage of 3 of the 8 American shad passed at Safe Harbor occurred between 1400 hrs and 1459 hrs.

SUMMARY

The 2011 Safe Harbor fishway operating season was conducted with minimal disruptions to operations due to mechanical problems.

A total of 8 American shad were passed into Lake Clarke, or 38% of the American shad that were passed into Lake Aldred by the Holtwood fishway (Table 4). Six of the 8 American shad were passed at Safe Harbor on or after 1 June. Due to the high river flows experienced during 2011 American shad passage was well below average at all lower Susquehanna River fish passage facilities.

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.

TABLES AND FIGURES

Table 1. Number and disposition of fish passed by the Safe Harbor fishway in 2011.

Date:	*26-May*	*27-May*	*28-May*	*1-Jun*	*2-Jun*	*3-Jun*	*4-Jun*	*5-Jun*	*6-Jun*	***Season Total***
Hours of Operation:	*7.3*	*3.2*	*6.8*	*8.5*	*2.8*	*6.1*	*6.8*	*7.6*	*6.9*	**55.9**
Viewing Start Time:	*8:00*	*13:00*	*8:00*	*7:45*	*12:30*	*8:40*	*8:00*	*7:25*	*8:00*	
Viewing End Time:	*15:17*	*16:13*	*14:50*	*16:12*	*15:15*	*14:45*	*14:45*	*15:00*	*14:55*	
Number of Lifts:	*8*	*4*	*7*	*10*	*4*	*7*	*7*	*7*	*7*	**61**
Water Temperature (°F):	*64.5*	*68.7*	*70.5*	*73.5*	*74.3*	*73.4*	*73*	*73*	*72.5*	
American Shad	0	2	0	2	2	2	0	0	0	**8**
Gizzard shad	115	383	519	505	115	420	574	349	236	**3,216**
Carp	97	108	56	27	0	8	8	4	6	**314**
Quillback	458	410	174	374	160	105	115	211	30	**2,037**
Shorthead redhorse	1	15	2	1	5	0	0	0	0	**24**
Channel catfish	187	365	356	104	205	305	421	290	90	**2,323**
Bluegill	0	0	0	0	1	1	0	0	0	**2**
Smallmouth bass	9	12	26	3	3	6	6	4	1	**70**
Largemouth bass	0	1	0	0	0	1	0	1	1	**4**
Walleye	9	9	14	3	4	4	4	9	5	**61**
Daily Total	**876**	**1,305**	**1,147**	**1,019**	**495**	**852**	**1,128**	**868**	**369**	**8,059**

Table 2. Number and disposition of fish passed by the Safe Harbor fishway in 2011.

Date:	*26-May*	*27-May*	*28-May*	*1-Jun*	*2-Jun*	*3-Jun*	*4-Jun*	*5-Jun*	*6-Jun*	***Season Total***
Hours of Operation:	*7.3*	*3.2*	*6.8*	*8.5*	*2.8*	*6.1*	*6.8*	*7.6*	*6.9*	**55.9**
Viewing Start Time:	*8:00*	*13:00*	*8:00*	*7:45*	*12:30*	*8:40*	*8:00*	*7:25*	*8:00*	
Viewing End Time:	*15:17*	*16:13*	*14:50*	*16:12*	*15:15*	*14:45*	*14:45*	*15:00*	*14:55*	
Number of Lifts:	*8*	*4*	*7*	*10*	*4*	*7*	*7*	*7*	*7*	**61**
Water Temperature (°F):	*64.5*	*68.7*	*70.5*	*73.5*	*74.3*	*73.4*	*73*	*73*	*72.5*	
American Shad	0	2	0	2	2	2	0	0	0	**8**
Gizzard shad	115	383	519	505	115	420	574	349	236	**3,216**
Carp	97	108	56	27	0	8	8	4	6	**314**
Quillback	458	410	174	374	160	105	115	211	30	**2,037**
Shorthead redhorse	1	15	2	1	5	0	0	0	0	**24**
Channel catfish	187	365	356	104	205	305	421	290	90	**2,323**
Bluegill	0	0	0	0	1	1	0	0	0	**2**
Smallmouth bass	9	12	26	3	3	6	6	4	1	**70**
Largemouth bass	0	1	0	0	0	1	0	1	1	**4**
Walleye	9	9	14	3	4	4	4	9	5	**61**
Daily Total	**876**	**1,305**	**1,147**	**1,019**	**495**	**852**	**1,128**	**868**	**369**	**8,059**

Table 3. Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2011.

Date:	*26-May*	*27-May*	*28-May*	*1-Jun*	*2-Jun*	*3-Jun*	*4-Jun*	*5-Jun*	*6-Jun*	
Observation Time-Start:	*8:00*	*8:10*	*7:40*	*7:40*	*8:20*	*8:00*	*8:20*	*7:45*	*7:40*	***Season***
Observation Time-End:	*17:23*	*17:45*	*17:30*	*16:30*	*16:30*	*16:35*	*16:30*	*16:40*	*17:40*	***Total***
Military Time (hrs)										
0700 to 0759	--	--	--	--	--	--	--	--	--	0
0800 to 0859	--	--	--	--	--	--	--	--	--	0
0900 to 0959	--	--	--	--	--	--	--	--	--	0
1000 to 1059	--	--	--	1	--	1	--	--	--	2
1100 to 1159	--	--	--	1	--	--	--	--	--	1
1200 to 1259	--	--	--	--	1	1	--	--	--	2
1300 to 1359	--	--	--	--	--	--	--	--	--	0
1400 to 1459	--	2	--	--	1	--	--	--	--	3
1500 to 1559	--	--	--	--	--	--	--	--	--	0
1600 to 1659	--	--	--	--	--	--	--	--	--	0
1700 to 1759	--	--	--	--	--	--	--	--	--	0
1800 to 1859	--	--	--	--	--	--	--	--	--	0
1900 to 1959	--	--	--	--	--	--	--	--	--	0
Total	**0**	**2**	**0**	**2**	**2**	**2**	**0**	**0**	**0**	8

Table 4. Summary of American shad passage counts and percent passage at Susquehanna River dams, 1997-2011.

	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	**20,517**	**21**	**0.1%**	**8**	**38.1%**	**0**	**0.0%**

Figure 1. Plot of River Flow (as measured at Holtwood Dam) March through June 2011.

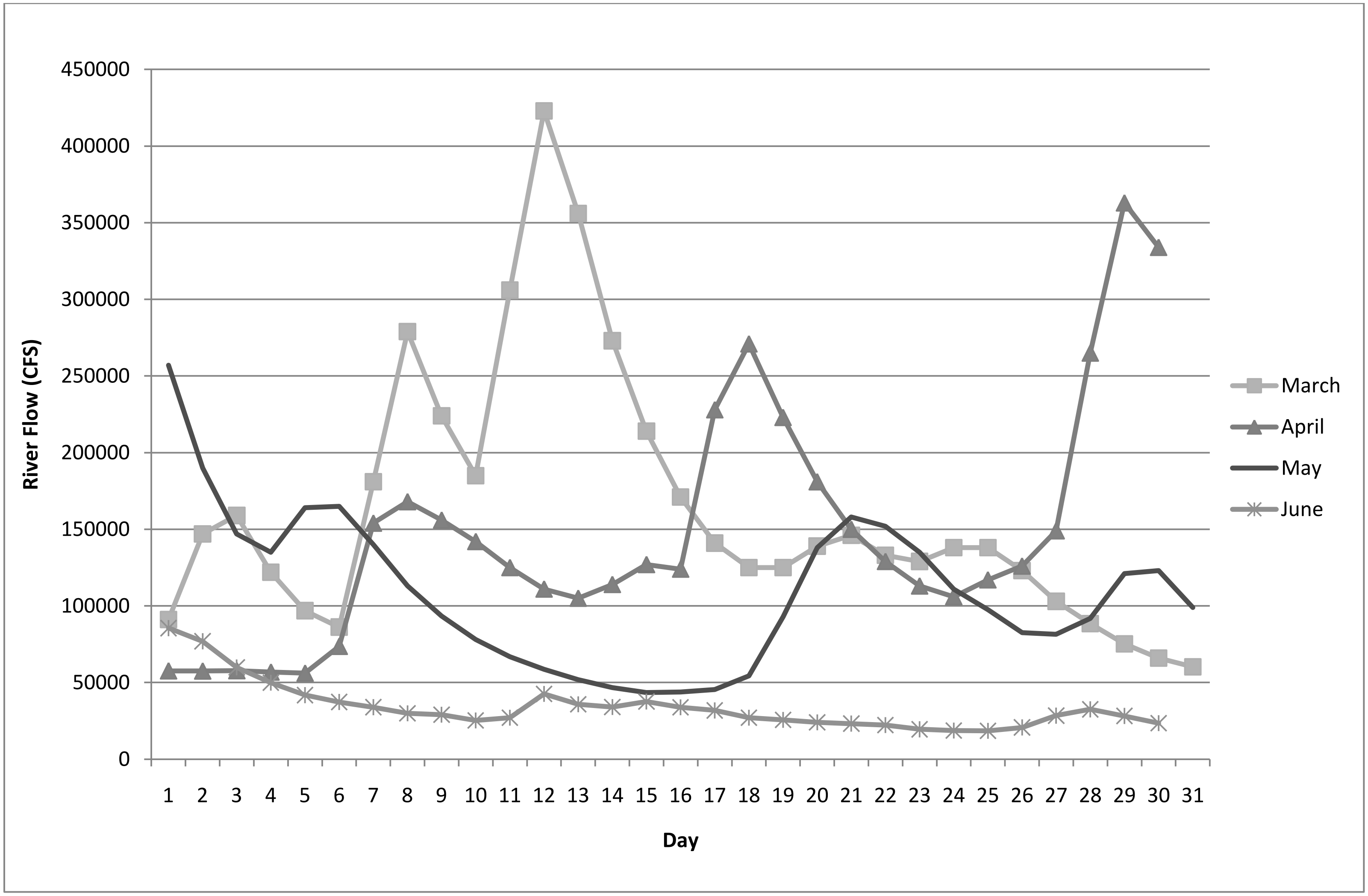
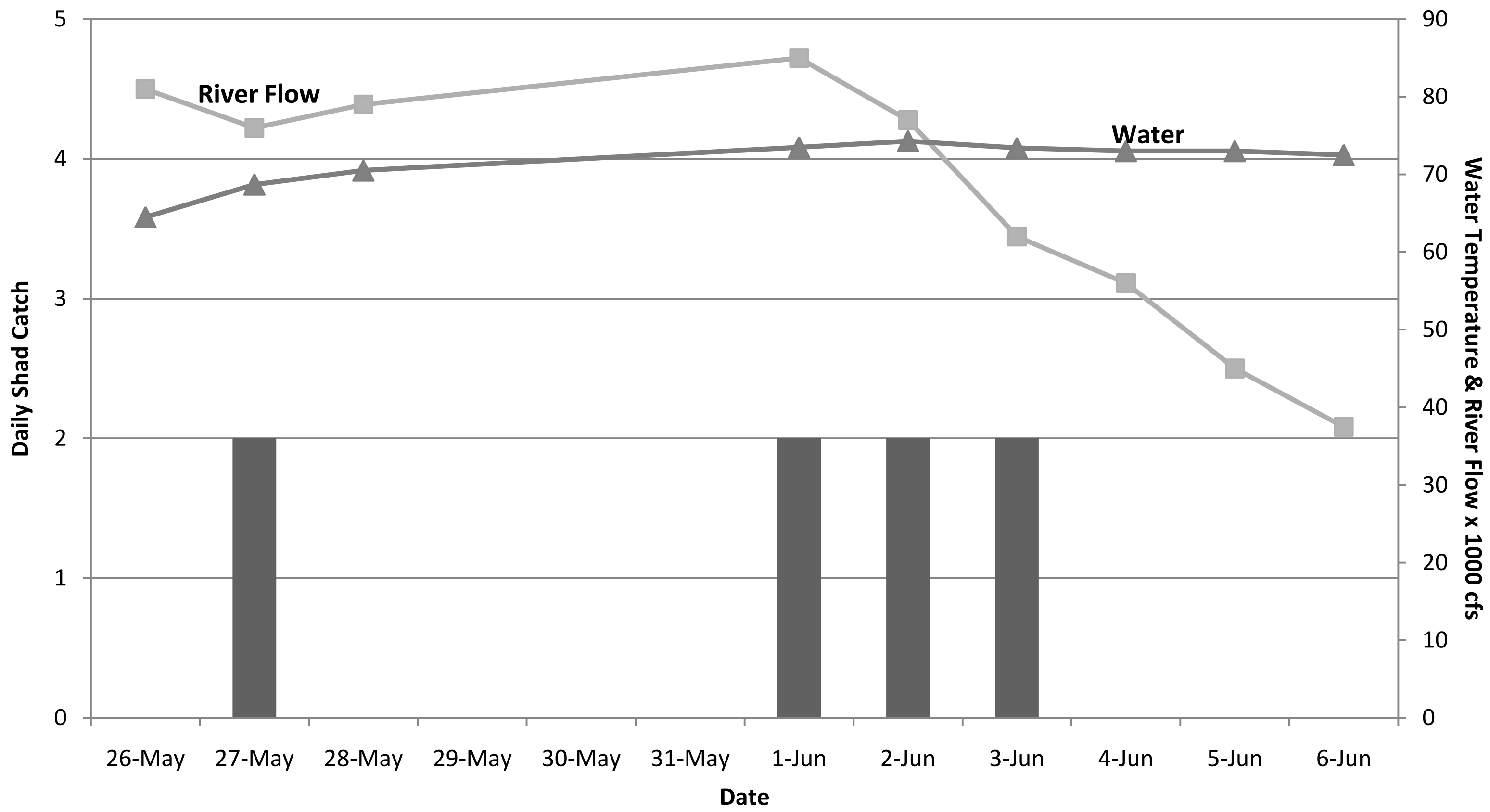


Figure 2. A plot of river flow (x 1000cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the daily American shad catch at the Safe Harbor Fish Passage Facility, spring 2011.



SUMMARY OF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT, IN 2011

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EXECUTIVE SUMMARY

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.

High River flows resulted in flooding at the Project in mid-March which resulted in cancelation of the York Haven FPTAC meeting that was scheduled prior to Fishway operation. Although the FPTAC was not able to reschedule the meeting 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 2011 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 flow is 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

Although Fishway preparations were delayed until late March by high River flows that flooded the power station and peaked at 385,000 cfs on 12 March the fish ladder was opened allowing volitional passage (unmanned) to begin on 1 April. Only the entrance and exit gate were open during a 66 day unmanned period of Fishway operation between 1 April and 5 June.

High spring River flows coupled with mechanical difficulties at the Holtwood Fish lift limited upstream American shad passage in the lower River during the spring of 2011. The first American shad passed the Conowingo East fish lift on 8 May; between 8 and 19 May some 20,571 shad were passed upstream. A total of 21 American shad passed upstream through the Holtwood fish Lift and only eight passed upstream through the Safe Harbor Lift. Due to the limited upstream passage of American shad at the Holtwood and Safe Harbor fish lifts, manned Fishway operation at York Haven was limited to 6 and 7 June. Since only 8 shad had passed upstream through the Safe Harbor lift and no shad were observed passing the ladder on 6 or 7 June members of the FPTAC mutually agreed to end manned Fishway operation. Manned operation ended at 1600 hrs on 7 June.

Generally during manned Fishway operation, fish were counted and allowed to pass upstream between 0800 hrs and 1600 hrs. Both fixed wheel gates and the diffuser gate were opened. 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.

The Fishway was staffed by two people in 2011. These individuals, a biologist and a 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 7 June, the South fixed wheel gate was closed.

On 8 June, the fish ladder and North fixed wheel gate were set to deliver a minimum flow of 400 cfs into the East Channel. The Fishway remained open through 9/21/2011 and was set to deliver a minimum stream flow of at least 400 cfs to the East Channel.

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 1600 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 two days the Fishway was manned varied from 8 in. to 12 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

A total of 1,417 fish of 9 taxa were counted as they passed upstream through the York Haven Fishway on 6 and 7 June (Table 1). Total daily passage varied from 392 fish on 6 June to 1,025 fish on 7 June. Channel catfish (659) was the dominant fish species passed on both days and comprised over 46% of the fish passed. Other predominant fishes passed included gizzard shad (317), quillback (217) and carp (125).

American Shad Passage

None of the 8 American shad that passed upstream through the Safe Harbor fish lift in 2011 were observed passing through the York Haven Fishway.

Other Alosids

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

Observations

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. No fish were observed trying to swim over the 67 ft weir or through the fixed wheel gates. No fish were observed downstream of the Main Dam.

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

Since only 8 American shad passed the Safe Harbor fish lift and no shad were observed passing the York haven Fishway in 2011, Station personnel did not make any observations for post-spawned adult shad in the forebay.

Juvenile Passage

While Station personnel had planned to implement the juvenile Downstream Passage Protocol, there was no need to implement the Protocol as record rainfall resulted in high River flows and continuous spill at the Project throughout the fall outmigration period. Spills at the Project began on 29 August during Hurricane Irene and continued through early September when tropical Storm Lee moved into the Susquehanna River Valley. On 9 September, flood flows associated with Tropical Storm Lee reached 590,000 cfs at Harrisburg (USGS Gage # 01570500). These flood flows were followed by above average river flows during the remainder of September and most of October and November (Figure 4). The high River flows during the fall outmigration period were a direct result of record rainfall that occurred in 2011. Rainfall at Harrisburg International Airport through November was the highest ever recorded.

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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 AND FIGURES

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 2011.

Date	6-Jun	7-Jun	Total
Observation Time (hrs.)	8.0	8.0	**16.0**
Water Temperature (°F)	72.5	73.0	
American shad	0	0	**0**
Alewife	0	0	**0**
Blueback herring	0	0	**0**
Gizzard shad	113	204	**317**
Hickory shad	0	0	**0**
Striped bass	0	0	**0**
White perch	0	0	**0**
American eel	0	0	**0**
Carp	43	82	**125**
Quillback	72	145	**217**
Shorthead redhorse	1	2	**3**
Channel catfish	156	503	**659**
Green sunfish	1	1	**2**
Smallmouth bass	0	7	**7**
Walleye	5	77	**82**
Flathead catfish	1	4	**5**
Total	**392**	**1,025**	**1,417**

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East Channel, sum of average flow from power station and main dam, water temperature, secchi, stop log gate position, and East Channel and fishway water elevations during operation of the York Haven fishway complex in 2011.

Date	River Flow (cfs)	East Channel Flow	Main Channel Flow	Water Temp. (°F)	Secchi (in)			Stop Log Gate	Elevation (ft)					
									Head Pond			Tailwater		
					Avg.	Min.	Max.		Avg.	Min.	Max.	Avg.	Min.	Max.
6-Jun	32,800	3,900	28,900	72.5	8	8	8	closed	281.3	281.2	281.3	274.2	274.1	274.2
7-Jun	30,000	3,300	26,700	73.0	11	10	12	closed	279.2	279.2	279.2	274.0	274.0	274.0

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2011.

Date	River Flow (cfs)	Elevation (ft)																				
		Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
6-Jun	32,800	281.3	281.2	281.3	274.2	274.1	274.2	275.0	275.0	275.0	278.8	278.8	278.8	278.9	278.9	278.9	277.5	277.5	277.5	278.6	278.6	278.7
7-Jun	30,000	279.2	279.2	279.2	274.0	274.0	274.0	274.8	274.8	274.8	278.6	278.6	278.6	278.9	278.9	278.9	277.5	277.5	277.5	278.3	278.3	278.3

Figure 1. General layout of the York Haven Hydroelectric Project showing the location of the fishway.

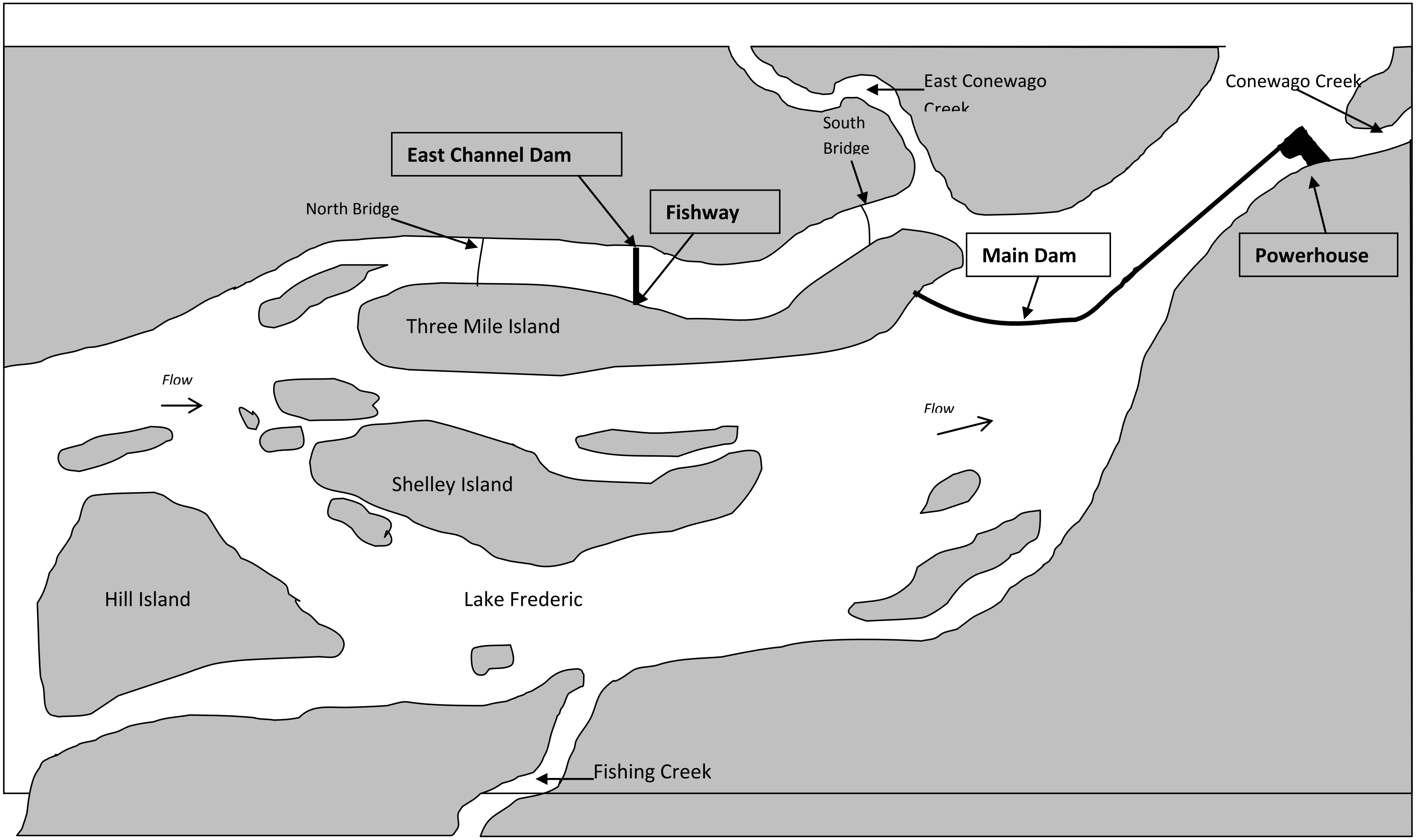


Figure 2. General arrangement of the York Haven Fishway.

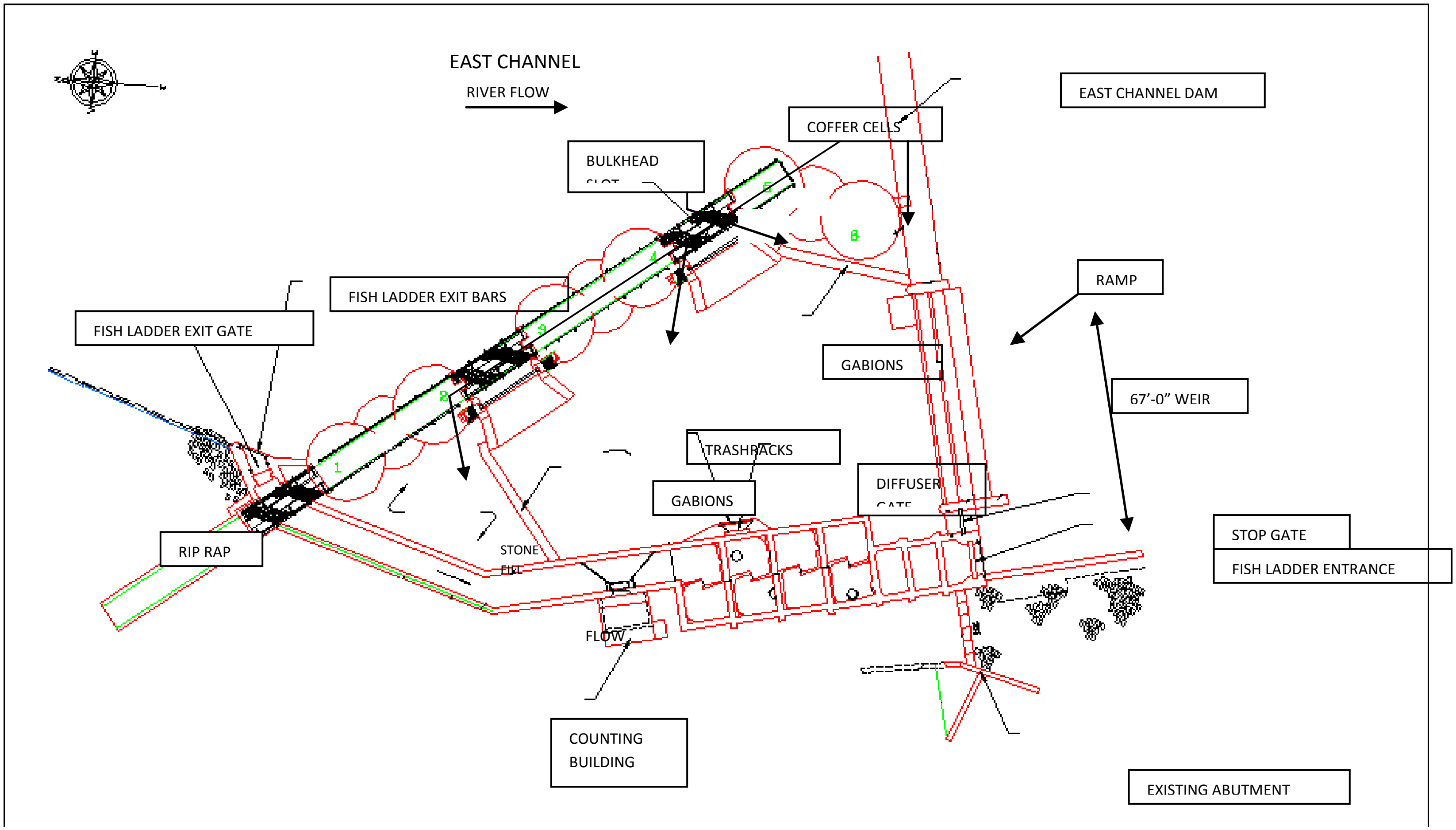


Figure 3. Plot of river flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River during the spring of 2011.

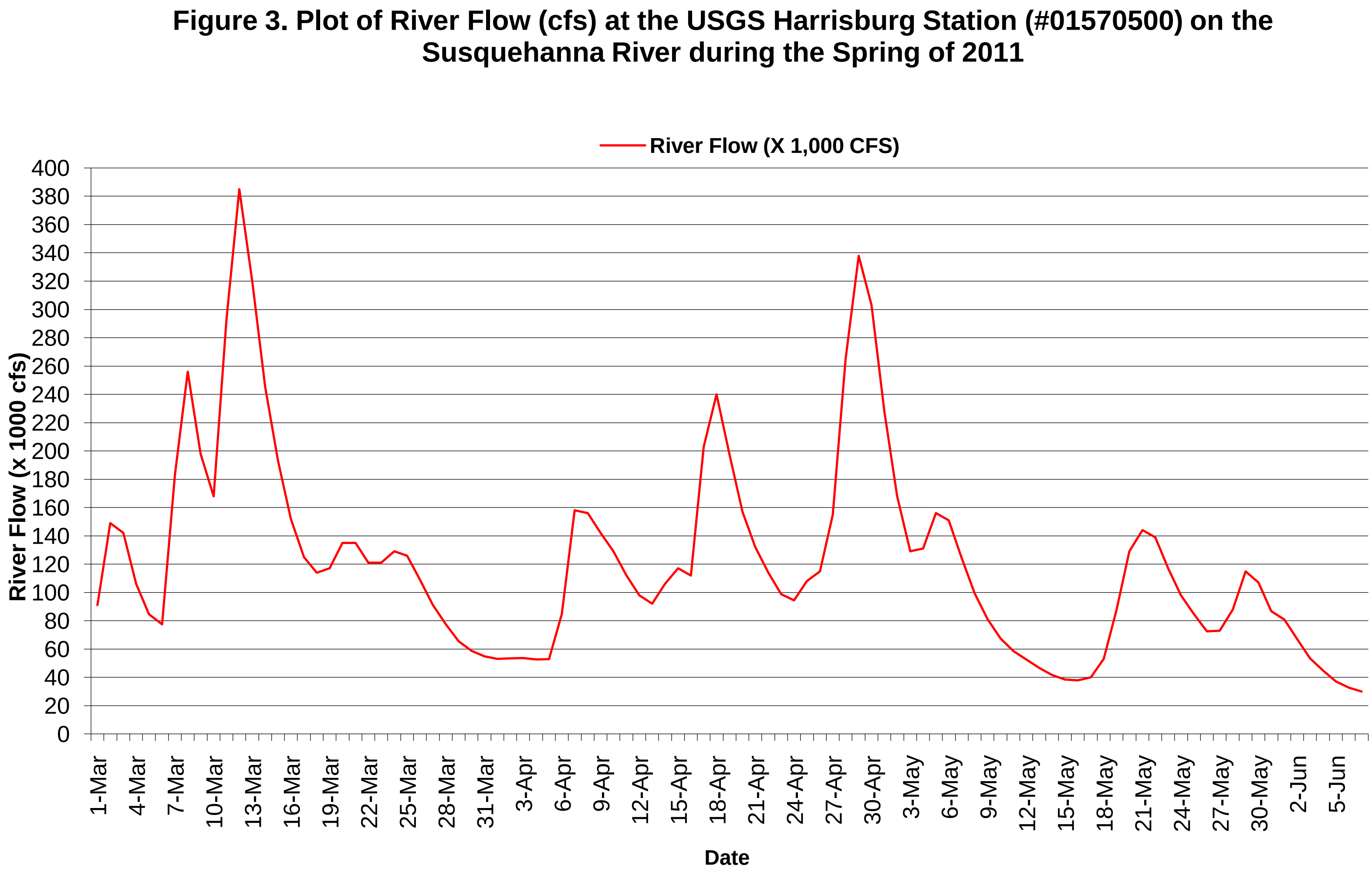
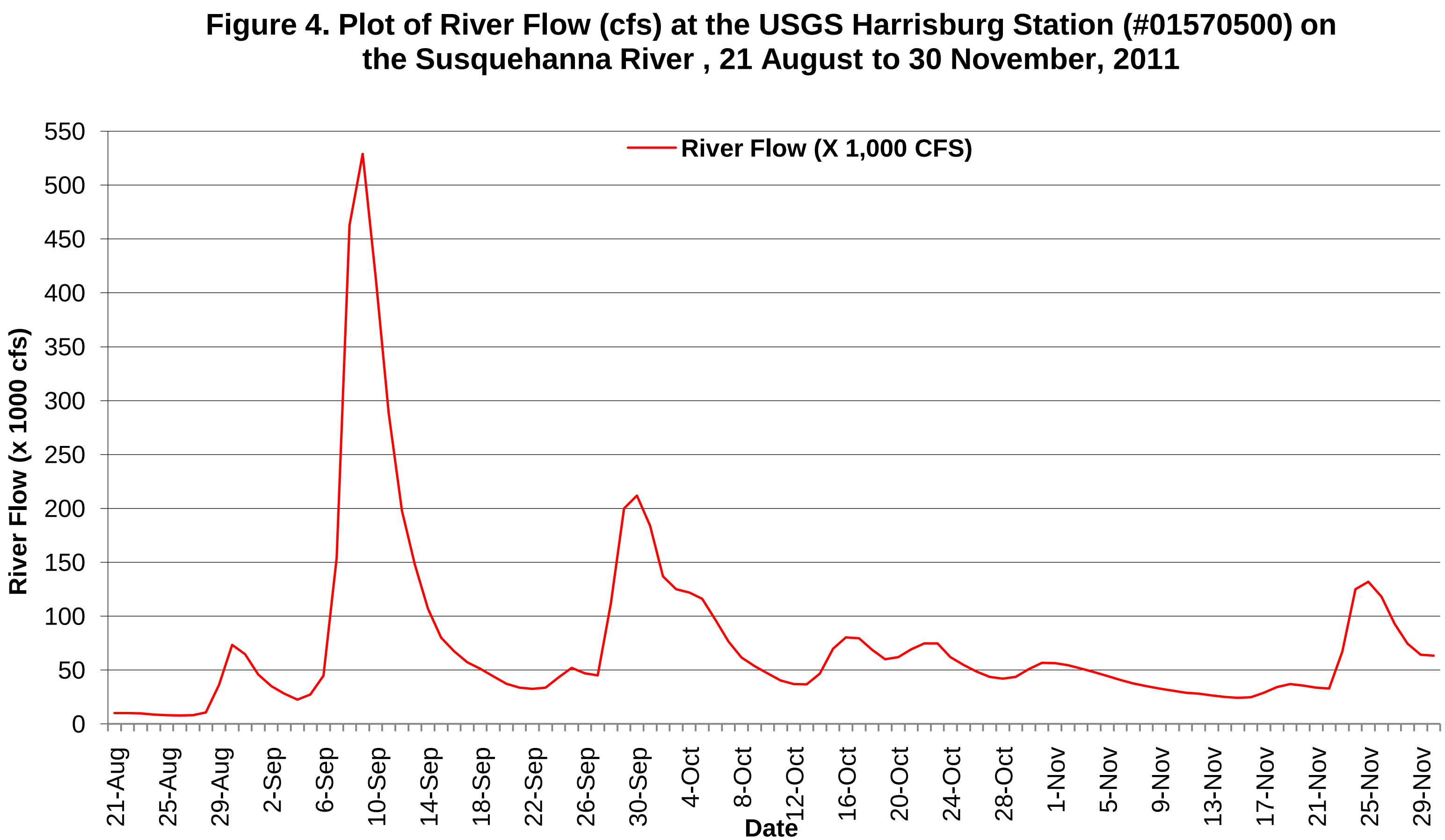


Figure 4. Plot of river flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River, 21 August to 30 November 2011.



JOB II, PART 1. SUSQUEHANNA RIVER AMERICAN SHAD RESTORATION: POTOMAC RIVER EGG COLLECTION, 2011

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13 August 2011

ABSTRACT

During April and May, 2011 we used monofilament gill nets to collect 772 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 a total of 19 days and supplied a total of 137 L of American shad eggs (6.2 million) with a 44% fertilization rate resulting in 2.7 million viable eggs. The U.S. Fish and Wildlife Service's sixth attempt to deliver eggs for Susquehanna River American shad restoration resulted in a similar number of viable eggs as in previous years with the exception of 2010.

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 in to the Pennsylvania Boat and Fish Commission (The Native Fish Conservancy 2005).

The U.S. Fish and Wildlife Service (Service) is partnered with state, Federal, and hydro-power companies, through the Susquehanna River Anadromous Fish Restoration Cooperative to restore American shad to the Susquehanna River 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 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 (≈ 18.3 m) area to relatively shallow depths (≤ 3.5 m). Channel substrate consists of firm sandy mud with intermittent shell. Sand increases in the shoal area forming a comparatively harder substrate.

MATERIALS AND METHODS

Two Service boats with a crew of three each, fished for American shad nightly. We used two different types of net in 2011 egg collections. One net was used for targeting ripe females and the other was used 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 used 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 five 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 gill nets were set (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). A subsample of American shad otolith samples, total length (nearest mm) and weight (nearest 0.1 gram) were taken from American shad captured. The samples were taken as a permit requirement of the Potomac River Fisheries Commission.

RESULTS

During spring 2011 we sampled the Potomac River a total of 19 days from April 12- May 12. During the 19 days of fishing we collected ≥ 5.0 L of eggs 10 times (67%). We shipped a total of 137.4 L (Range = 5.0 – 21.3 L, $\bar{x}$ = 13.7 L/shipment) of eggs from the Potomac River (M. Hendricks, pers. comm.). The overall egg viability was 44%, although daily shipments had a range of 5.6 – 63.3% (M. Hendricks, pers. comm.).

Gill net sampling produced 3,837 fish from the Potomac River, representing fourteen fish species from eight families (Table 1). In 2011, green females were more common than ripe females with a 1.71:1 ratio, but males were more common than ripe females with a 1.1:1 ratio (Figure 2).

From early April to early May, surface water temperature and dissolved oxygen displayed a slight rising trend on the Potomac River. However, during the second week of May there was a sharp increase in surface water temperature (Figure 1). Surface water temperatures ranged from 13.3 to 20.0 ^{o}C ($\bar{x}$ = 17.3 ^{o}C) while dissolved oxygen ranged from 10.5 to 114.6 mg/L ($\bar{x}$ = 11.8 mg/L) (Figure 1). CPUE for shad was variable and there was no apparent relation to tide or to lunar cycle. The CPUE was the highest on the third day (4/14/2011) of sampling (0.195/hr/m^2) and lowest on the last day (5/122011) of sampling (0.000/hr/m^2). The highest CPUE values were between the thirteenth day (5/4/2011) and fifteenth day (5/8/2011) of sampling. During this time the CPUE ranged from 0.114/hr/m^2 to 0.189/hr/ft^2 with an average of 0.153/hr/m^2 (Figure 1).

DISCUSSION

American shad harvest in numbers sufficient to yield egg shipments was very inconsistent on the Potomac River. The greatest numbers of ripe/running male and female American shad were caught between surface water temperatures of 16.8-18.6 ^{o}C as opposed to 2010 sampling when the greatest numbers of ripe/running male and female American shad were collected between water temperatures were of 16.5-17.2 ^{o}C. In contrast to other 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 2011 season. In the Potomac River males are substantially smaller than females. To collect a higher number of males, we set at least one smaller mesh gill net (11.75 cm) along with up to eight of the larger mesh gill net (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 to be stocked into the Susquehanna River watershed.

CONCLUSION

The USFWS provided Pennsylvania with 137 L of eggs, with an overall viability of 44% (6,874,612 viable eggs) (Table 3). Unstable river flows and variable water temperature made collection of viable eggs more difficult than in previous years. Due to weather, high flows, or large amounts of debris we were unable to fish on five occasions (Figure 3). Our 2011 viability of 44% is equal to the greatest viability to date and greater than our six year average (40%) since Potomac River egg collection began in 2006.

PROJECT SUMMARY

Over the past six years the USFWS has provided Pennsylvania with close to 20 million viable shad eggs.

Year	Volume (L)	Viable Eggs (N)	Viability (%)
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 Maryland Fishery Resources Office thanks those who participated in this year's sampling Dylan Carey, Sheila Eyler, Chris Jones, Lexi Maple, Mark McBride, 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 AND TABLES

Figure 1. Spring 2011 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 ≤ 0.10 ppt.

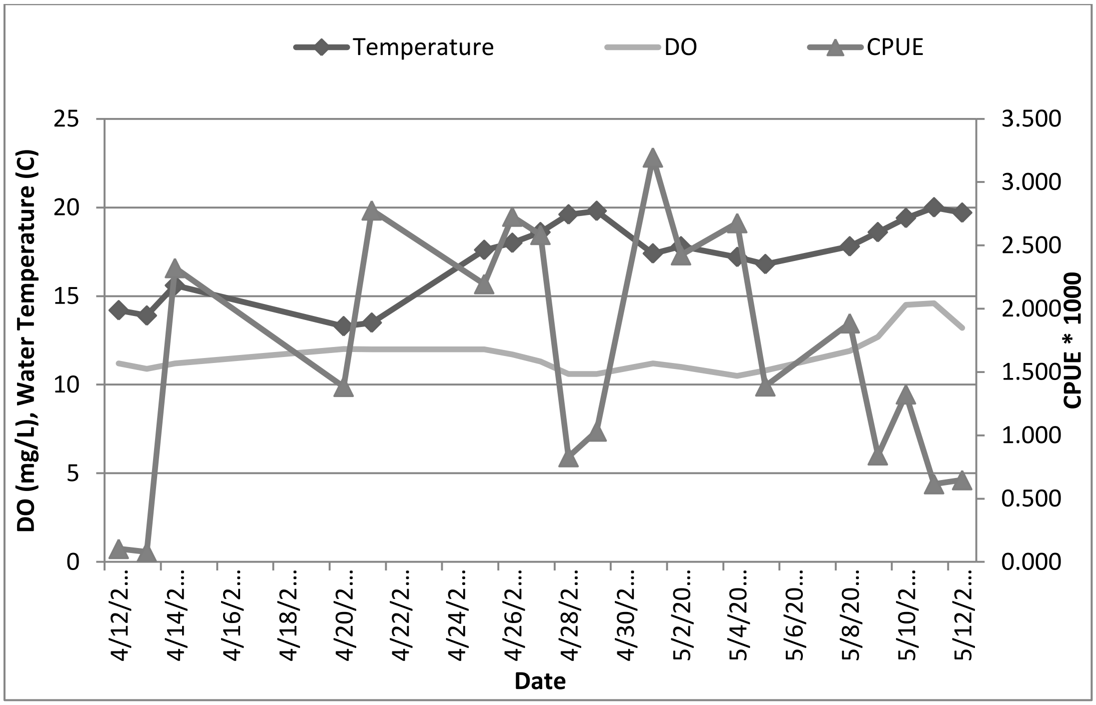

Figure 2. Spring 2011 species composition from Potomac River gill net sampling at Marshall Hall, MD. Other species and number caught listed in Table 1.

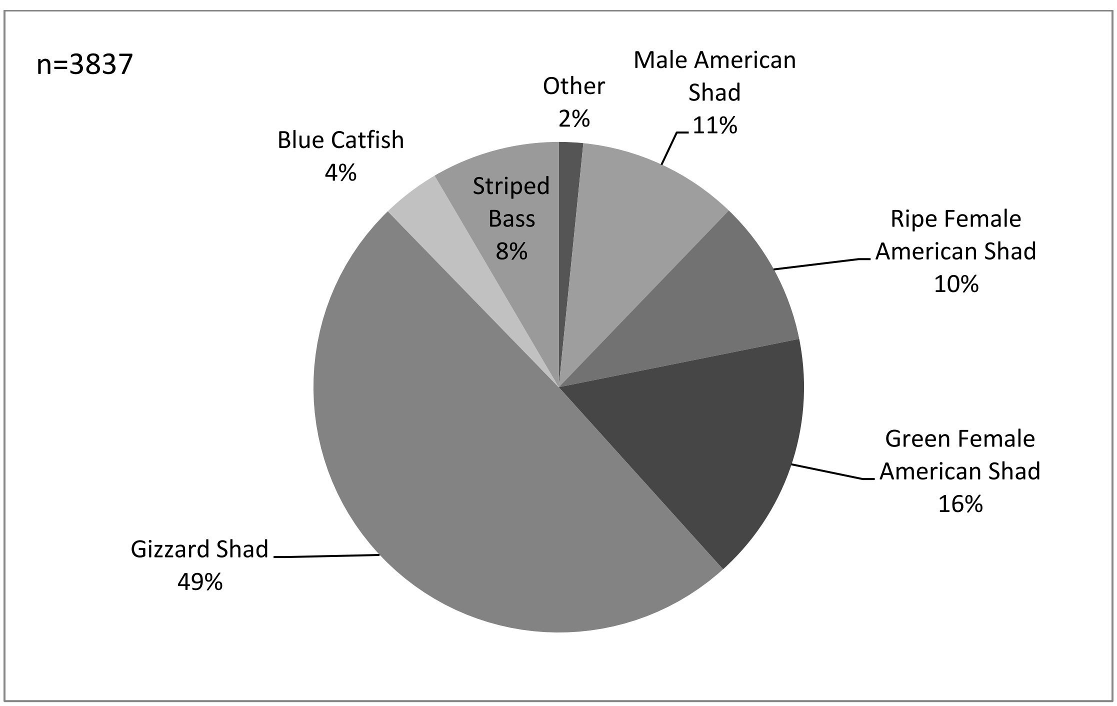

Figure 3. Daily discharge at Little Falls Pump Station during the American shad egg collection on the Potomac River.

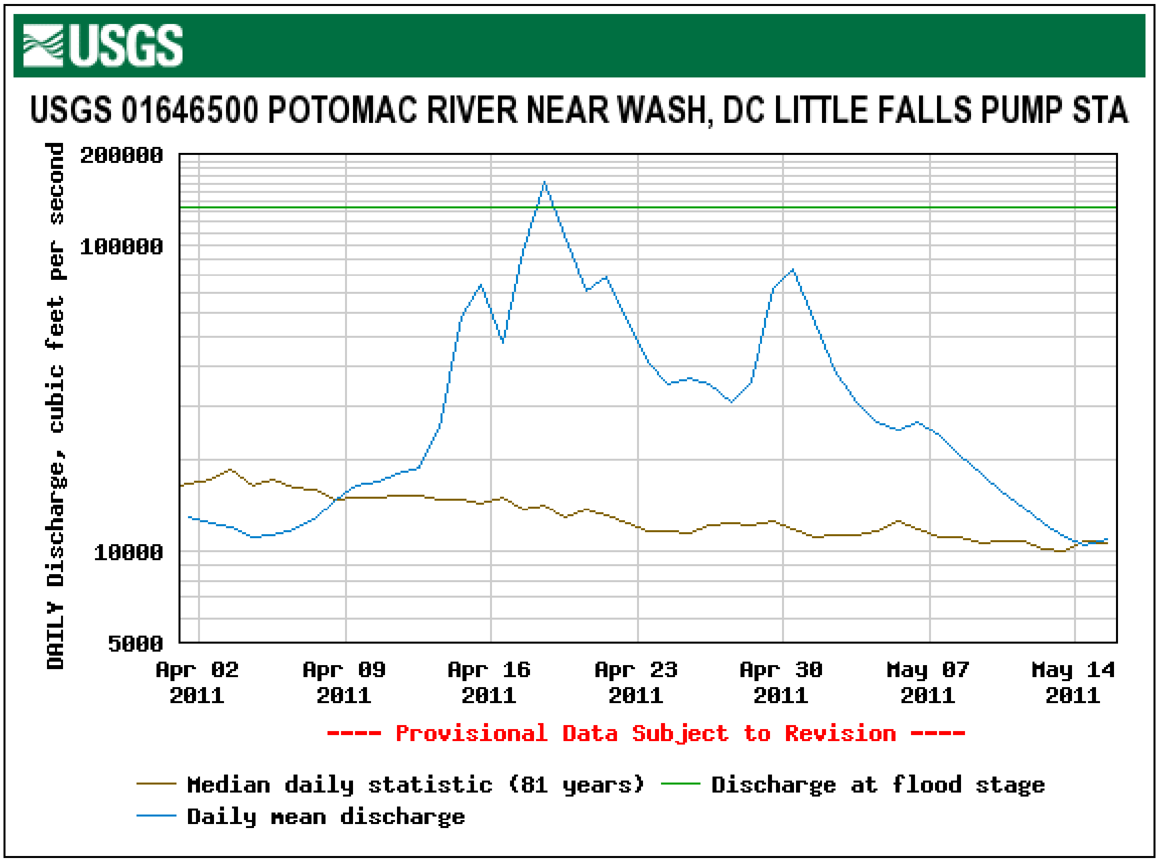

Table 1. List of species and number collected in gill nets from the Potomac River during spring, 2011.

Family	Scientific Name	Common Name	Number Captured
Belonidae	*Strongylura marina*	Atlantic needlefish	1
Catostomidae	*Carpiodes cyprinus*	quilback sucker	4
Centrarchidae	*Micropterus salmoides*	largemouth bass	2
Clupeidae	*Alosa mediocris*	hickory shad	1
	Alosa sapidissima	American shad	1424
	Dorosoma cepedianum	gizzard shad	1884
Cyprinidae	*Carassius auratus*	goldfish	6
	Cyprinus carpio	common carp	5
Ictaluridae	*Ictalurus furcatus*	blue catfish	146
	Ictalurus nebulosus	brown bullhead	1
	Ictalurus punctatus	channel catfish	7
Lepisosteidae	*Lepisosteus osseus*	longnose gar	33
Moronidae	*Morone americana*	white perch	1
	Morone saxatilis	striped bass	322

Table 2. American shad catch totals with respect to male and female ratio and the associated viability and liters of eggs produced during spring, 2011.

Date	Ripe Male	Running Female	Ratio Male:Female	Liters	Viability
4/12/2011	17	8	2.12:1	0	0
4/13/2011	11	5	**2.2:**1	0	0
4/14/2011	19	57	1:3	19.8	34.1
4/20/2011	12	1	12:1	0	0
4/21/2011	10	5	2:1	0	0
4/25/2011	29	15	1.93:1	7.1	33.9
4/26/2011	23	15	1.53:1	5	5.6
4/27/2011	9	2	4.5:1	0	0
4/28/2011	8	30	1**:3.75**	10.3	14.1
4/29/2011	7	46	1:6.57	21.3	43.1
5/1/2011	47	29	1.62:1	14.8	60.4
5/2/2011	90	9	10:1	0	0
5/4/2011	26	36	01:01.4	20.2	63.3
5/5/2011	18	26	1:1.44	17	61.3
5/8/2011	28	50	1:1.78	13.4	34.5
5/9/2011	24	17	1:1.41	8.5	45.4
5/10/2011	5	6	1.2:1	0	0
5/11/2011	21	11	1:2.6	0	0
5/12/2011	0	0	1:2.5	0	0

Table 3. 2011 Shipment and viability summary for American shad eggs, delivered to the Van Dyke Hatchery from various collection sites (Hendricks 2011, unpublished).

Site	Shipments (N)	Volume (L)	Eggs (N)	Viable Eggs (N)	Viability (%)
Potomac	10	137.36	6216484	2714435	44
Delaware	13	171.85	9990842	1467015	15
Susq. Conowingo	8	106.4	7362615	1156431	16
Grand total	31	415.61	23569941	5337880	23

JOB II - PART 2. COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2011

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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 dependent 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 2011, 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 15, 2011 and terminating on June 2, 2011. Eighteen 200-foot gill nets were set on four nights, 15 nets were set on two nights, 14 nets were set on two nights, 11 nets were set on three nights and 8 nets were set on two nights (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 twp 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 2011, 57 to 100% 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 2011, 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 floating boxes with fine mesh sides and bottom 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 about one to three hours.

In 2011, a second year of controlled experiments was conducted using two different methods for egg handling. Control eggs were handled in the same manner as previous years: 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 zip ties to minimize leakage. Bags were then 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. Test and control eggs were water hardened as per usual practice, and then placed into experimental egg incubation coolers fitted with a 120v, aquarium style, air-pump. Incubation coolers used in 2011 (Figure 1) were refined versions of the 2010 model (Figure 2). A false bottom, sloped towards the center of the coolers' long axis, was built into the floor of each cooler (Figure 3). A Regent Aqua-Tech bubble curtain was secured to the valley created by the sloped bottom and connected to an aquarium pump with tubing and a "T" connection. Visual observation indicated that the 2011 incubation coolers kept all eggs moving or in suspension, similar to rolling in incubation jars. Additionally, the sloped floor and centrally located aeration eliminated areas where eggs may accumulate. During transport, power was supplied to the pump via an inverter. Test and control eggs were incubated in separate egg jars to permit comparison of egg viability. For a full discussion of this experiment, see Job III, Appendix 1.

In previous years, egg collections of less than 2 liters were released back into the Delaware River rather than shipped to Van Dyke. No egg collection events yielded less than 5L in 2011; therefore, no eggs were released into the Delaware River. Sampling occurred on 13 of the 14 scheduled nights. Sampling was canceled on May 19 due to high river flows and severe thunderstorms (Table 1).

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. 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. Both scale samples and otoliths were collected from all individual shad for age determination.

RESULTS AND DISCUSSION

Table 1 summarizes daily Delaware River shad egg collections during May and June 2011. Egg shipments were dependent on the availability of captured male shad and the spawning readiness of females. Spawning operations commenced on May 15, when river flow was 4910 cfs (USGS gauge at Montague, NJ), and river temperature was 14.8˚ C (58.1˚ F). All collection events yielded sufficient egg volumes for shipment to the Van Dyke Hatchery. Egg shipment volumes ranged from 5.1 L to 30.8 L and were dependent on the number and spawning readiness of collected females. Spawning ready males were not limiting during initial egg take operations (5/15, 16, 17 and18); however, were somewhat limiting throughout many of the remaining collection events. Egg take ended on June 2, when river flow was 7,830 cfs and temperature was 20.0˚ C (68.0˚ F). Flow conditions during the 2011 egg-take operation were less than ideal with river flows above average for many of the collections and two high water episodes (Figure 4). Although, shad catch and egg collections did not seem hampered.

A total of 1,010 adult American shad were caught (Table 1), which was above the long-term average of 780. Nightly catches ranged from 24 to 159 shad. The overall sex ratio (male to female) was 0.25:1, and ranged from 0.12:1 to 1.29:1 for nightly catches (male to female ratios for 12 of 13 collection events were below 0.95:1). Some 171.9L (9.9 million) fertilized eggs were collected and shipped to the Van Dyke Hatchery in 2011, compared to the long-term average of 6.1 million. Egg viability per shipment was highly variable in 2011 ranging from a low of 0% to a high of 58.6%, with an overall viability of 14.7%. Egg viability is related to a multitude of factors; however, the condition of the gonads prior to strip-spawning can have a dramatic impact on egg viability. For example, if the ovaries are not completely in ripe/running condition (i.e., fully hydrated eggs), viability will be reduced. Egg mortality during transportation can also impact egg viability.

A total of 473 thousand American shad larvae were stocked in the Lehigh River, and 643 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 2011, 183 million American shad eggs were collected from the Delaware River (Figure 5). From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 17.5 million in the Lehigh River, 7.5 million in the Schuylkill River, and 0.4 million in the Delaware River.

Egg collection CPUE (Figure 6) was the highest since 1995. Anglers also reported excellent catches of shad. Anglers reported many 30-40 fish days, making 2011 the best shad year in 20 years. The catch was dominated by 6 year old females from the excellent 2005 year class. Some 80% of the shad caught at Smithfield Beach were age 6. Four year-old shad constituted only 1.8% of the catch, despite a juvenile index of 176 in 2007, the second best in the 28 year time series.

SUMMARY

Fishing occurred from 15 May through 2 June 2011. Eggs were collected and shipped on 13 of the 13 nights of fishing. A total of 1,010 adult shad were captured and 171.9 liters of eggs were shipped for a hatchery count of more than 9.9 million eggs. Overall, the viability for Delaware River American shad eggs was 14.7%.

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FIGURES AND TABLES

Figure 1. Modified egg incubation cooler used in 2011 (v2.0).

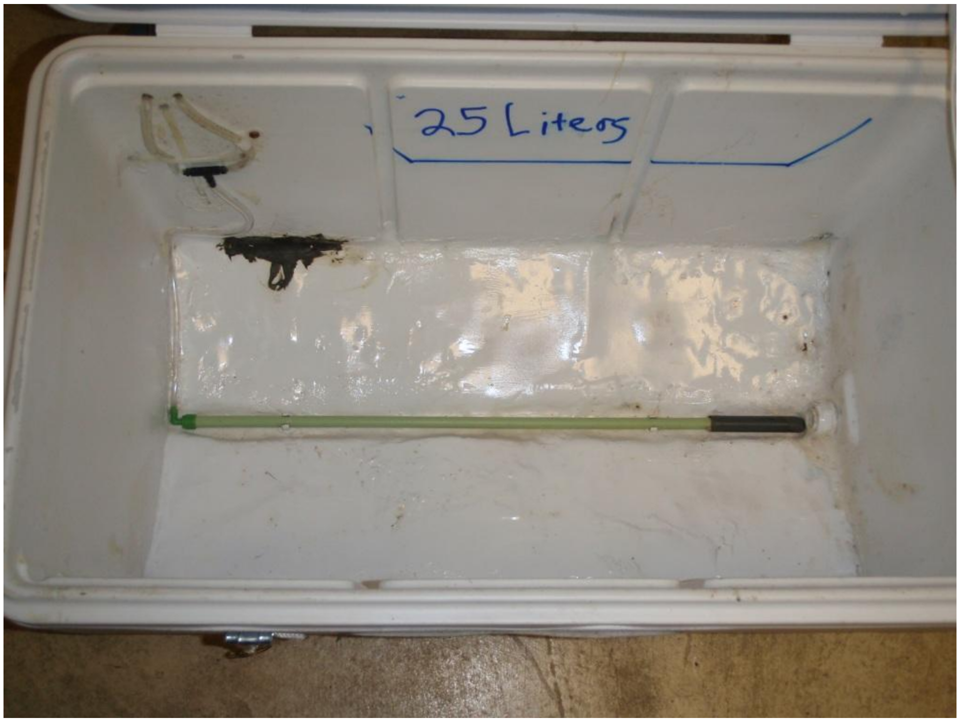

Figure 2. Modified egg incubation cooler used in 2010.

Figure 3. Modified egg incubation cooler used in 2011, showing the sloped false-bottom floor and aeration tube (bubble curtain).

Figure 4. American shad eggs collected in the Delaware River at Smithfield Beach, 2011.

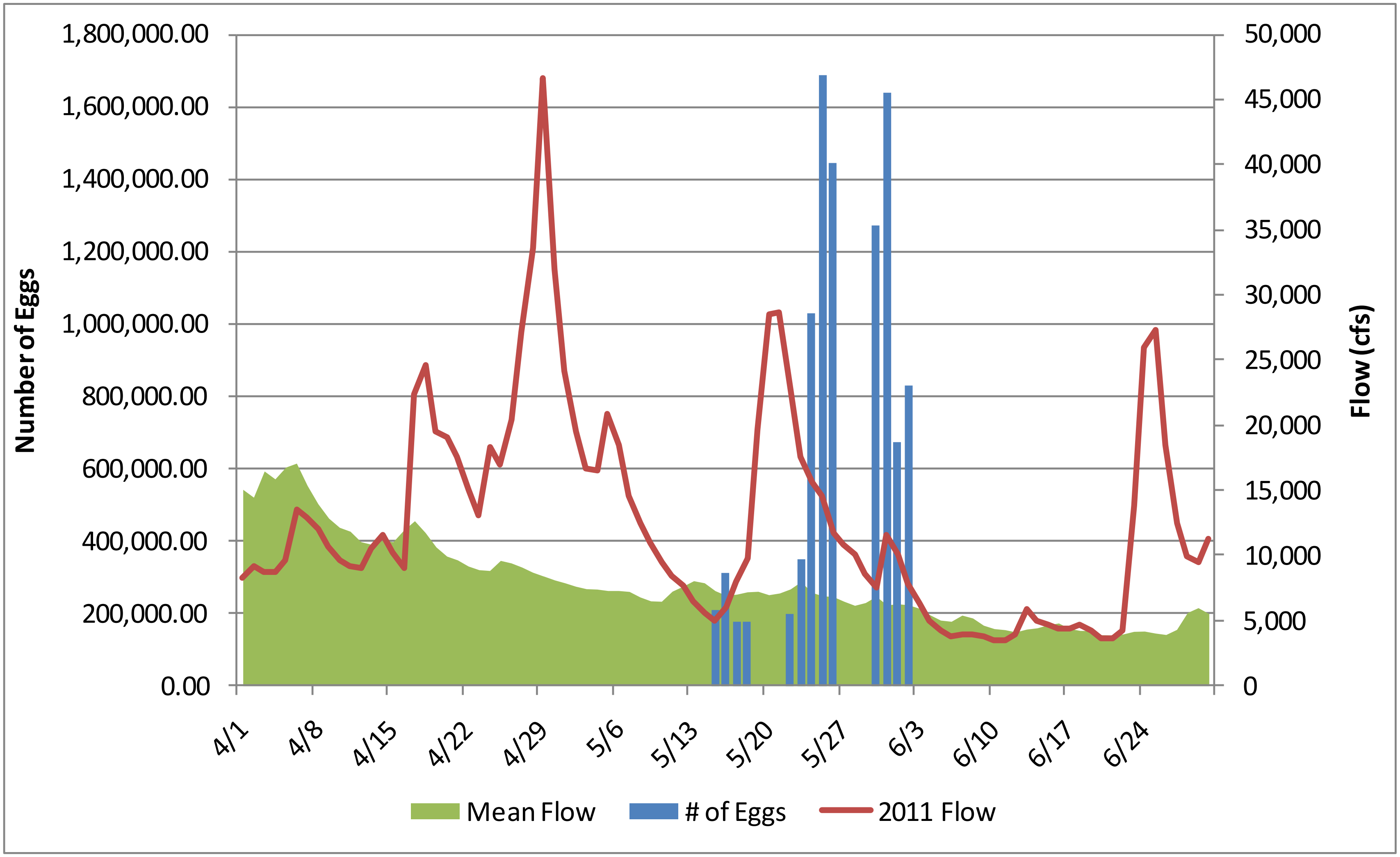

Figure 5. American shad eggs collected from the Delaware River, 1983 - 2011.

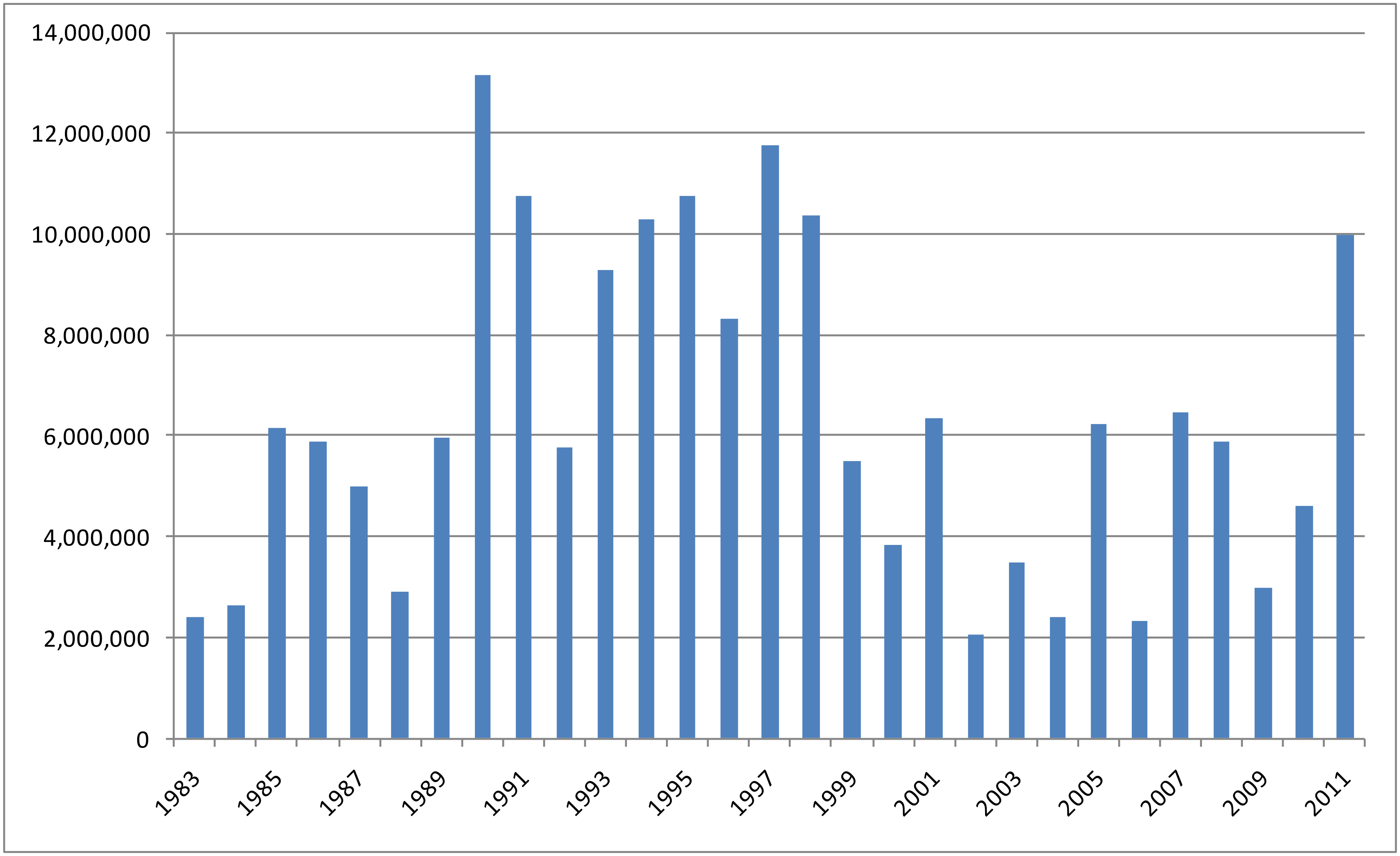

Figure 6. Catch-per-unit-effort for adult American shad collected by gill net at Smithfield Beach, Delaware River, 1990-2011.

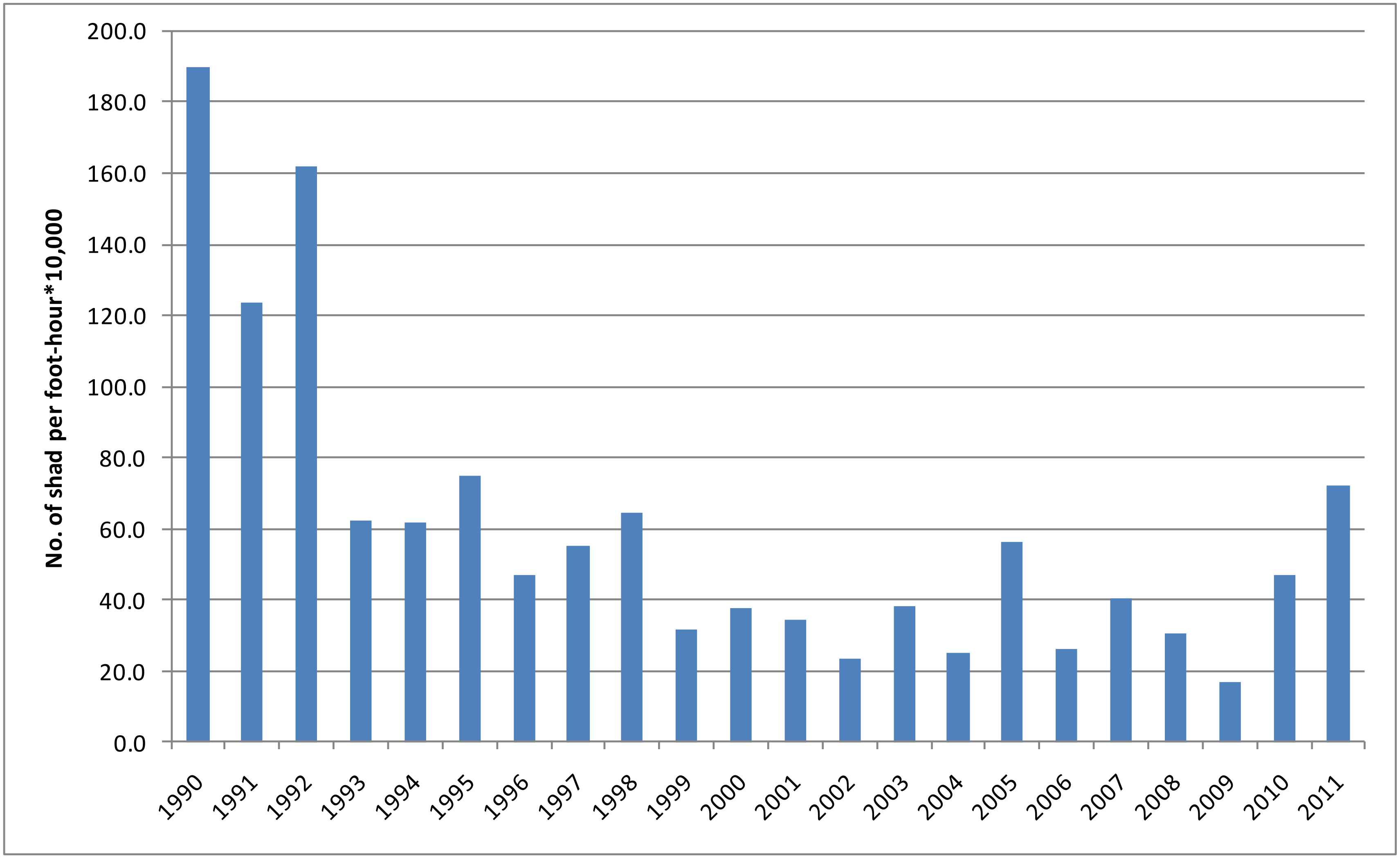

Table 1. Delaware River American shad egg collections, 2011.

Date	Water Temp (oC)	No. of Nets	No. shad Captured	Gravid Females	Ripe Females	Spent Females	Males	Egg Volume (L)	No. of eggs	Viable eggs	Percent Viable
5/15	14.8	8	48	9	20	0	19	5.4	206,148	11,296	5.48%
5/16	14.2	8	42	6	24	1	11	8.2	313,374	173,724	55.44%
5/17	14.0	11	42	3	17	0	22	6	174,134	101,987	58.57%
5/18	14.6	11	24	6	10	0	8	5.1	177,242	39,839	22.48%
5/19	*no sampling - canceled due to high river flows and severe thunderstorms*										
5/22	13.5	11	25	7	14	0	4	5.2	197,319	30,010	15.21%
5/23	14.0	14	47	11	23	0	13	11.4	350,084	68,587	19.59%
5/24	14.5	15	99	4	59	8	28	27.8	1,028,904	584,915	56.85%
5/25	15.5	15	159	22	99	6	32	30.8	1,686,809	215,976	12.80%
5/26	18.5	14	96	10	61	10	15	17.85	1,442,344	56,338	3.91%
5/30	20.0	18	133	6	80	26	21	13.1	1,272,730	-	0.00%
5/31	21.5	18	148	8	92	34	14	16.1	1,640,515	43,179	2.63%
6/1	20.0	18	70	2	47	15	6	9.7	670,769	120,650	17.99%
6/2	20.0	18	77	3	59	8	7	15.2	830,471	20,514	2.47%
	Total	**179**	**1010**	**97**	**605**	**108**	**200**	**171.85**	**9,990,842**	**1,467,015**	**14.68%**

JOB II, PART 3. HICKORY AND AMERICAN SHAD SPAWNING TESTS CONDUCTED AT CONOWINGO DAM, SPRING 2011

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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.

METHODS AND MATERIALS

The methods used to conduct the hormone induced spawning tests at the Conowingo West Fish lift in 2011 were generally similar to those used in the past ten years. Beginning with the 2008 tests and continuing for the 2011 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 2011was 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 2011 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 both species 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. 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.

The West Fish Lift captures few, if any, hickory shad in a typical year. Shore anglers at the mouth of Deer Creek and electrofishing operations by Maryland Department of Natural

Resources biologists at Lapidum were the source of all hickory shad brood stock for the 2011 tests. Following the transport of hickory shad from Lapidum or Deer Creek by a PA Fish and Boat Commission transport truck, only sex and numbers were recorded before the fish were placed into a spawning tank. The smaller size of hickory shad permits stocking densities of up to 75 fish in the 10 ft tank and 125 fish in the 12 ft tank. The sex ratio in hickory shad spawning tests varied greatly and was based on availability. Stocking densities for American shad were 50 fish in the 10 ft tank and 75 fish in the 12 ft tank. A 3:2 (M/F) sex ratio, if available, was utilized for all American shad tests.

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 2011. This request to eliminate controls was prompted by the anticipation of an abbreviated testing season. High river flows in late April and early May delayed the installation of weir and crowder motors on the West Fish Lift and the Lift wasn't operational until May 13th.

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.

Shore anglers below the Dam were the source of the 75 American shad utilized to begin the first spawning test. The Conowingo West Fish Lift was the source of the remaining 861 pre-spawned American shad used in this year's spawning tests. All fish were measured for total length and a sub-sample (298) 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 four spawning tests with 378 hickory shad at the West Fish Lift between April 14 and May 12 produced 29.1 liters of eggs (Table 1 and Appendix Table A-1). All but 0.4 liters were shipped to the PFBC Van Dyke Hatchery. The overall viability of the shipped eggs was 78.9% (Mike Hendricks, personal communication) which is above the 62.9% average recorded for seven years of hickory shad spawning tests conducted at the West Lift since 2003 (Table 2). The average volume of eggs produced by each female hickory shad in the 2011 tests (0.208 liters) was slightly lower than the 0.225 liter average recorded from previous tests but the average volume of viable eggs per female in 2011 was above average (Figure 1). Water temperatures ranged from 9.0-16.1°C and oxygen levels were between 9.5 and 12.8 ppm. The overall mortality rate for hickory shad during the four spawning tests was 14.6%.

A total of 15 on-site spawning tests with 936 American shad from 12 May to 7 June produced 116.9 liters of eggs (Table 3 and Appendix Table A-2). Over 106.4 liters of eggs were shipped to the Van Dyke Hatchery and the remaining 10.5 liters were released into the river below Conowingo Dam. The overall estimated viability of the eggs shipped to Van Dyke was 15.7% (Mike Hendricks, personal communication). The total volume of eggs produced per female in 2011 (0.300 liters) was slightly below the average of 0.320 liter observed for the previous ten years (Figure 2). The volume of viable eggs produced per female in the 2011 tests averaged 0.047 liters (Figure 2). 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 18.0 to 24.7°C and 5.0 to 9.2 ppm.

The overall mortality rate for adult American shad during the 2011 tests was 9.4 %. Mortality rates have ranged from 2 to 15% in previous years (Table 4).

SUMMARY

This was the 8th year of hickory shad spawning tests and the 11th year of hormone induced American shad spawning tests at the Conowingo West Fish Lift. Hickory shad continued to outperform the American shad in these tests without the benefit of hormone injections. Hickory shad egg viability in 2011 (78.9%) was the second highest recorded since 2003. The overall viability (15.7%) of the 2011 American shad eggs was near the ten year average of 18.7%. The late start of the American shad tests due to river conditions raised some doubts that a full complement of 15± tests with 936 injected fish could be completed before the end of the American shad runs that typically end in early June. The elimination of control tests and a steady supply of pre-spawn brood stock from the West Lift helped speed up the testing schedule. During the first week of June, river temperature reached 24.0°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 three spawning tests

Table1. Summary of egg production data for spawning tests conducted with hickory shad at Conowingo Dam, Spring, 2011

Test #		Start/Stop Date	M/F	Liters of eggs	No. Liters Shipped	Date Shipped	
1		4-14/4-21	77/6	0.4	0.0		
2		4-25/4-29	52/38	7.9	7.9	4/26	
				7.9	7.9	4/27	
3		4-27/4-29	68/52	2.8	2.8	4/29	
4		5-5/5-12	45/40	5.3	5.3	5/7	
				4.8	4.8	5/8	
Totals			**242/136**	**29.1**	**28.7**		
Shipment Date	**Liters**	**Total Eggs**	**No. Viable Eggs**	**Percent Viable**			
26-Apr	7.9	2,318,069	1,921,383	82.9			
27-Apr	7.9	2,911,705	2,321,278	79.7			
29-Apr	2.8	1,483,827	926,948	62.5			
7-May	5.3	2,357,688	1,720,283	75.0			
8-May	4.8	3,109,676	2,714,972	87.3			
Totals	**28.7**	**12,180,965**	**9,604,864**	**78.9**			
Total Males			**242**				
Total Females			**136**				
Total Fish			**378**				
Total liters of eggs			**29.1**				
Mean liters/test.			**7.3**				
Mean No. of Eggs/ Liter			**425,908**				
Mean No. of Eggs/Female			**88,626**				
Mean No. of Viable Eggs/ Female			**69,926**				

Table 2. Summary of hormone induced spawning trials with hickory shad at Conowingo Dam, 2003-2011.

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2011**
Start/Finish date	4-15/4-27	4-19/4-26	4-15/4-27	4-11/4-19	4-23/5-1	4-11/4-24	4-13/4-28	4-14/5-12
Tank diameter (ft)	10, 12	10, 12	10, 12	10, 12	12	10,12	10,12	10, 12
Tank volume (liters)	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200	9,200	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200
No. of test groups	5	4	8	4	3	4	4	4
Total fish	381	349	721	398	384	256	399	378
Males/Females per trial	40/36	48/39	55/34	62/38	59/69	38/26	76/24	61/34
Stocking density (fish/liters)	1/99	1/89	1/78	1/71	1/72	1/75-1/221	1/63-1/107	1/71-1/77
Male:Female ratio	1:0.9	1:0.8	1:0.6	1:0.6	1:1.2	1:0.7	1:0.3	1:0.6
Hormone injected	$LHRH_a$	$LHRH_a$	$LHRH_a$	$LHRH_a$	$LHRH_a$	sGnRHa*	None	None
Liquid, Pellet	L+P	L+P	L+P	L+P	P	P	N/A	N/A
Dose(ug) Male/Female	50/50	50/50	50/50	50/50	25/25	75/75	0	0
Eggs collected (liters)	30.2	33.4	73.8	26.8	27.9	31.1	30.25	29.1
Liters of eggs /Female	0.167	0.215	0.271	0.177	0.135	0.296	0.312	0.214
No. eggs/liter	477,607	405,853	388,208	565,893	459,455	315,233	379,510	425,165
Total no. of eggs shipped	14,423,730	13,555,505	28,727,411	15,165,928	11,532,320	9,803,731	11,480,173	12,180,965
Viability (%)	44.1	46.1	61.4	60.6	69.3	73.6	84.9	78.9
Total number of viable eggs	6,360,865	6,245,259	17,645,251	9,194,583	7,994,797	7,216,392	9,742,474	9,604,864
Total liters of viable eggs	13.3	15.4	45.5	16.3	17.4	22.9	25.7	22.9
Adult mortality rate (%)	14.0	3.7	2.2	22.1	3.1	2.3	4.5	14.6

*Only two of the four test groups received hormone injections

Table 3. 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, 2011.

Test Group	Start/Stop Date	Male/Female	Liters Collected	River Release	Release Date	Total Liters Shipped	Date Shipped
1	5-12/5-15	45/30	12.6			12.6	14-May
2	5-13/5-15	30/20	8.5			8.5	15-May
3	5-15/5-17	45/30	9.7			9.7	17-May
4	5-15/5-17	30/20	10.7			10.7	17-May
5	5-17/5-19	45/30	12.5			12.5	19-May
6	5-17/5-19	30/20	9.5			9.5	19-May
7	5-19/5-21	45/30	12.0			12.0	21-May
8	5-19/5-21	30/20	8.8			8.8	21-May
9	5-21/5-24	45/30	7.2			7.2	23-May
10	5-27/5-29	45/30	8.4			8.4	29-May
11	5-28/5-31	30/20	2.6			2.6	30-May
12	5-29/5-31	35/40	3.9			3.9	30-May
12			4.2	4.2	31-May	0	
13	6-3/6-5	29/21	1.6	1.6	5-Jun	0	
14	5-5/6-7	45/30	3.5	3.5	7-Jun	0	
15	6-5/6-7	16/20	1.2	1.2	7-Jun	0	
Totals		**545/391**	**116.9**	**10.5**		**106.4**	

Shipping Date	Liters Shipped	No. eggs	No. Viable	Viabil.(%)
14-May	12.6	821,265	66,545	8.1
15-May	8.5	481,269	94,262	19.6
17-May	20.4	1,273,333	267,067	21.0
19-May	22.0	1,509,191	213,663	14.2
21-May	20.8	1,184,690	268,890	22.7
23-May	7.2	577,542	69,724	12.1
29-May	8.4	974,848	87,788	9.0
30-May	6.5	540,475	88,491	16.4
Totals	**106.4**	**7,362,613**	**1,156,430**	**15.7**

Total Males	**545**
Total Females	**391**
Total Fish	**936**
Mean egg vol.(liters) / test group	**7.8**
Mean No. of Eggs / Liter	**69,179**
Mean No. of Eggs/Female	**20,683**
Mean No. of Viable Eggs/ Female	**3,247**

Table 4. Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-2011.

Year:	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
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
Tank diameter (ft)	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
Number of test groups	10	10	12	10	11	20	14	16*	16*	17*	15
Total fish	599	1,000	1,504	1,055	1,135	1,557	1,504	1010	994	1,075	936
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
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
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
Hormone injected	LHRHa	sGnRHa	LHRHa	LHRHa	LHRHa	LHRHa	LHRHa	sGnRHa	sGnRHa	sGnRHa	sGnRHa
Liquid, Pellet	P	P	L+P	L+P	L+P	L+P	L+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
Eggs collected (liters)	103	146.8	234	90.4	160.5	169.25	89.6	110.5	98.7	122.2	116.9
Liters of eggs /Female	0.429	0.432	0.387	0.244	0.418	0.270	0.148	0.272	0.318	0.279	0.3
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
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
Viability (%)	33.2	10.1	17.7	20	23.9	21.7	8.9	9.8	23.2	18.2	15.7
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
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
Adult mortality rate (%)	6.0	3.6	2.0	11.5	3.3	3.5	8.3	10.3	15.0	10	9.4

*Includes 3-4 control groups

Figure 1. Comparison of total hickory shad egg volume (solid line) and viable egg volume (broken line) per female for the spawning tests conducted at Conowingo Dam, 2003-2011. Hickory shad tests were not conducted in 2010.

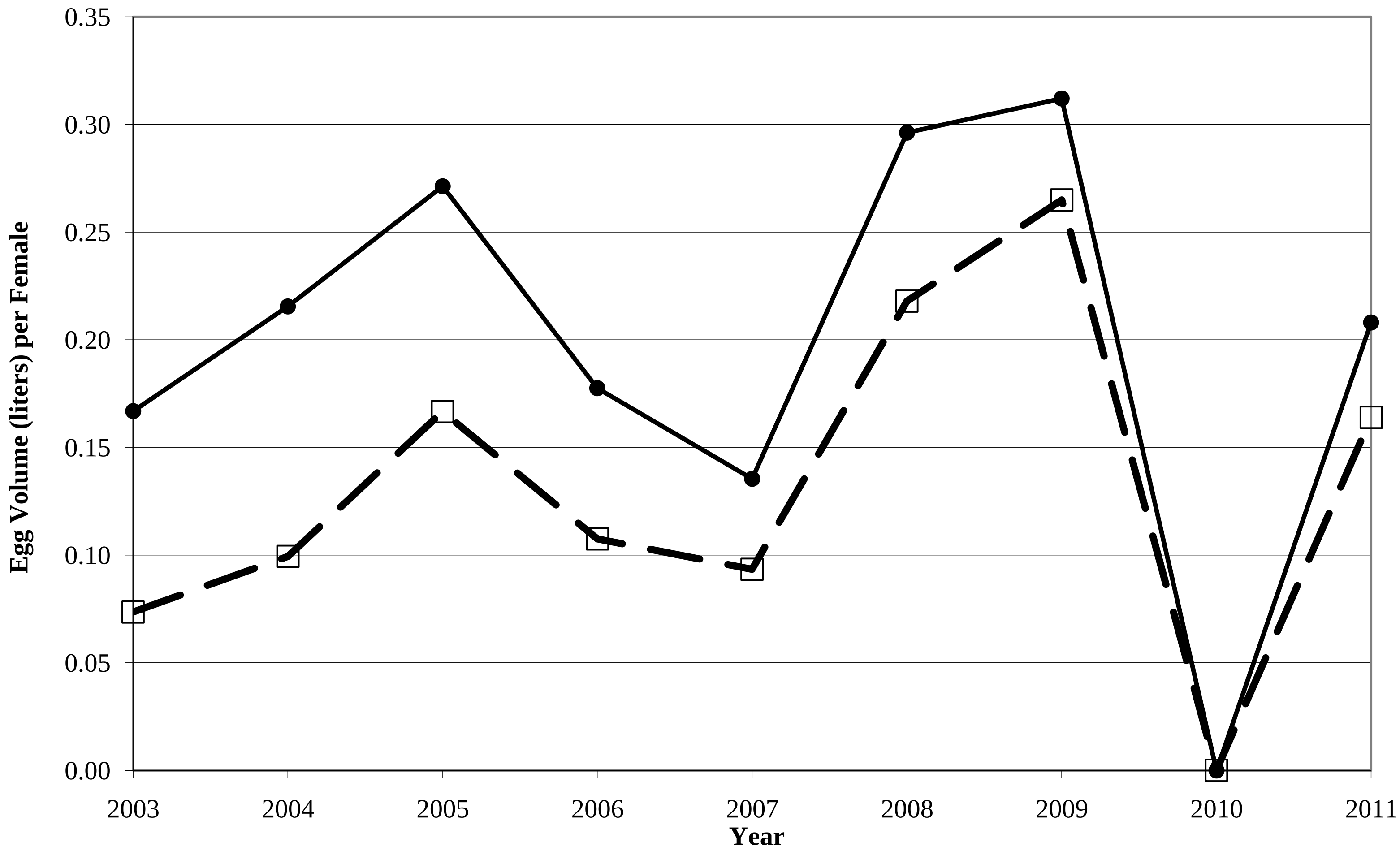
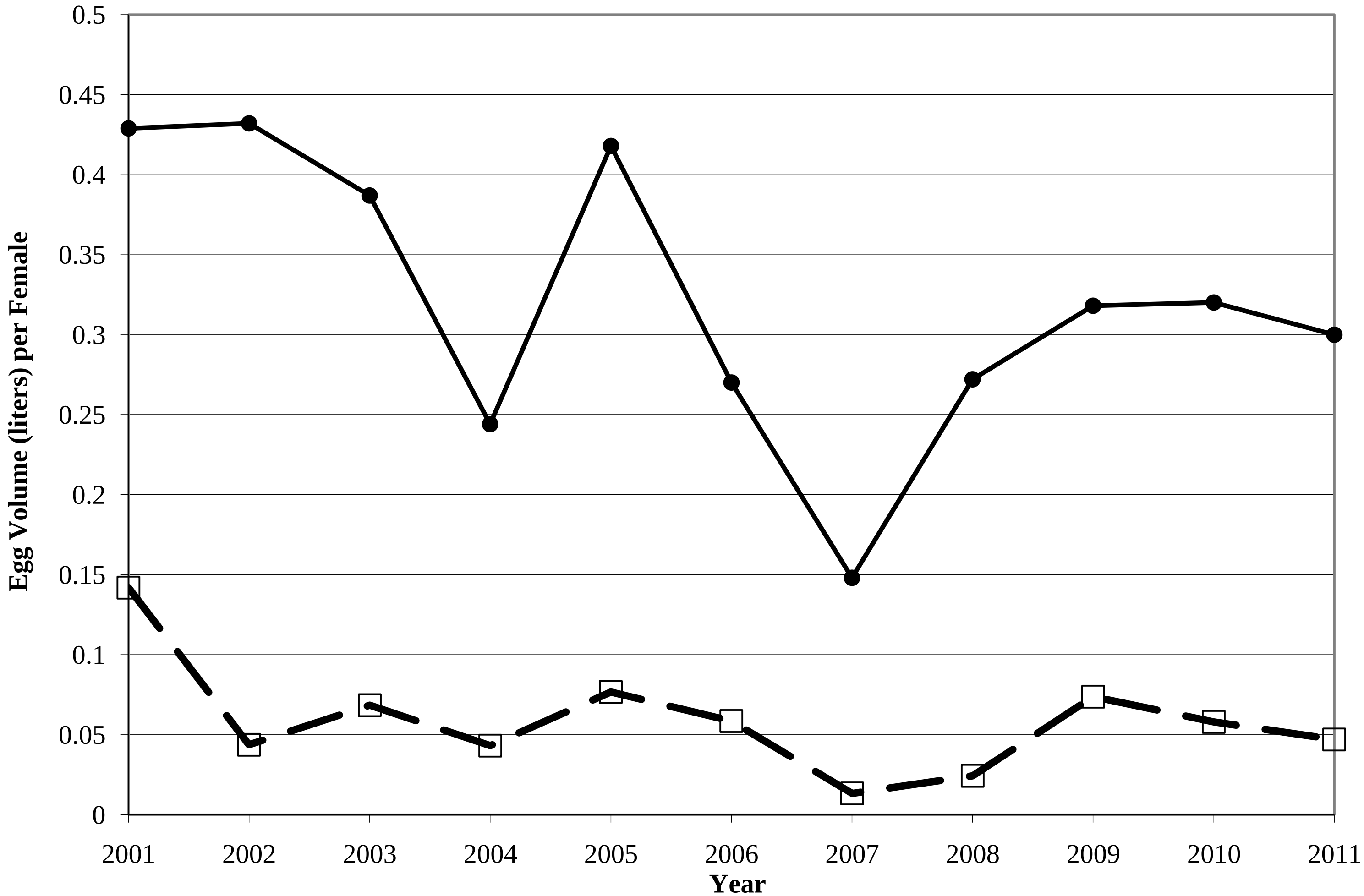


Figure 2. Comparison of total American shad egg volume (solid line) and viable egg volume (broken line) per female for the spawning tests conducted at Conowingo Dam, 2001-2011.



Appendix Table A-1. Individual test group data for hickory shad spawning tests conducted at Conowingo Dam West Fish Lift, 2011.

			Test Group 1				
M/F Ratio	77/6				10 ft tank		
Start Date	4/14/11	1600					
End Date	4/21/11	0730					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/14/11	1600	13.5	10				
4/15/11	0950	11.9	10.5				
4/15/11	1625	12.7	10.8				
4/16/11	1215	12.2	10.6				7m
4//17/11	1010	12.6	10.6	0.4 kept in sock			1m
4/18/11	1215	11.9	11.1			0.4	1m
4/19/11	1145	10.9	11.8				1f
4/20/11	1420	10.1	12.0				3m
4/21/2011	0725	9.9	12.8				5m, 1f

			Test Group 2				
M/F Ratio	52/38				10 ft tank		
Start Date	4/25/11	1500					
End Date	4/29/11	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/11	1500	14.0	9.5				
4/26/11	0720	13.0	10.3	7.9	7.9		3m
4/27/11	0720	14	10				
4/27/11	1200			7.9	7.9		
4/28/11	0743	16.0	10.2				
4/29/11	0757	16.1	10.5				2m, 3f

Appendix, Table A-1 (continued)

		Test Group 3					
M/F Ratio	68/52				12 ft tank		
Start Date	4/27/11	1400					
End Date	4/29/11	1030					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
4/27/11	1400	14.6	10.2				
4/28/11	0740	16	9.8				
4/29/11	0755	16.1	10.6				
4/29/11	1030			2.8	2.8		12m, 15f

		Test Group 4					
M/F Ratio	45/40				10 ft tank		
Start Date	5/5/11	1430					
End Date	5/12/11	1550					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/5/11	1435	16	10.4				
5/6/11	0740	14.8	10.4				
5/7/11	0735	14.6	10.4				
5/7/11	0930			5.3	5.3		
5/8/11	0736	14.5	10.7				
5/8/11	0830			4.75	4.75		
5/9/11	0730	15.0	10.4				
5/10/11	0730	15.8	10.2				
5/11/10	0730	16.7	10.1				
5/12/11	0815	17.3	10.1				1m

Appendix Table A-2. Individual test group data for hormone induced American shad spawning tests conducted at Conowingo Dam West Fish Lift, Spring 2011.

			Test Group 1				
M/F	45/30	12 ft tank					
Start Date	5/12/11	1300		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/15/11	0945					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/12/11	1500	18.6	9				
5/13/11	0845	18	8.2				
5/14/11	0900	18.3	7.6	12.6	12.6		
5/15/11	0900	18.3	7.6				4m,5f

			Test Group 2				
M/F	30/20	10 ft tank					
Start Date	5/13/11	1500		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/15/11	1000					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/13/11	1525	18.2	9.2				
5/14/2011	902	18.3	8.3				
5/15/11	0902	18.3	8.3	8.5	8.5		2f

			Test Group 3				
M/F	45/30	12 ft tank					
Start Date	5/15/11	1130		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/17/11	0940					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/15/11	1140	19.5	7.1				
5/15/11	1652	20	6.8				
5/16/11	0032	19.5	7.3				
5/17/11	0940	19.7	8	9.7	9.7		1m, 6f

			Test Group 4				
M/F	30/20	10ft tank					
Start Date	5/15/11	1550		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/17/11	1015					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/15/11	1650	20.1	7.9				
5/16/11	0835	19.5	8.6				
5/17/11	0910	19.7	9.1				
5/17/11	1015			10.7	10.7		1m

Appendix Table A-2. (continued)

			Test Group 5				
M/F	45/30	12 ft tank					
Start Date	5/17/11	1130		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/19/11	0940					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/17/11	1405	20	8.0				
5/18/11	0842	19.2	7.2				
5/19/11	0900	19.7	7.4	12.5	12.5		1m, 2f
			Test Group 6				
M/F	30/20	10 ft tank					
Start Date	5/17/11	1150		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/19/11						
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/17/11	1406	20	8.7				
5/18/11	0845	19.3	8.4				
5/19/11	0902	19.7	8.4				
5/18/11	1000			9.5	9.5		1m, 6f
			Test Group 7				
M/F	45/30	12 ft tank					
Start Date	5/19/11	1115		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/21/11	930					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/19/11	1350	20.7	6.8				
5/20/11	0724	18.6	7.4				
5/20/11	1844	18.8	7.5				
5/21/11	0830	17.9	8.4				
5/21/11	0930			12.0	12.0		4f
			Test Group 8				
M/F	30/20	10 ft tank					
Start Date	5/19/11	1145		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/21/11	1000					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/19/11	1352	20.5	7.8				
5/20/11	0726	18.6	8.2				
5/20/11	1846	18.7	8.4				
5/21/11	0831	17.9	9.2				
5/21/11	1000			8.8	8.8		3f

Appendix Table A-2. (continued)

			Test Group 9				
M/F	45/30	12 ft tank					
Start Date	5/21/11	1115		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/24/11	900					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/21/11	1304	18.8	7.7				
5/22/11	1300	18	8.0				
5/23/11	0756	17.6	8.2				
5/23/11	0900			7.2	7.2		
5/24/11	0730	18	8.0	1.2		1.2	2m, 2f

			Test Group 10				
M/F	45/30	12ft tank					
Start Date	5/27/11	1500		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/29/11	1000					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/27/11	1810	21.7	6.8				
5/28/11	0735	21.9	6.7				
5/28/11	1648	23	5.8				
5/29/11	0742	22.9	6.2				
5/29/11	0930			8.4	8.4		2m, 7f

			Test Group 11				
M/F	30/20	10 ft tank					
Start Date	5/28/11	1415		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/31/11	900					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/28/11	1650	22.8	7.6				
5/29/11	0745	22.9	7.5				
5/29/11	1235	23.5	7.4				
5/30/11	0735	22.8	7.0	2.6	2.6		
5/31/11	0728	23.2	7.4				2m, 5f

			Test Group 12				
M/F	35/40	12 ft tank					
Start Date	5/29/11	1200		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	5/31/11	1000					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/29/11	1233	24	6.0				
5/30/11	0735	22.8	5	3.9	3.9		
5/31/11	0726	23.2	6.2	4.2		4.2	2m, 7f

Appendix Table A-2. (continued)

			Test Group 13				
M/F	29/21	10 ft tank					
Start Date	6/3/11	1130		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	6/5/11	1130					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
6/3/11	1644	24.7	6.1				
6/4/11	0745	23.1	7.1				
6/4/11	1640	24.3	8.4				1f
6/5/11	0730	23.5	7.8	1.6		1.6	7f

			Test Group 14				
M/F	45/30	12ft tank					
Start Date	6/5/11	1100		Dose/fish 75 ug sGnRHa (pellet implant)			
End Date	6/7/11	930					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
6/5/11	1336	24.2	6.3				
6/6/11	0733	23.4	5.0				
6/7/11	0630	23.7	6				
6/7/11	0924	24.1	5.6	3.5		3.5	7m, 5f

			Test Group 15				
M/F	30/20	10 ft tank					
Start Date	6/5/11	1230		Dose/fish 75 ug sGnRHa (pellet implant)*			
End Date	6/7/11	1030					
		Temp.	Oxygen	Eggs (Liters)	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
6/5/11	1338	24.1	7.6				
6/6/11	0735	23.7	7.2				
6/7/11	0632	23.8	7.2				
6/7/11	0925	24.1	7	1.2		1.2	1m, 2f

* 14 of 30 males received no hormone injection.

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2011

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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 due to budget constraints, however it resumed in 2011.

As in previous years, production goals for American shad for 2011 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 23.5 million American shad eggs (415.6 L) was received in 31 shipments in 2011 (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 22.6%, yielding 5.3 million viable eggs. Experimental shipment coolers were used in 2011 for the transport of fertilized American shad eggs from the Delaware and Potomac rivers (results summarized in Appendix 1). Ten Potomac River egg shipments (6.2 million eggs) were received from April 14 to May 8, 2011, with an overall viability of 43.7% (Table 1). There were 11.6 million fewer Potomac River eggs available for culture work in 2011 than in 2010 (Table 3).

Delaware River egg shipments were received from May 15 to June 2. A total of thirteen shipments, consisting of 9.9 million eggs were processed at Van Dyke. This was the largest egg take since 1998 (Table 3, Figure 1); however, overall egg viability of 14.7% was the lowest on record for the Delaware River (Figure 2).

American shad and hickory shad eggs were also obtained from tank-spawning efforts at Conowingo Dam, operated by Normandeau Associates. Pre-spawn adult hickory shad were obtained from shore anglers at the mouth of Deer Creek and electrofishing operations conducted by Maryland Department of Natural Resources (MDNR) biologists at Lapidum, MD. All captured hickory shad broodstock were taken to the tank-spawning facility by Pennsylvania Fish & Boat Commission transport truck. American shad broodstock were obtained from the West Fish Lift at Conowingo Dam.

All American shad were injected with hormones and allowed to spawn naturally, whereas hickory shad received no injections. The tank-spawn array at Conowingo uses water pumped directly from the river and is subject to natural fluctuations in water temperature. Ability to control temperature in the tank (gradual warming to optimal temperature) is thought to be critical for successful tank-spawning without hormones (Jeff Evans, NC Wildlife Resource Commission, personal communication).

Spawning trials of American shad in 2011 produced 7.3 million eggs, in eight shipments delivered to the Van Dyke Hatchery. Overall viability of those eggs averaged 15.7% (or some 1.1 million 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%.

Tank-spawning of hickory shad (non-hormone spawning) produced 12.1 million eggs over five shipments in 2011. Average egg viability was 78.9%, the second highest recorded in eight years of spawning trials, and falls within the upper range of viabilities (range 44.1% to 84.9%).

No eggs were collected from the Hudson River in 2011 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 3a). Larval American shad in culture tanks B1 and B4 were split into two additional tanks (D2 and D3, respectively) due to higher than estimated densities and concerns over increased mortality (resulting from intra-specific competition) (Figure 3b). Approximately half of the larvae in tank B1 were moved to D2 at 19d (via water brailing). Mortality substantially increased in D2 following the move with a final (40d) survival of 37%. Survival in B1 was relatively stable throughout culturing (40d survival of 79%). Culture tank B4 was also split, with about half of its larvae going into D3 at 3d. Both tanks experienced similar mortality rates through stocking (26d survival of 86% and 84%, respectively). The cause of the higher than normal mortality in D2 likely resulted from handling stress induced during the tank-to-tank transfer. Culture tank H1 also experienced higher than normal mortality (22d survival of 57%) for unknown reasons (Figure 3a). The mortality experienced in 2011 was below average based on the overall survival of 78% compared to an average of 63%

(range of 19% to 94%) since hatchery operations began in 1976 (Table 2). Additionally, no tanks suffered complete mortality in 2011.

The fluidized bed system installed in 2008 worked extremely well and pH of the fish culture water ranged from 7.0 to 7.6 with a mean of 7.3. 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 101.4% with a maximum of 106.5%. The high value occurred a few days after the initial egg shipment was received and was quickly corrected before any hatching occurred. Nitrogen saturation averaged 100.6% with a maximum of 104.9%. Total gas saturation averaged 100.2% with a maximum of 103.7%. As a result, no incidents of gas bubble disease occurred. Larvae stocked in 2011 appeared active and robust.

LARVAL PRODUCTION

Production and stocking of American shad larvae, summarized in Tables 2, 3, and 4, totaled 4.1 million. A total of 1.3 million were released in the Juniata River, 83 thousand in the North Branch Susquehanna River in Pennsylvania, 1.4 million in the West Branch Susquehanna River and 191 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 2011 yielded the 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 (473 thousand), the Schuylkill River (643 thousand). No larvae were stocked in the Delaware River. More than 80 percent of the 2011 spawning run being composed of the 2005 year class (which was also the dominant year class of the 2010 run).

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 512-

ppm. 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 1.4 million larvae received marks on days 3 and18 and were stocked in the West Branch Susquehanna River. This was a unique mark used in 2011 as a result of protracted high flows in the Juniata River (original destination for fry with day 3 OTC mark) and flows conducive for stocking in the West Branch Susquehanna River (fry OTC marked on day 18 prior to stocking). Bald Eagle Creek, a tributary to the West Branch, received some 191 thousand larvae marked on days 3, 6, 9, 12, and 15. One million larvae were marked on days 3, 6 and 9 (Susquehanna River egg source) and an additional 296 thousand larvae marked on day 3, all being stocked in the Juniata River. The North Branch Susquehanna River in Pennsylvania received some 83 thousand larvae, marked on days 3, 6, 9, and 15. The Lehigh River received 473 thousand larvae marked on days 9, 12, and 15. The Schuylkill River received 643 thousand larvae marked on days 3, 6, 9, and 12.

Octoraro Creek, a tributary to the lower Susquehanna River, received 500 thousand hickory shad larvae that were marked on day 3. Pennypack Creek (a tributary to the Delaware River) received 1.9 million hickory shad larvae marked on day 3. Ridley Creek, another tributary to the Delaware River, was stocked with 1.2 million hickory shad larvae marked on day 3, days 3 and 9, and days 3 and 15.

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 2011, yielding specimens for verification of each mark produced. All fingerling American and hickory 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 2011 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 and 3,6,9), North Branch Susquehanna (3,6,9,15) and the Lehigh River (9,12,15). The Schuylkill River group (3,6,9,12) exhibited mark retention of 97 percent. American shad larvae grown out to fingerlings were fed OTC laced feed prior to stocking and those examined exhibited 100 percent retention of the feed mark. The single group of hickory shad examined exhibited 96 percent retention of the day 3 immersion mark (stocked in Octoraro and Pennypack creeks). Some hickory shad fry were kept in the hatchery for feed trials. These hickory shad were given an additional immersion mark (3, 9 or 3,15), but none were retained for mark retention.

SUMMARY

A total of 31 shipments of American shad eggs (23.5 million eggs) were received at Van Dyke in 2011. Total egg viability was 22.6% and survival of viable eggs to stocking was 78%, resulting in production of 4.1 million larvae. Larvae were stocked in the Juniata River (1.3 million), the West Branch Susquehanna River (1.4 million), Bald Eagle Creek (191 thousand), and the North Branch Susquehanna River in Pennsylvania (83 thousand). Delaware River source American shad larvae were stocked in the Lehigh (473 thousand) and the Schuylkill (643 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.

A total of 5 shipments of hickory shad eggs (12.1 million eggs) were received and processed at Van Dyke in 2011. Overall egg viability was 78.9% resulting in the production of some 3.6 million larvae. Hickory shad larvae were stocked in Octoraro Creek (500 thousand), a tributary to the Susquehanna River, while Pennypack and Ridley creeks (tributaries to the Delaware River) received 1.9 and 1.2 million hickory shad larvae, respectively.

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 and hickory 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**.**

RECOMMENDATIONS FOR 2012

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 512ppm 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 in 2009 and 2010 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. Obtain permission to use the UV microscope at the Northeast Fishery Center in Lamar to view critical otolith specimens.

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FIGURES AND TABLES

Figure 1. American shad eggs incubated at Van Dyke, 1983-2011.

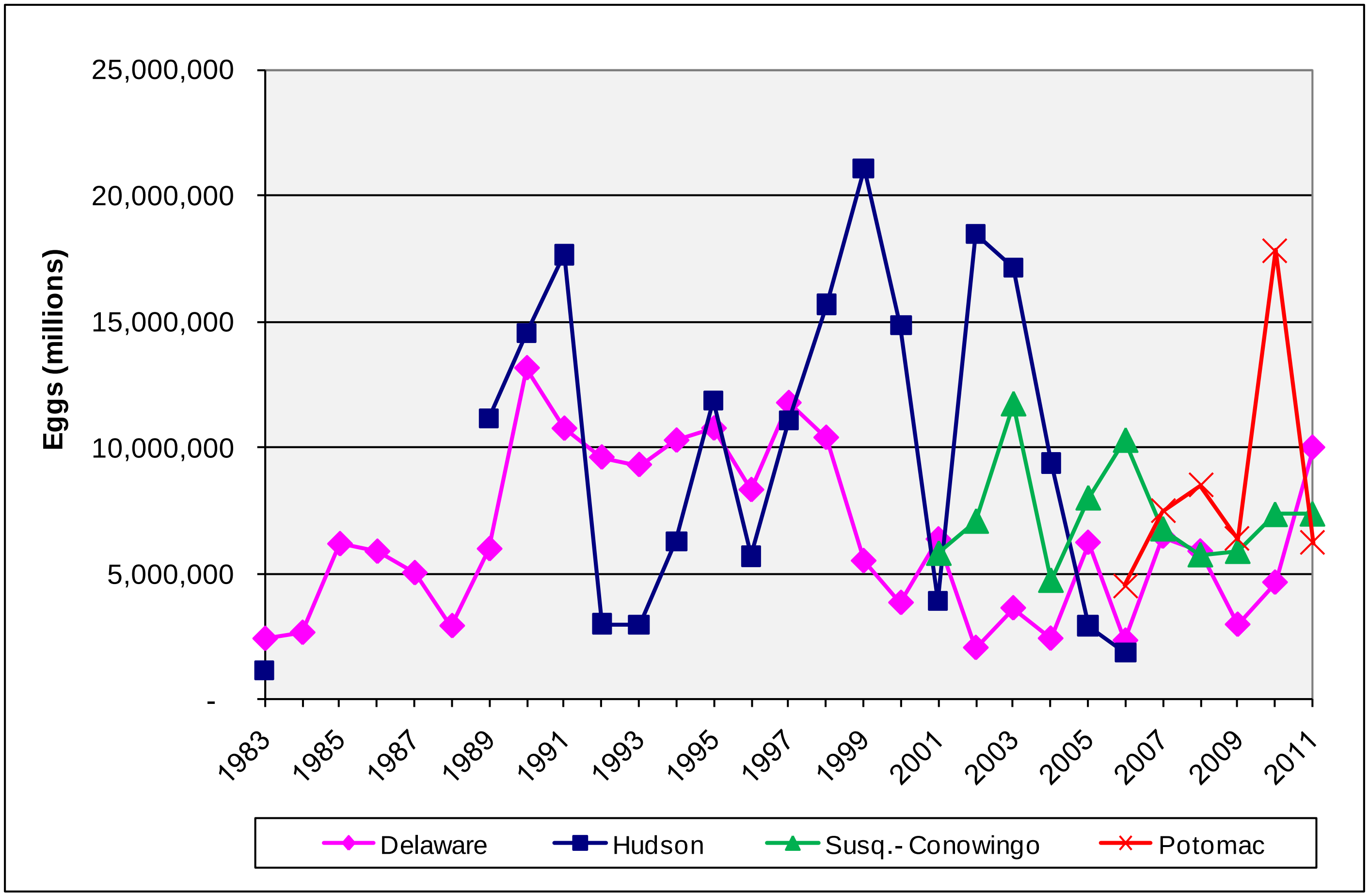

Figure 2. Egg viability (percentage of collected eggs that ultimately hatch) for American shad strip spawning operations on the Delaware, Potomac and Hudson rivers.

Figure 3a. Survival of American shad larvae, by tank, Van Dyke, 2011 (tanks B1, B4, D2, D3 excluded – see Figure 3b).

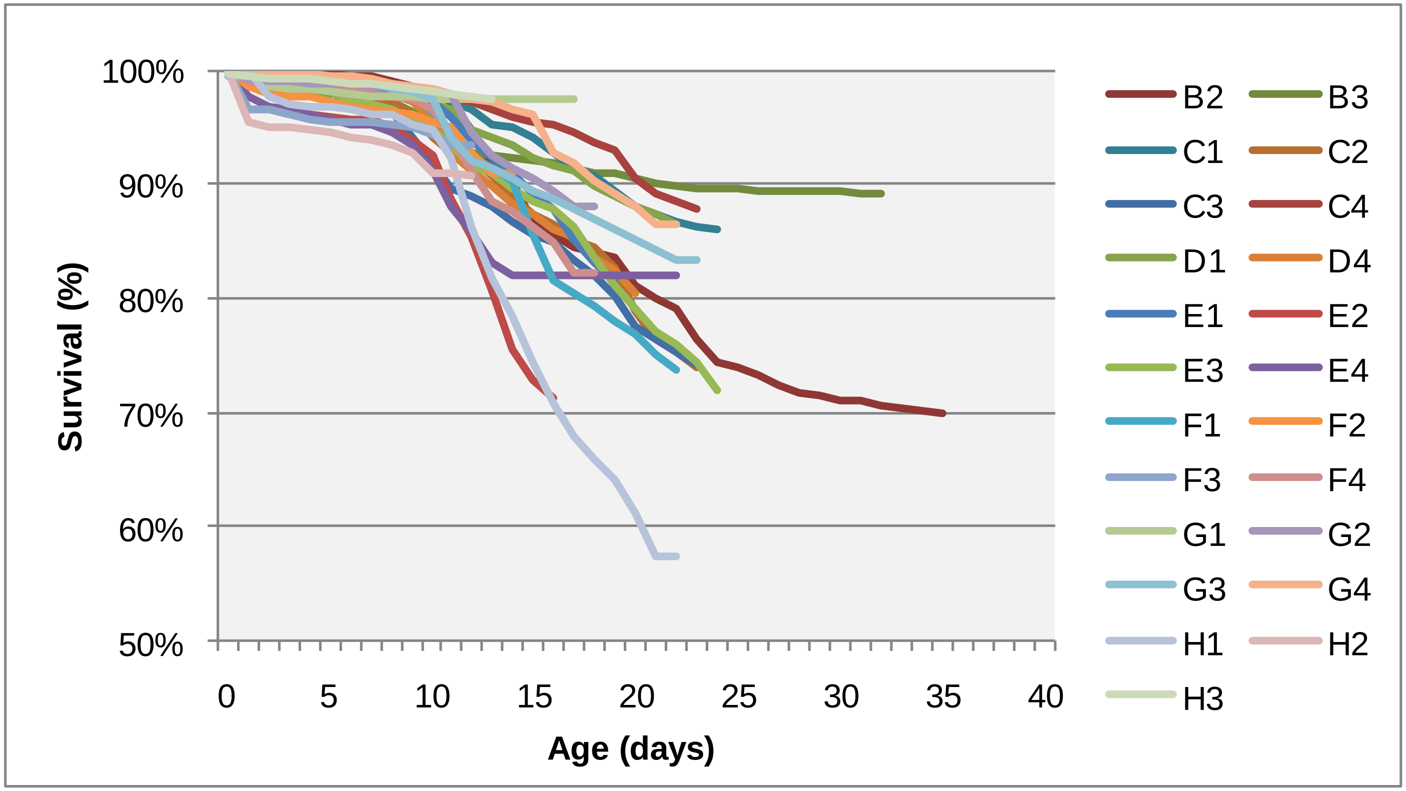

Figure 3b. Survival of American shad larvae in tanks B1, B4, D2 and D3 at Van Dyke, 2011 (B1 was split into D2 @ 19 days of age and B4 was split into D3 @ 4 days of age).

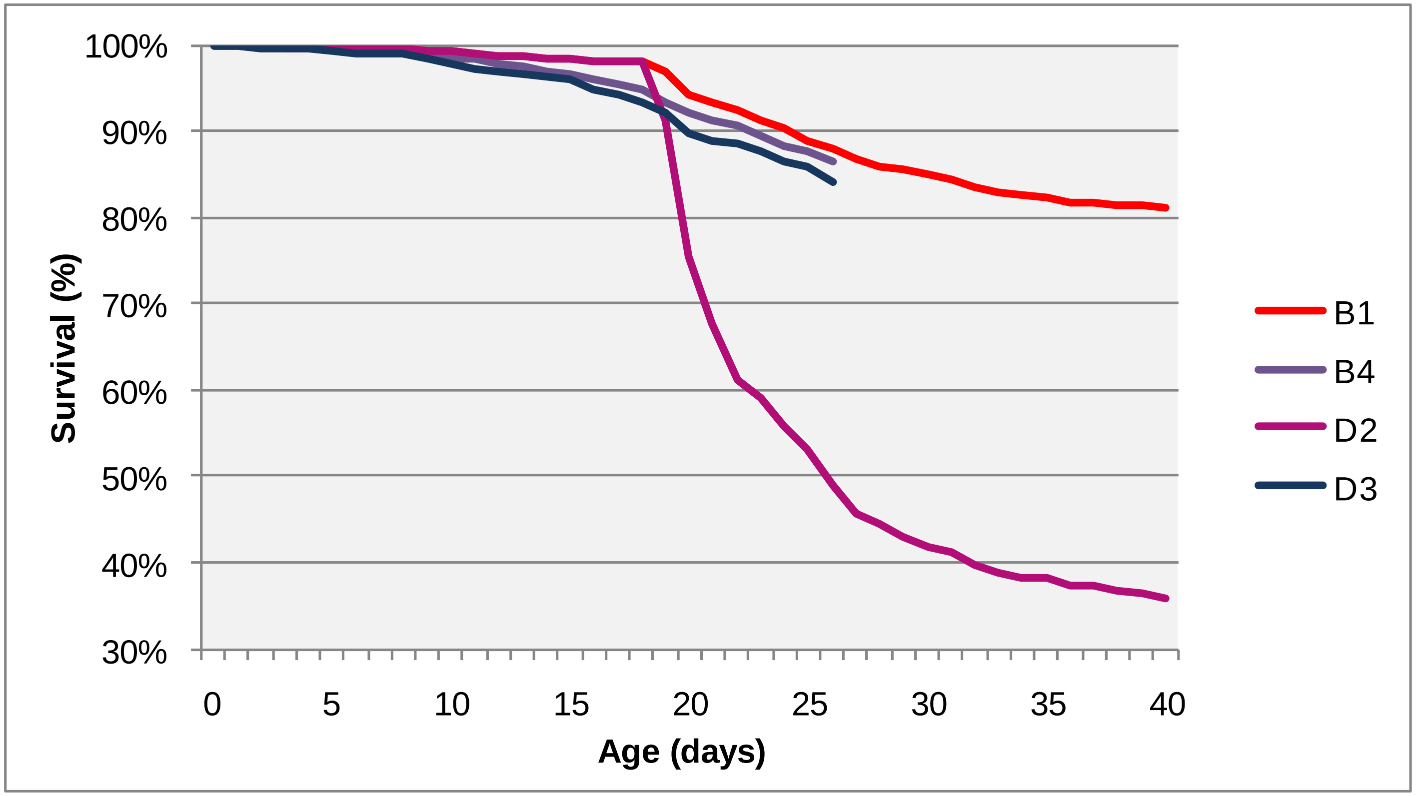

Table 1. Egg shipments received at Van Dyke, 2011.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American shad	Potomac	4/14/11	4/15/11	19.8	912,775	310,882	34.1%
2	American shad	Potomac	4/25/11	4/26/11	7.1	279,487	94,607	33.9%
3	Hickory shad	Susquehanna	4/26/11	4/26/11	7.9	2,318,069	1,921,383	82.9%
4	American shad	Potomac	4/26/11	4/27/11	5.0	190,917	10,710	5.6%
5	Hickory shad	Susquehanna	4/27/11	4/27/11	7.9	2,911,705	2,321,278	79.7%
6	American Shad	Potomac	4/28/11	4/29/11	10.3	588,455	82,943	14.1%
7	Hickory Shad	Susquehanna	4/28/11	4/29/11	2.8	1,483,827	926,948	62.5%
8	American Shad	Potomac	4/29/11	4/30/11	21.3	987,072	425,302	43.1%
9	American Shad	Potomac	5/1/11	5/2/11	14.8	784,317	473,467	60.4%
10	American shad	Potomac	5/4/11	5/5/11	20.2	861,733	545,721	63.3%
11	American shad	Potomac	5/5/11	5/6/11	17.0	655,675	402,075	61.3%
12	Hickory shad	Susquehanna	5/6/11	5/7/11	5.3	2,357,688	1,720,283	73.0%
13	Hickory Shad	Susquehanna	5/7/11	5/8/11	4.8	3,109,676	2,714,972	87.3%
14	American shad	Potomac	5/8/11	5/9/11	13.4	599,788	207,133	34.5%
15	American shad	Potomac	5/8/11	5/9/11	8.5	356,267	161,594	45.4%
16	American Shad	Susquehanna	5/13/11	5/14/11	12.6	821,265	66,545	8.1%
17	American Shad	Susquehanna	5/14/11	5/15/11	8.5	481,269	94,262	19.6%
18	American Shad	Delaware	5/15/11	5/16/11	5.4	206,148	11,296	5.5%
19	American shad	Susquehanna	5/16/11	5/17/11	20.4	1,273,333	267,067	21.0%
20	American shad	Delaware	5/16/11	5/17/11	8.2	313,374	173,724	55.4%
21	American shad	Delaware	5/17/11	5/18/11	6.0	174,134	101,987	58.6%
22	American Shad	Delaware	5/18/11	5/19/11	5.1	177,242	39,839	22.5%
23	American Shad	Susquehanna	5/19/11	5/19/11	22.0	1,509,191	213,663	14.2%
24	American Shad	Susquehanna	5/21/11	5/21/11	20.8	1,184,690	268,890	22.7%
25	American Shad	Delaware	5/22/11	5/23/11	5.2	197,319	30,010	15.2%
26	American Shad	Susquehanna	5/22/11	5/23/11	7.2	577,542	69,724	12.1%
27	American shad	Delaware	5/23/11	5/24/11	11.4	350,084	68,587	19.6%
28	American shad	Delaware	5/24/11	5/25/11	27.8	1,028,904	584,915	56.8%
29	American shad	Delaware	5/25/11	5/26/11	30.8	1,686,809	215,976	12.8%
30	American Shad	Delaware	5/26/11	5/27/11	17.9	1,442,344	56,338	3.9%
31	American shad	Susquehanna	5/29/11	5/29/11	8.4	974,848	87,788	9.0%
32	American Shad	Susquehanna	5/29/11	5/30/11	6.5	540,475	88,491	16.4%
33	American shad	Delaware	5/30/11	5/31/11	13.1	1,272,730	0	0.0%
34	American shad	Delaware	5/31/11	6/1/11	16.1	1,640,515	43,179	2.6%
35	American shad	Delaware	6/1/11	6/2/11	9.7	670,769	120,650	18.0%
36	American Shad	Delaware	6/2/11	6/3/11	15.2	830,471	20,514	2.5%
Totals			No. of shipments					
	American shad	Potomac	10		137.4	6,216,484	2,714,435	43.7%
		Delaware	13		171.9	9,990,842	1,467,015	14.7%
		Susq.- Conowingo	8		106.4	7,362,615	1,156,431	15.7%
		Grand total	31		415.6	23,569,941	5,337,880	22.6%
	Hickory shad	Susq.- Conowingo	5		28.6	12,180,966	9,604,864	78.9%

Table 2. Annual summary of American shad production, 1976-2011.

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
						Total	**264,619**		
						Total since 1985 (OTC marked)	**233,222**		

*Includes fry reared at Manning Hatchery.

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
Total	190.81	191.50	80.75	21.57	0.02	15.74	23.53	85.08	13.88	64.84	0.12	291.62	96.84	1,076.30

Table 4. American shad stocking, 2011.

Date	Tank	Number	Species	Location	Origin	OTC Mark (days)	Age (days)	Size
5/6/11	A1	1,914,188	Hickory shad	Pennypack Creek	Susquehanna	3	4	Fry
5/6/11	A2	1,000,000	Hickory shad	Ridley Creek	Susquehanna	3	4	Fry
5/25/11	A3	1,000	Hickory shad	Ridley Creek	Susquehanna	3,15	21	Fry
5/25/11	A4	199,000	Hickory shad	Ridley Creek	Susquehanna	3,9	14	Fry
5/27/11	A12	500,000	Hickory shad	Octoraro Creek	Susquehanna	3,9	15	Fry
6/1/11	B1	126,956	American shad	Bald Eagle Creek	Potomac	3,6,9,12,15	40	Fry
6/8/11	B2	73,693	American shad	N Br Susquehanna (PA)	Potomac	3,6,9,15	35	Fry
6/8/11	B3	10,000	American shad	N Br Susquehanna (PA)	Potomac	3,6,9,15	32	Fry
6/2/11	B4	150,000	American shad	West Br. Susquehanna R.	Potomac	3,18	26	Fry
6/2/11	C1	300,000	American shad	West Br. Susquehanna R.	Potomac	3,18	24	Fry
6/3/11	C2	251,351	American shad	West Br. Susquehanna R.	Potomac	3,18	23	Fry
6/3/11	C3	236,311	American shad	West Br. Susquehanna R.	Potomac	3,18	23	Fry
6/3/11	C4	253,742	American shad	West Br. Susquehanna R.	Potomac	3,18	22	Fry
6/3/11	D1	131,778	American shad	West Br. Susquehanna R.	Potomac	3,18	22	Fry
6/1/11	D2	64,633	American shad	Bald Eagle Creek	Potomac	3,6,9,12,15	40	Fry
6/2/11	D3	150,000	American shad	West Br. Susquehanna R.	Potomac	3,18	26	Fry
6/6/11	D4	166,681	American shad	Thompsontown	Potomac	3	20	Fry
6/6/11	E1	129,685	American shad	Thompsontown	Potomac	3	19	Fry
6/7/11	E2	114,554	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	17	Fry
6/17/11	E3	136,902	American shad	Lehigh	Delaware	9,12,15	24	Fry
6/7/11	E4	218,961	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	15	Fry
6/17/11	F1	103,901	American shad	Lehigh	Delaware	9,12,15	22	Fry
6/7/11	F2	194,475	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	12	Fry
6/7/11	F3	251,060	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	11	Fry
6/17/11	F4	82,562	American shad	Lehigh	Delaware	9,12,15	17	Fry
6/10/11	G1	68,597	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	10	Fry
6/17/11	G2	150,000	American shad	Lehigh	Delaware	9,12,15	16	Fry
6/23/11	G3	270,391	American shad	Schuylkill	Delaware	3,6,9,12	22	Fry
6/23/11	G4	147,971	American shad	Schuylkill	Delaware	3,6,9,12	21	Fry
6/23/11	H1	125,000	American shad	Schuylkill	Delaware	3,6,9,12	21	Fry
6/15/11	H2	160,392	American shad	Millerstown (Rt. 17)	Susquehanna	3,6,9	10	Fry
6/23/11	H3	100,000	American shad	Schuylkill	Delaware	3,6,10,12	13	Fry
9/27/11	BS-ICU	9,083	American shad	Lewistown Narrows	various	116*	131*	Fing.

* Mean age at marking and stocking

Table 5. Summary of juvenile Alosines stocked from the Van Dyke Hatchery, 2011.

	Site	Fry	Fingerling
American shad releases	Millerstown (Rt. 17 Bridge)	1,008,039	
	Thompsontown	296,366	
	Lewistown Narrows		9,083
	Juniata River Subtotal	1,304,405	9,083
	North Branch Susquehanna River (PA)	83,693	
	West Banch Susquehanna River	1,473,182	
	Bald Eagle Creek	191,590	
	Susquehanna River Basin Subtotal	3,052,870	9,083
	Schuylkill River	643,361	
	Lehigh River	473,366	
	Total American shad	**4,169,597**	**9,083**
Hickory shad releases	Octoraro Creek	500,000	
	Susquehanna River Basin Subtotal	500,000	
	Pennypack Creek	1,914,188	
	Ridley Creek	1,200,000	
	Delaware River Basin Subtotal	3,114,188	
	Total Hickory shad	**3,614,188**	

Table 6. Summary of marked Alosines stocked in Pennsylvania, 2011.

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										
1,473,182	Fry	3,18	W. Br. Susq. R.	Potomac	512ppm OTC	100%	-	-	Van Dyke	-
191,590	Fry	3,6,9,12,15	Bald Eagle Creek	Potomac	512ppm OTC	100%	-	-	Van Dyke	
1,008,039	Fry	3,6,9	Juniata R.	Susquehanna	512ppm OTC	100%	-	-	Van Dyke	-
296,366	Fry	3	Juniata R.	Potomac	512ppm OTC	100%	-	-	Van Dyke	-
83,693	Fry	3,6,9,15	N. Br. Susq. R.(PA)	Potomac	512ppm OTC	100%	-	-	Van Dyke	-
3,052,870	Fry	Total Susquehanna River Basin								
473,366	Fry	9,12,15	Lehigh R.	Delaware	512ppm OTC	100%	-	-	Van Dyke	-
643,361	Fry	3,6,9,12	Schuylkill R.	Delaware	512ppm OTC	97%	-	-	Van Dyke	-
1,116,727	Fry	Total Delaware River Basin								
9,083	Fing.	various	Juniata R.	various	512ppm OTC	96%*	single	100%	Van Dyke	Benner Spring
4,178,680		**Total American shad stocked**								
Hickory shad										
500,000	Fry	3	Octoraro Creek	Susquehanna	512ppm OTC	96%	-	-	Van Dyke	-
1,914,188	Fry	3	Pennypack Creek	Susquehanna	512ppm OTC		-	-	Van Dyke	-
1,200,000	Fry	(3), (3,9) & (3,15)	Ridley Creek	Susquehanna	512ppm OTC	**	-	-	Van Dyke	-
3,614,188		**Total Hickory shad stocked**								

* Fingerlings with feed tags had various immersion (fry) tags; 26 of 27 exhibited marks.

** Some hickory shad fry were kept in the hatchery to attempt to feed them. These were given an additional mark. None were retained for mark retention.

JOB IV. ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER, 2011

Michael L, Hendricks

Pennsylvania Fish and Boat Commission

Benner Spring Fish Research Station

INTRODUCTION

This report summarizes the results of bio-monitoring activities for juvenile alosines conducted in the Susquehanna River and its tributaries in 2011.

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 3,074 adult shad were collected at the Conowingo West Lift. The majority were released back into the Conowingo tailrace, with 936 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 2011 spring migration, Conowingo East Lift passed 20,571 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 21, 8, and 0 American shad, respectively. Some 17 blueback herring and 2 alewife were passed at Conowingo Dam. No river herring were passed at Holtwood or York Haven Dams. The five alewife passed at Safe Harbor Dam were likely fish from landlocked populations in freshwater lakes such as Raystown Dam. Some 20 hickory shad were passed at Conowingo, but none passed any of the other 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 2011 production season, the PFBC Van Dyke Research Station for Anadromous Fish produced 3.1 million shad larvae which were released in the Susquehanna Basin in Pennsylvania. Larval releases occurred from 1 June to 15 June during a period of steadily decreasing flows. Larvae were released in the following locations and numbers:

Juniata River	1,304,405
North Branch Susquehanna River (PA)	83,693
West Branch Susquehanna River	1,473,182
Bald Eagle Creek	191,590

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. Extremely high flows were experienced in the river due to storms and hurricanes and many sampling dates were cancelled. As a result, only fifteen sampling events were conducted in 2011. Sampling was concentrated near the Columbia Borough boat launch (8 events) and City Island in Harrisburg (7 events). 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 2011. Intake screen sampling was conducted from 2 November to 2 December, 2011. 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.

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

Five juvenile American shad were captured by haul seine; three at the Columbia boat launch (Figure 1, Table 1) and two at City Island (Figure 2, Table 4). The Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) for the Columbia site was 0.03 (Tables 2 and 5). Table 3 lists weekly catches of American shad by haul seine at Columbia from 1989 to 2011. 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 -2011 when there was no peak. The Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) for the City Island site was 0.03 (Tables 4 and 5). Table 6 lists weekly catches of American shad by haul seine at City Island in 2010 and 2011.

Lift Netting at Holtwood

Lift netting did not occur in 2011 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 no juvenile American shad and 25 alewife between 2 November and 2 December (Tables 9 and 10).

Cooling water intake strainers at Conowingo produced one American shad collected on October 21 (Tables 11 and 12). One alewife and one unidentified *Alosa sp*. were collected in strainer samples in 2011.

Electrofishing

Electrofishing collections were made at numerous sites by Normandeau Associates as part of FERC re-licensing studies. One juvenile shad was collected by electrofishing gear in Conowingo Pond on 23 September and one in Lake Aldred on 28 September.

Susquehanna River Mouth and Flats

In 2011, 118 juvenile American shad were captured at seven permanent sites and 57 at seven auxiliary sites (Table 13).

Otolith Mark Analysis

Results of otolith analysis are presented in Table 14. (see Job III, Appendix 1 for a discussion of relative survival). All seven of the specimens evaluated for otolith marks were hatchery.

DISCUSSION

River conditions for the Susquehanna River Basin during 2011 could be characterized as unusually high except for the period from early June through late August (Figure 3). High water events began in late August and resulted in higher than average flows through November.

Fish passage at Conowingo Dam was suspended on May 20 due to maintenance issues with the fish lift at Holtwood. SRAFRC partners agreed that passing fish into Conowingo Pool, with little chance of them passing Holtwood, was counter-productive. Fish passage efficiency at Holtwood (21) was less than one percent, the worst in the time-series. The fish lift at Safe Harbor passed 8 shad while the vertical slot ladder at York Haven did not pass any shad. Production of wild juvenile shad was, no doubt, negatively impacted by the low numbers of shad passed into spawning habitat above York Haven Dam.

Abundance – Main Stem

Comparison of relative abundance of juvenile alosines in the Susquehanna River from year to year is difficult due to the opportunistic nature of sampling and wide variation in river conditions, which may influence catches. In 2011, 5 juvenile shad were collected by haul seine. This is well below the numbers captured during 1990 to 2001 when an average of 330 juvenile shad was captured by haul seine.

GM CPUE for haul seine at Columbia for individual hauls and combined daily hauls was 0.04 and 0.06, respectively (Table 2). GM CPUE for haul seine at City Island for individual hauls and combined daily hauls was 0.03 and 0.04, respectively (Table 5). Juvenile shad abundance has been well below normal for seven consecutive years (Figure 4), a disturbing trend that will impact upstream fish passage counts until at least 2016. 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 2011 are troubling. The number of larvae stocked during those years averaged 3.2 million. This represents 41% of the average number of larvae stocked during 1993 to 2001. In comparison, CPUE for 2008 to 2011 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 resulted in poor year classes for 2005 to 2011. 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.

Stock Composition and Mark Analysis

For all sites combined, hatchery contribution was 100% (7 of 7 successfully processed shad). Juvenile shad were captured from releases at a number of sites including the Juniata R. (day 3 mark, 2 specimens), the Juniata R. (Susquehanna source eggs; day 3,6,9 mark, 3 specimens), the North Branch Susquehanna River (1 specimen), and Bald Eagle Creek (1 specimen). The only stocking site not represented in the recaptures was the North Branch Susquehanna River.

SUMMARY

- Juvenile American shad were collected by haul seine at City Island and Columbia, in strainers at Conowingo Dam and by electrofishing in Lake Aldred and Conowingo pond.
- Haul seine GM CPUE at Columbia (combined daily lifts) of 0.06 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 100% hatchery origin.
- Production of hatchery larvae from the Van Dyke Hatchery was 3.1 million. Adult shad passage was the worst recorded due to high flows and maintenance issues at Holtwood.
- **Based on haul seine CPUE at Columbia, survival of hatchery-reared American shad larvae was 106 times lower during 2008 to 2011 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. John Cingolani and Brant Hoover processed shad otoliths.

LITERATURE CITED

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

FIGURES AND TABLES

Figure 1. Location of the haul seine stations sampled in the lower Susquehanna River near Columbia, Pennsylvania in 2011

Figure 2. Location of the haul seine stations sampled in the middle Susquehanna River around City Island near Harrisburg, Pennsylvania in 2011.

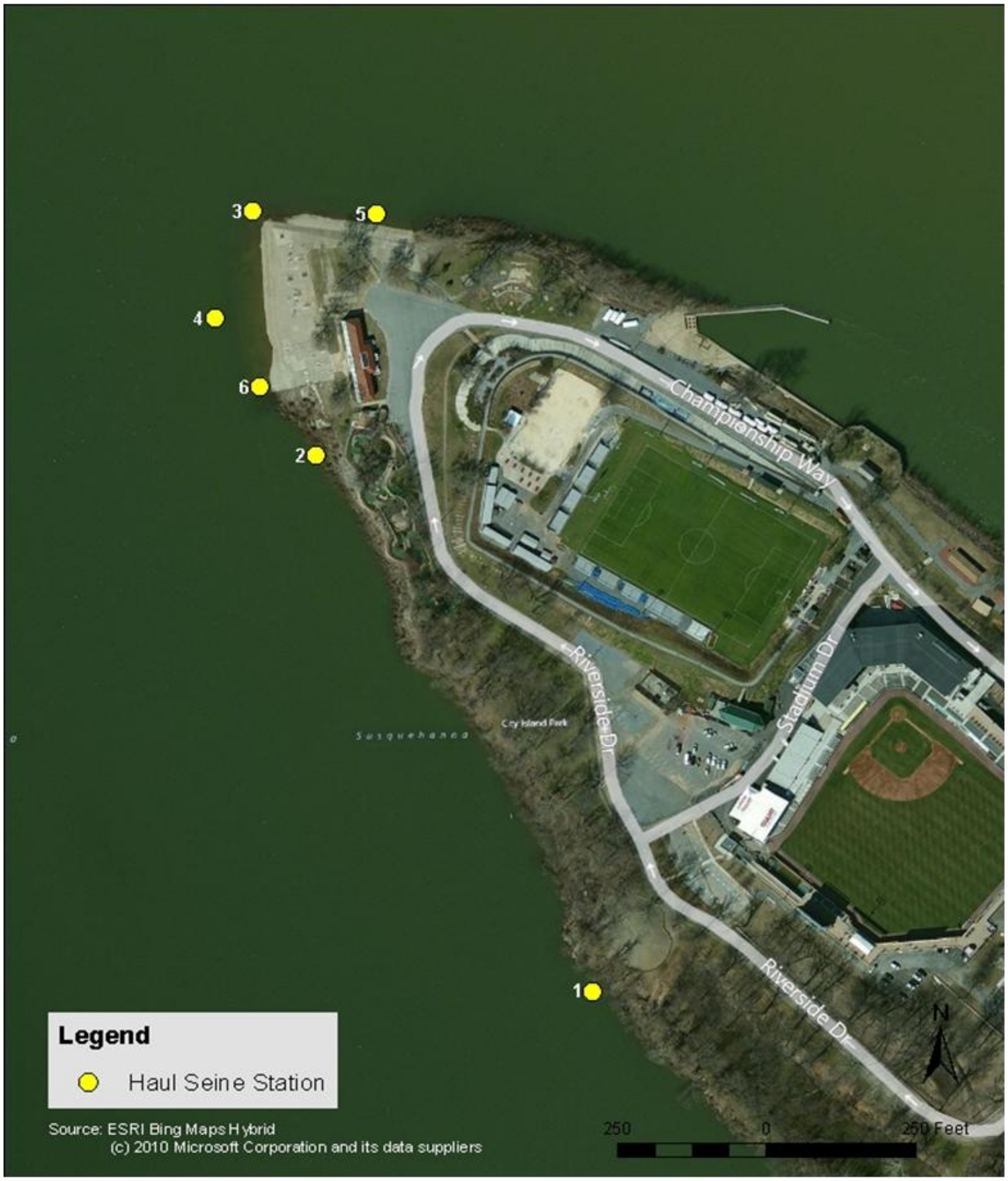

Figure 3. Discharge (cfs) in the Susquehanna River at Marietta, April 1, 2011 to November 30, 2011.

Figure 4. Annual YOY American shad CPUE for haul seine collections in the Susquehanna River.

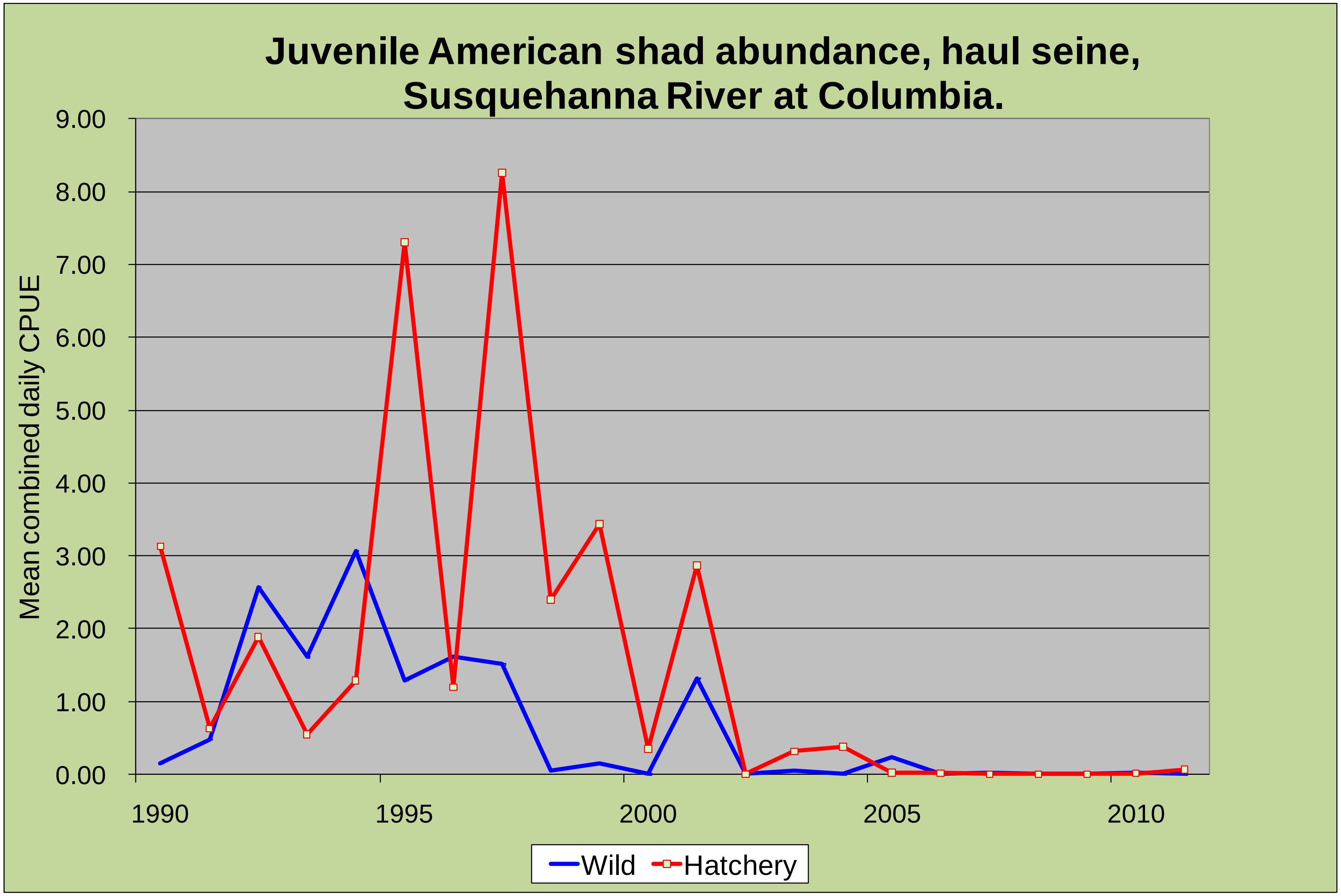
Juvenile American shad abundance, haul seine, Susquehanna River at Columbia.
Mean combined daily CPUE
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1990
1995
2000
2005
2010
Wild
Hatchery

Table 1. Number and percent composition of the fish collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2011.

Date	**21-Jul**	**28-Jul**	**4-Aug**	**11-Aug**	**18-Aug**	**25-Aug**	**29-Aug**	**23-Sep**	**Total**	**%**
Daily Mean River Flow (cfs)	8,330	11,000	7,540	14,500	13,800	10,000	27,100	36,800		
Water Temperature (°C)	32.0	25.5	24.5	24.5	25.0	23.5	19.8	16.5		
Secchi Disk (in)	39	40	42	32	33	33	11	22		
American shad	-	1	1	1	-	-	-	-	3	0.3%
Gizzard shad	-	2	33	46	14	97	49	15	256	26.8%
Common carp	-	-	2	-	2	-	-	-	4	0.4%
Comely shiner	15	9	54	11	13	6	17	7	132	13.8%
Common shiner	-	-	2	-	-	-	-	-	2	0.2%
Spottail shiner	-	1	-	-	-	2	16	18	37	3.9%
Spotfin shiner	38	100	116	15	27	18	32	40	386	40.3%
Mimic shiner	-	-	-	1	1	-	-	-	2	0.2%
Bluntnose minnow	-	3	-	1	1	-	1	1	7	0.7%
Fallfish	1	3	7	4	-	1	2	-	18	1.9%
Quillback	2	2	-	-	-	-	-	1	5	0.5%
White sucker	1	-	-	-	-	-	-	-	1	0.1%
Northern hog sucker	2	-	-	-	-	-	-	-	2	0.2%
Shorthead redhorse	-	-	-	-	-	-	1	1	2	0.2%
Channel catfish	33	3	-	6	2	2	23	2	71	7.4%
Banded killifish	-	2	-	1	1	1	-	-	5	0.5%
Rock bass	-	-	-	-	1	-	2	5	8	0.8%
Bluegill	-	-	-	-	-	-	2	3	5	0.5%
Smallmouth bass	1	2	-	1	-	-	-	-	4	0.4%
Largemouth bass	2	-	-	-	-	-	-	-	2	0.2%
Tessellated darter	-	-	-	2	1	1	-	-	4	0.4%
Walleye	-	-	-	-	-	-	-	1	1	0.1%
Total	**95**	**128**	**215**	**89**	**63**	**128**	**145**	**94**	**957**	**100.0%**
No. of Species	**9**	**11**	**7**	**11**	**10**	**8**	**10**	**11**	**22**	

Table 2. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, Susquehanna River, 1990-2011.

2011	50	3	0.06	0.06	0.04	0	0	0	3	0	0

Table 3. Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River near Columbia, 1989 through 2011.

Month	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	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	250
24-31 Jul	45	31	-	-	0	60	24	15	22	144	1	0	42	0	0	*	0	*	2	0	0		1	387
1-7 Aug	-	0	0	20	0	24	29	32	14	30	1	2	70	0	*	*	5	0	0	0	*		1	228
8-15 Aug	61	0	0	2	8	13	35	56	20	0	0	6	37	0	*	0	1	0	0	0	0		1	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	440
24-31 Aug	-	-	-	-	13	-	42	39	120	10	10	0	36	0	8	16	2	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	*	302
8-15 Sep	-	97	16	-	41	75	65	4	135	3	264	0	31	0	4	4	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	253
24-30 Sep	-	0	73	-	11	5	15	15	32	0	20	1	34	0	*	*	2	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	*	*	228
8-15 Oct	-	0	7	-	0	2	31	3	0	0	3	11	1	0	0	0	2	0	0	0	0	1	*	61
16-23 Oct	-	-	5	-	-	10	-	-	14	0	5	0	0	*	*	0	3	1	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
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**	**4,922**

* 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 2011.

Date	11-Jul	19-Jul	26-Jul	2-Aug	8-Aug	16-Aug	24-Aug	Total	%
Daily Mean River Flow (cfs)	11,200	7,300	7,300	6,460	17,200	12,500	8,640		
Water Temperature (°C)	28.0	30.5	31.5	29.0	27.0	23.5	23.0		
Secchi Disk (in)	42	48	40	53	45	38	61		
American shad	-	-	-	1	1	-	-	2	0.3%
Central stoneroller	-	-	5	-	-	-	-	5	0.7%
Comely shiner	-	1	3	3	-	1	7	15	2.1%
Spottail shiner	5	-	2	4	-	2	32	45	6.3%
Spotfin shiner	10	84	39	25	31	42	4	235	32.9%
Mimic shiner	-	-	2	7	3	1	-	13	1.8%
Bluntnose minnow	2	2	7	2	1	-	2	16	2.2%
Fallfish	48	11	4	6	3	8	-	80	11.2%
Quillback	24	2	-	-	10	1	-	37	5.2%
White sucker	5	23	-	-	-	-	-	28	3.9%
Northern hog sucker	1	1	-	-	-	3	-	5	0.7%
Shorthead redhorse	-	-	-	-	-	1	1	2	0.3%
Channel catfish	1	1	2	5	-	2	-	11	1.5%
Banded killifish	1	12	23	72	10	41	41	200	28.0%
Rock bass	4	-	-	-	-	1	1	6	0.8%
Redbreast sunfish	1	-	-	-	-	-	-	1	0.1%
Pumpkinseed	1	-	-	-	-	-	-	1	0.1%
Bluegill	-	-	-	-	-	1	1	2	0.3%
Smallmouth bass	-	1	2	2	1	1	1	8	1.1%
White crappie	-	-	-	-	-	-	1	1	0.1%
Walleye	1	-	-	-	-	-	-	1	0.1%
Total	**104**	**138**	**89**	**127**	**60**	**105**	**91**	**714**	**100.0%**
No. of Species	**13**	**10**	**10**	**10**	**8**	**13**	**10**	**21**	

Table 5. Index of abundance for juvenile American shad collected by haul seine from the middle Susquehanna River at City Island, Harrisburg, Pennsylvania in 2011.

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	0.033558	0	0	0	2	0.05	0.05

Table 6. Weekly catch of juvenile American shad by haul seine from the middle Susquehanna River at City Island, Harrisburg, Pennsylvania, 2010-2011.

* 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.

***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 2 December, 2011.

Species	Unit 2	Unit 3	Total
Alewife	9	16	**25**
American shad	0	0	**0**
Gizzard shad	1,117	1,994	**3,111**
Gold fish	0	1	**1**
Comely shiner	15	22	**37**
Spottail shiner	1	0	**1**
Spotfin shiner	8	5	**13**
Fathead minnow	0	1	**1**
Golden shiner	2	1	**3**
Shorthead redhorse	0	3	**3**
Channel catfish	28	41	**69**
Flathead catfish	8	5	**13**
Tiger muskie	0	1	**1**
Rock bass	1	5	**6**
Green sunfish	1	2	**3**
Pumpkinseed	0	1	**1**
Bluegill	1,394	1,017	**2,411**
Redbreast sunfish	2	4	**6**
Largemouth bass	2	10	**12**
White crappie	2	12	**14**
Black crappie	0	2	**2**
Tessellated darter	1	0	**1**
Yellow perch	0	3	**3**
Logperch	0	1	**1**
TOTAL	***2,591***	***3,147***	***5,738***

Table 10. Number of juvenile American shad collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall, 2011.

Date	Unit 2	Unit 3	Total
2 November - 2 December	0	0	**0**
TOTAL	***0***	***0***	***0***

Table 11. Species and number of fish collected during cooling water intake sampling at Conowingo Dam in fall, 2011.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	1	0	**1**
Alewife	1	0	**1**
Alosa sp. (Decapitated)	1	0	**1**
Gizzard shad	182	290	**472**
Carp	1	0	**1**
Comely shiner	16	4	**20**
Channel catfish	12	0	**12**
Spotfin shiner	11	0	**11**
Shorthead redhorse	1	0	**1**
Bluegill	14	7	**21**
TOTAL	***240***	***301***	***541***

Table 12. Number of juvenile American shad collected during cooling water intake strainer sampling at Conowingo Dam in fall, 2011.

Date	Francis Units (7)	Kaplan Units (4)	Total
21 Oct	1	0	**1**
TOTAL	***1***	***0***	***1***

Table 13. Catch of juvenile American shad by location from the upper Chesapeake Bay during the 2011 Maryland DNR juvenile finfish haul seine survey.

SITE	AMSHAD Round 1	AM SHAD Round 2	AM SHAD Round 3
UPPER BAY PERM			
HOWELL PT.	0	23	16
TIMS CR	0	2	2
SASSAFRAS NRMA	0	7	2
PARLOR PT.	1	1	1
ELK NECK PARK	21	9	0
WELCH PT.	1	0	2
HYLAND PT.	29	0	1
TOTALS	52	42	24

Table 13. (continued)

HOB (AUX)

CARPENTER PT	0	1	0
POPLAR PT	Not sampled	Not sampled	Not sampled26
PLUM PT	26	20	6
SPOIL ISLAND	0	1	0
TYDINGS ESTATE	1	0	0
TOLCHESTER	0	0	2
TOTALS	27	22	8

Table 14. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2011.

		Day	Days	Days	Days	Days	Days				
		3	3,6,9	3,6,9,15	3,18	3,6,9,12,15	various + sngl feed				
Collection Site	Coll. Date	Jun/ Susq.	Jun/ Susq.	N. Br. Susq. (PA)	W. Br. Susq.	Bald Eagle Cr.	Raceway	Total Hatchery	Total Wild	Total Processed	Total Collected
City Island	8/2/2011	0	1	0	0	0	0	1	0	1	1
	8/8/2011	0	1	0	0	0	0	1	0	1	1
Columbia	7/28/2011	0	1	0	0	0	0	1	0	1	1
	8/4/2011	1	0	0	0	0	0	1	0	1	1
	8/11/2011	1	0	0	0	0	0	1	0	1	1
Lake Aldred	9/28/2011							0	0	0	1
Conowingo Pond	9/23/2011	0	0	0	1	0	0	1	0	1	1
Conowingo Strainers	10/21/2011	0	0	0	0	1	0	1	0	1	1
Grand Total		2.3	3.4	0.0	1.1	1.1	0.0	8.0	0.0	7.0	8.0
Percent		28.6%	42.9%	0.0%	14.3%	14.3%	0.0%	100%	0.0%		

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

JOB V. PART 1. ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 2011

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ABSTRACT

A total of 137 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2011. Based on tetracycline marking and otolith microstructure, 63% of the 134 readable otoliths were identified as wild and 37% 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 1986-2006 year classes, stocking of approximately 388 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 adult 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 2011. Age composition data was gathered as follows: for 1996 to 2011, 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 137 shad was sacrificed for otolith analysis from Conowingo Dam in 2011. Of these, 76 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 3 unreadable otoliths (Table 1). A total of 84 (63%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 50 (37%) fish exhibited tetracycline marks including single, double, triple, and quintuple marks.

Five shad were collected with an OTC tag at day 18 only. That mark was used in 2006 only and thus these five fish were known age (age 5). All five 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 2010. Scale samples were provided to MD DNR and the 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 with a slight increasing trend in the last three years (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 2006, increased again in 2007, decreased again in 2008 and 2009 and increased in 2010 and 2011. 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. Two known repeat spawn shad were captured in the West Lift in 2011. Scale samples were provided to MD DNR and the scales and otoliths of this fish have been archived for future reference. We now have four known repeat spawn scale samples in our reference collection.

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 2006 are not fully recruited and are not included in the analysis. For the period 1986-2006, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 68 to 1,795, with a mean of 388 (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 2006 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 0.52 and 0.54, respectively. Relative survival of adults for the West Branch was the highest of any site for the 2004 and 2006 cohorts. This may be reflective of recent water quality improvements associated with mine drainage abatement projects.

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FIGURES AND TABLES

Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking.

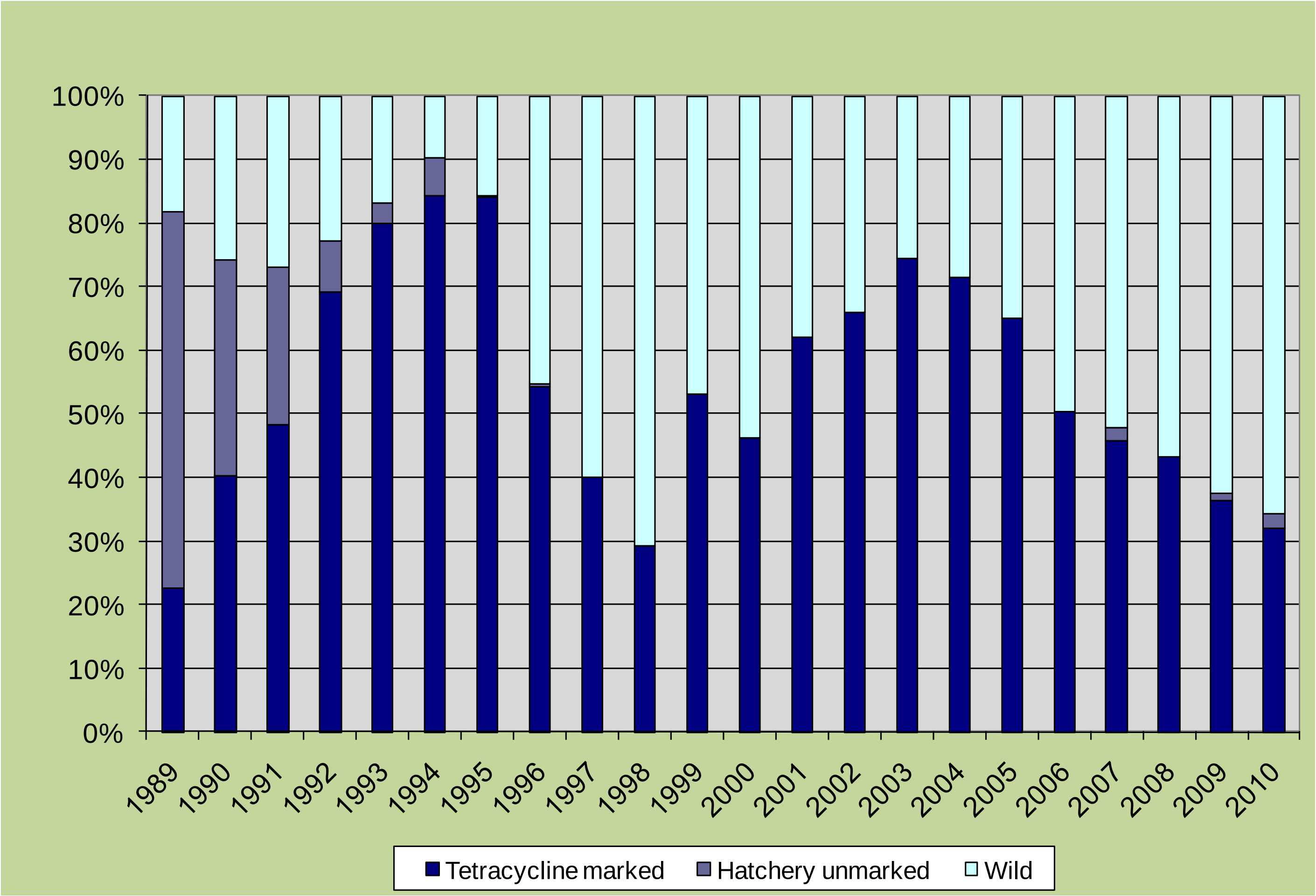

Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

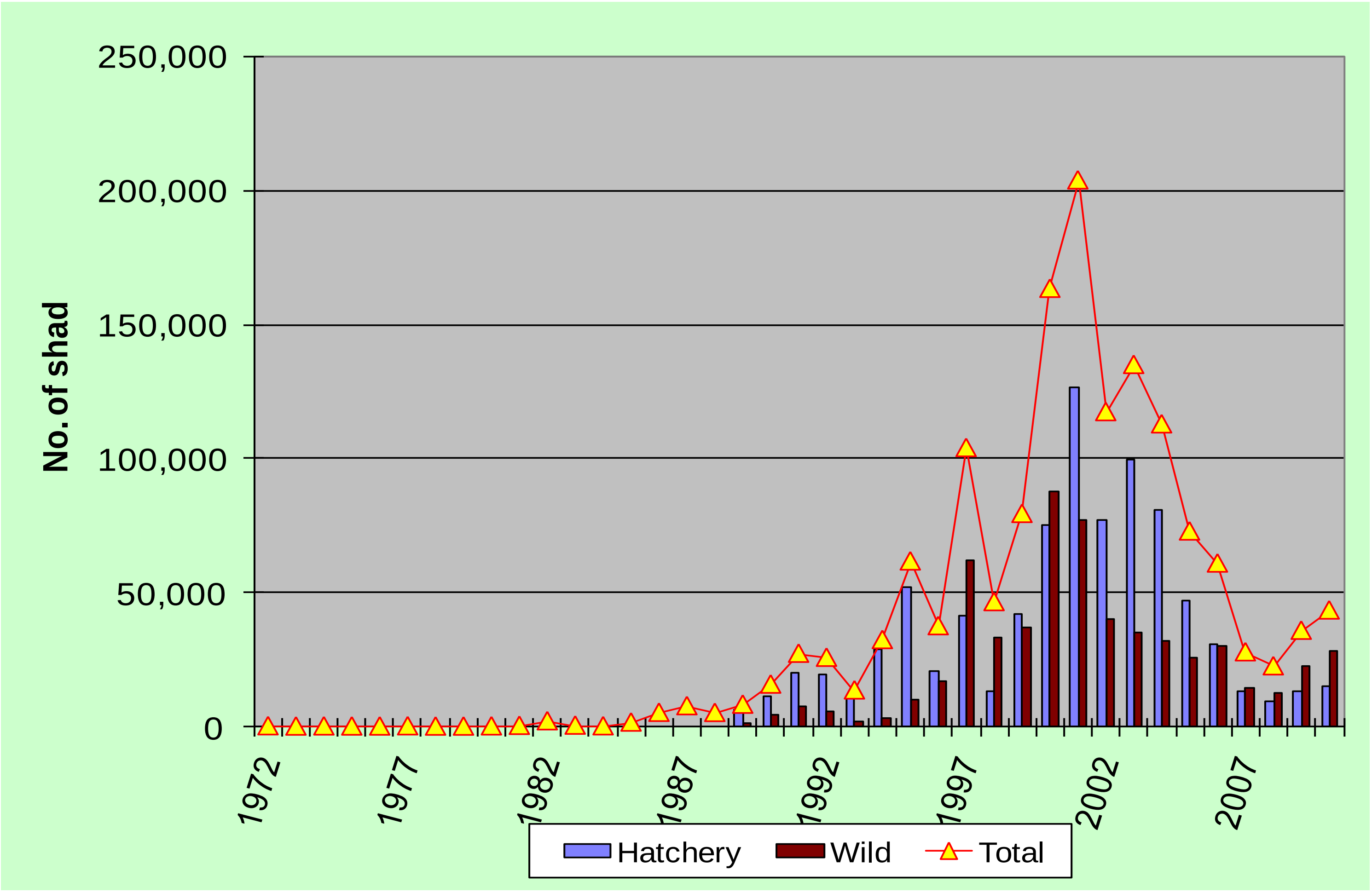

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2011. One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis. Collections were supplemented with fish from tank-spawn trials.

Conowingo Dam		Conowingo Dam N	%
Wild Microstructure, No TC Mark		84	63%
Hatchery Microstructure			
Tagged, can't distinguish TC Mark*		0	0%
Single TC Mark	Day 3	2	1%
	Day 18	5	4%
Double TC Mark	Days 15,18	3	2%
Triple TC Mark	Days 3,6,9	32	24%
	Days 3,6,12	1	1%
Quintuple TC Mark	Days 3,6,9,12,15	7	5%
	Total Hatchery	50	37%
	Total readable otoliths	134	
	Unreadable Otoliths**	3	
	Total	137	

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

**Includes missing, broken and poorly ground otoliths.

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
Totals		2,452	54	154	3	25	1	251	6	1,831	40	4,534

Table 3. Length-frequency of American shad collected in the Susquehanna River at the Conowingo West Fish Lift, 1993-2011.

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
	1	0	2	4	27	113	294	496	541	383	156	36	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
	0	0	0	0	1	8	16	29	124	386	536	404	211	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
	1	0	2	4	28	121	310	525	665	769	692	440	218	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, 1995-2011.

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	4.7
1996	4	79	70	47	1	2	0	0	0	0	10	213	3.9
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	4.0
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	4.8
2003	0	4	49	17	17	2	1	0	0	0	2	92	4.7
2004	0	13	12	33	8	5	1	0	0	0	0	72	5.3
2005	0	7	62	28	22	3	1	0	0	0	1	124	4.8
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	4.4
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
Total	5	260	743	457	122	17	4	1	0	0	24	1633	4.4

Females													
	Otolith Age												Mea
	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	5.7
1996	0	3	44	74	16	5	0	0	0	0	12	154	5.1
1997	1	2	28	27	21	2	0	0	0	0	1	82	5.1
1998	0	0	12	34	14	1	0	0	0	0	0	61	5.2
1999	0	0	24	46	13	2	0	0	0	0	4	89	5.1
2000	0	1	13	27	14	2	0	0	0	0	0	57	5.4
2001	0	0	18	56	34	4	0	0	0	0	0	112	5.5
2002	0	0	13	43	42	9	3	0	0	0	2	112	6.0
2003	0	1	12	30	44	13	1	0	0	0	0	101	6.7
2004	0	0	5	43	16	18	2	0	0	0	0	84	7.4
2005	0	2	18	33	71	16	4	1	0	1	2	148	6.5
2006	0	0	14	66	14	8	1	1	0	0	0	104	5.8
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	6.3
2009	0	0	15	34	11	4	0	0	0	0	0	64	5.6
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	6.2
Total	1	9	257	716	445	102	15	2	0	1	32	1578	5.8

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**	**5.1**
1996	4	82	114	121	17	7	0	0	0	0	22	**367**	**4.4**
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**	**4.8**
1999	0	19	86	62	15	2	1	0	0	0	5	**190**	**4.5**
2000	0	20	98	52	19	2	0	0	0	0	0	**191**	**4.5**
2001	0	4	47	98	41	4	0	0	0	0	0	**194**	**5.2**
2002	0	16	28	74	51	11	3	1	0	0	3	**187**	**5.5**
2003	0	5	61	47	61	15	2	0	0	0	2	**193**	**5.8**
2004	0	13	17	76	24	23	3	0	0	0	0	**156**	**6.4**
2005	0	9	80	61	93	19	5	1	0	1	3	**272**	**5.7**
2006	1	5	46	93	21	8	1	1	0	0	0	**176**	**5.3**
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**	**5.4**
2009	0	0	89	60	17	4	0	0	0	0	0	**170**	**4.8**
2010	0	6	28	107	11	1	1	0	0	0	8	**162**	**4.9**
2011	0	1	15	58	59	3	0	0	0	0	2	**138**	**5.6**
Total	**6**	**269**	**1000**	**1173**	**567**	**119**	**19**	**3**	**0**	**1**	**56**	**3211**	**5.1**

Table 5. Mean total length and weight of adult American shad collected at the Conowingo Dam West Fish Lift, 1993-2011.

	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	90	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

*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, 1995-2011.

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					
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				

Table 7. Mean weight (g) at age for American shad collected at the Conowingo Dam West Fish Lift, 1995-2011.

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					
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				

Table 8. Sex ratio of American shad collected at the Conowingo Dam West Fish Lift, 1993-2011.

	Susquehanna
1993	1: 0.5
1994	no sex data
1995	1: 0.7
1996	1: 1.2
1997	1: 0.6
1998	1: 1.1
1999	1: 1.1
2000	1: 0.4
2001	1: 1.4
2002	1:0.8
2003	1: 1.1
2004	1: 0.8
2005	1: 1.1
2006	1: 1.4
2007	1: 2.0
2008	1: 1.2
2009	1:1.6
2010	1:1.1
2011	1:0.9

Table 9. Otolith age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2011.

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%

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%

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%

Table 10. Age composition and origin of Susquehanna River American shad collected at the Conowingo Dam Fish Lifts.

	Total											% Composition by Hatchery Release Site						
												Above Dams			Below Dams		Wild	
	Fish lift			% Age composition								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%					63%	
2010	43,362				0.552	0.552	8.287	66.3	20.99	3.315		35%					65%	
2011	23,645					2.174	42.8	42.0	10.87	0.725		38%					62%	

*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%	

* 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											
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
lumber 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):				**388**							

Table 12. (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	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
2010					0	84	0	813	9,176	2,783
2011						0	0	193	3,286	3,261
	84,739	**44,692**	**77,857**	**21,389**	**31,400**	**13,205**	**5,953**	**6,739**	**20,325**	**6,044**
	8.02	11.70	13.50	9.46	5.51	2.59	10.69	4.73	3.57	4.35
	95	262	173	442	175	196	1,795	702	176	719
	0.0106	0.0038	0.0058	0.0023	0.0057	0.0051	0.0006	0.0014	0.0057	0.0014

Table 13. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 1999.

		Cohort													
	Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	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
	2006												0	0	0
	2007													0	0
	2008														0
	2009														
Total recruits to lifts:		238	186	242	324	490	519	501	1,091	822	220	43	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
Number of fingerlings to return 1 adult:		305	437	264	186	184	105	44	73	170	0	0	#DIV/0!	#DIV/0!	#DIV/0!

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											
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
	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)

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
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	54	10,570	76		0.65	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	6	1,229	7	44	0.06	0.16
2006	1,336,518	Juniata/Susq. R.	Hudson	7	1,145	9		0.31	0.71
2006	1,423,294	Juniata/Susq. R.	Susquehanna	23	3,919	28		1.00	0.42
2006	315,388	W. Br. Susq. R.	Hudson	2	484	15		0.56	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		0.32	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	13	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		0.00	0.00

JOB V. PART 2. AMERICAN EEL SAMPLING AT CONOWINGO DAM, 2011

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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 Fishery 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 comprises 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 2011 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 2011 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 fine mesh collection bag placed in collection tanks (Figure 3). Aerated water was supplied to the collection and holding tanks 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), measured for total length (TL), and individually counted. Large numbers of eels were counted volumetrically. The collection of substantial numbers of eels allowed for the experimental stocking of elvers into Buffalo Creek, Pine Creek and Conowingo Creek. Stocking 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) (attachment 1).

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. A subsample of elvers captured was also sent to the Lamar Fish Health Center (Lamar, PA) for disease testing before any stocking occurred.

In previous years, eel pots with a 6 mm square mesh were set around the base of the West Fish Lift to catch larger eels. In 2011, we changed our collection device from a cylindrical eel pot to a double throated rectangular trap with a 25 mm by 13 mm mesh that is more consistent with local commercial gear. Yellow eels captured in eel pots were sedated with a concentrated solution of MS-222 (450g/L), measured, fin clipped, and had a Passive Integrated Transponder (PIT) tag inserted in the dorsal musculature and released.

In 2011, 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 June, and then released in Buffalo and Pine Creek (Table 1).

RESULTS

Eels were sampled between 23 May and 8 September 2011 and elvers were collected throughout the sampling timeframe (Table 2). A total of 85,000 elvers were collected during 2011 with the majority collected in two pulses. The first wave occurred in the month of July and the second wave occurred at the end of August through the beginning of September during high flows associated with hurricane Irene and tropical storm Lee. Sampling ended abruptly due to flooding subsequently caused by tropical storm Lee. The seasonal pattern of migration in 2011 was similar to that observed in 2008 when a majority of the eel collection occurred in the end of June through the end of July. During 2009 the migration was later and more protracted with the majority of elvers being collected in the end of July through August. In 2008, 2010 and 2011 we saw multiple waves of elvers throughout our sampling efforts; where as in 2009 there did not appear to be spikes in collections, but more of a steady level of migration through the sampling period (Figure 4).

Juvenile eel lengths ranged from 84 to 225 mm TL (Figure 5), slightly larger than previous years sampling. In 2011, 75%of elvers measured were between 110 and 149 mm, and from 2005-2009 56% of elvers measured were between 110 and 149 mm.

Yellow and silver eel collections in eel pots have taken place from 2007 - 2011. In 2011, we caught 224 yellow and silver eels that ranged from 333 to 659 mm TL. Of the 224 captures, 127 eels had new PIT tags inserted, 55 were recaptures from tagging done in 2011 or in previous year, and the rest were released without being tagged. This year we caught significantly more yellow and silver eels than in previous years. The largest number of yellow and silver eels previously caught was in 2009, when we had 68 new captures (Table 3). The addition of the 127 new captures brings the total number of PIT-tagged yellow eels in the study to 289. We are tracking annual growth rates of the 31 PIT tagged eels that have been recaptured after at least one year after tagging (Table 4).

A total of ten stockings from elvers captured at Conowingo Dam were conducted, with an estimated total of 62,000 elvers being stocked in Buffalo, Pine and Conowingo Creek (Table 1).

To evaluate stocking success at Buffalo and Pine Creek, we conducted electrofishing surveys using 3 backpack shockers and a barge shocker in August 2011. 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 release 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 2011, 441 elvers were recaptured in Buffalo Creek. All but 9 of these were recaptured at the Strawbridge Rd site. An attempt was made to sample at the foot bridge on Rte. 1003 but high flows prevented a depletion study from being conducted. The average TL of stocked elvers from Conowingo was 127 mm, and the average TL of glass eels stocked was 80mm, while the average TL of recaptured eels in Buffalo Creek was 137 mm (Figure 6). Sampling Pine Creek in 2011 provided 20 recaptured elvers, 12 of which were recaptured at the Darling Run site, and the rest were caught at the Ansonia Bridge site. The average TL of recaptured eels in Pine Creek was 143 mm. In addition to eels, 4,854 individuals of 30 fish species were collected in Buffalo Creek and 3,663 individuals of 23 fish species were collected in Pine Creek during electrofishing surveys. (Minkkinen et al. 2011)

Maryland DNR conducts an American eel young of year (glass eel) survey to characterize trends in American eel recruitment over time (ASMFC 2000). Sampling takes place at Turville Creek, MD using a modified Irish elver ramp. We compared estimated recruitment of glass eels from Turville Creek to captures of elvers below Conowingo dam one year later. Based on four years of data it appears that the glass eel recruitment index at Turville Creek does predict elver abundance the following year at Conowingo Dam (Figure 7).

A subsample of elvers was sacrificed to evaluate the presence of the parasite Anguillicola crassus. A total of 46 eels were euthanized using MS-222, then examined for the presence of Anguillicola crassus in the swim bladder. The samples were collected in 2010 and 2011, with 19 samples from 2010 and 27 samples from 2011. Anguillicola crassus was found in 22 of the samples, with the highest infection rate of 6 being found in one eel. There does not appear to be any relation between the length of an eel and the infection rate (Figure 8) or an increase in infection rate from one year to the next.

DISCUSSION

Throughout the project we have compared elver captures to several environmental factors. This year we increased the environmental factors analyzed. The factors we looked at were lunar fraction, river flow in Havre De Grace MD, 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. Using Pearson correlation it appears that turbidity, river flow and precipitation have the largest correlation value and these three values are directly related to one another (Table 5). With an increase of rain, for example the tropical storm that was observed this year, there was an increase in 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.

In 2012 we will attempt to release an additional 36,000 elvers in Pine Creek. We also will attempt to release elvers into Conowingo Creek in Maryland and Buffalo Creek in Pennsylvania. Elvers will be marked with OTC before being released. The Maryland Biological Stream Survey plans on conducting surveys in Conowingo Creek to evaluate the stocking effort. The Maryland

Fishery Resources Office will survey elvers released in Buffalo Creek and Pine Creek using methods identical to those used in 2010 and 2011.

REFERENCES

ASMFC (Atlantic States Marine Fisheries Commission). 2000. Standard procedures for American eel young of the year survey.

Maryland DNR. 2007. Maryland Biological Stream Survey: Sampling Manual Field Protocols. 65 pp.

Minkkinen S.P., Devers J.L. & W.A. Lellis. 2011. Experimental Stocking of American Eels in the Susquehanna River Watershed. Report of U.S. Fish and Wildlife Service to City of Sunbury, Pennsylvania.

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.

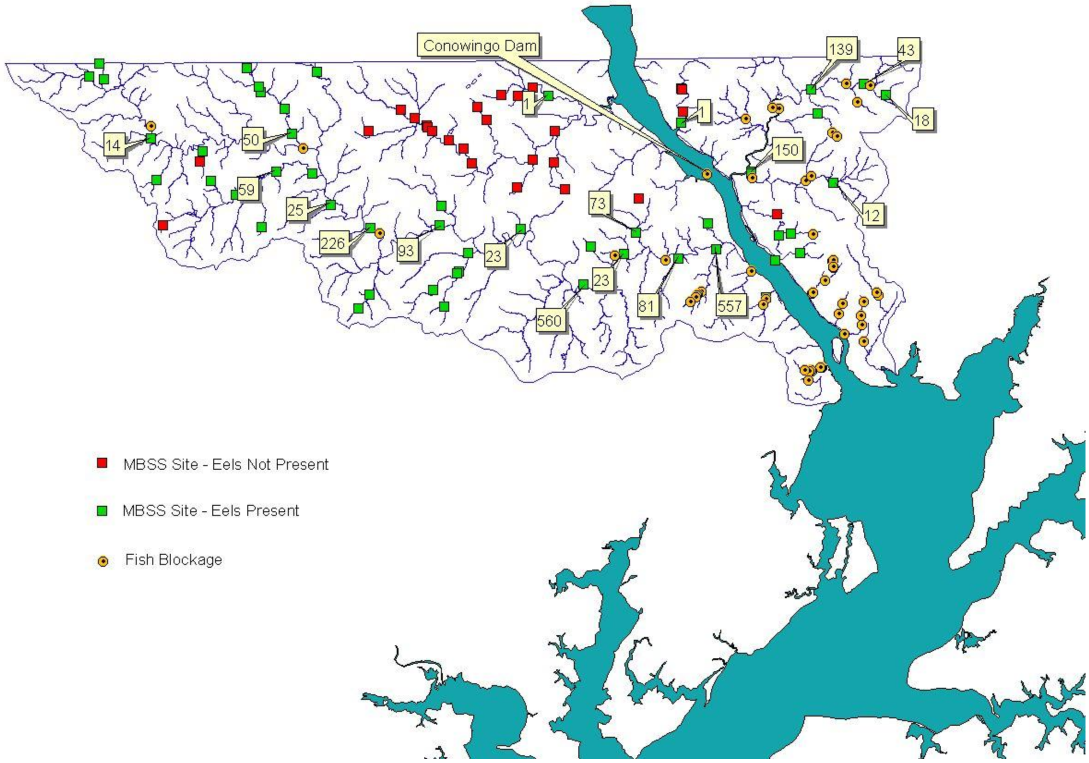

Figure 2. Eel trap constructed of industrial cable tray and landscape fabric.

Figure 3. The cable tray emptying into a collection bag in a holding tank.

Figure 4. Elver capture in relation to date for 2008 – 2011.

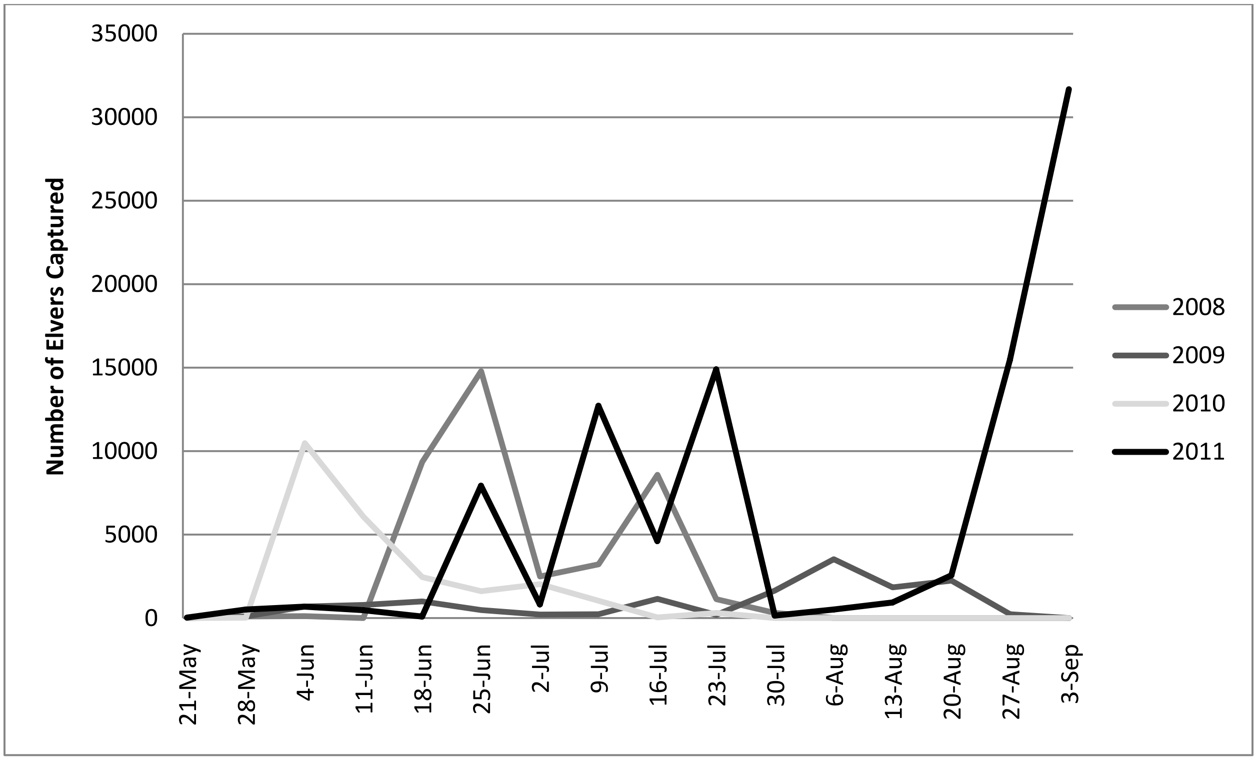

Figure 5. Length frequency of elvers captured below Conowingo Dam 2005-2011.

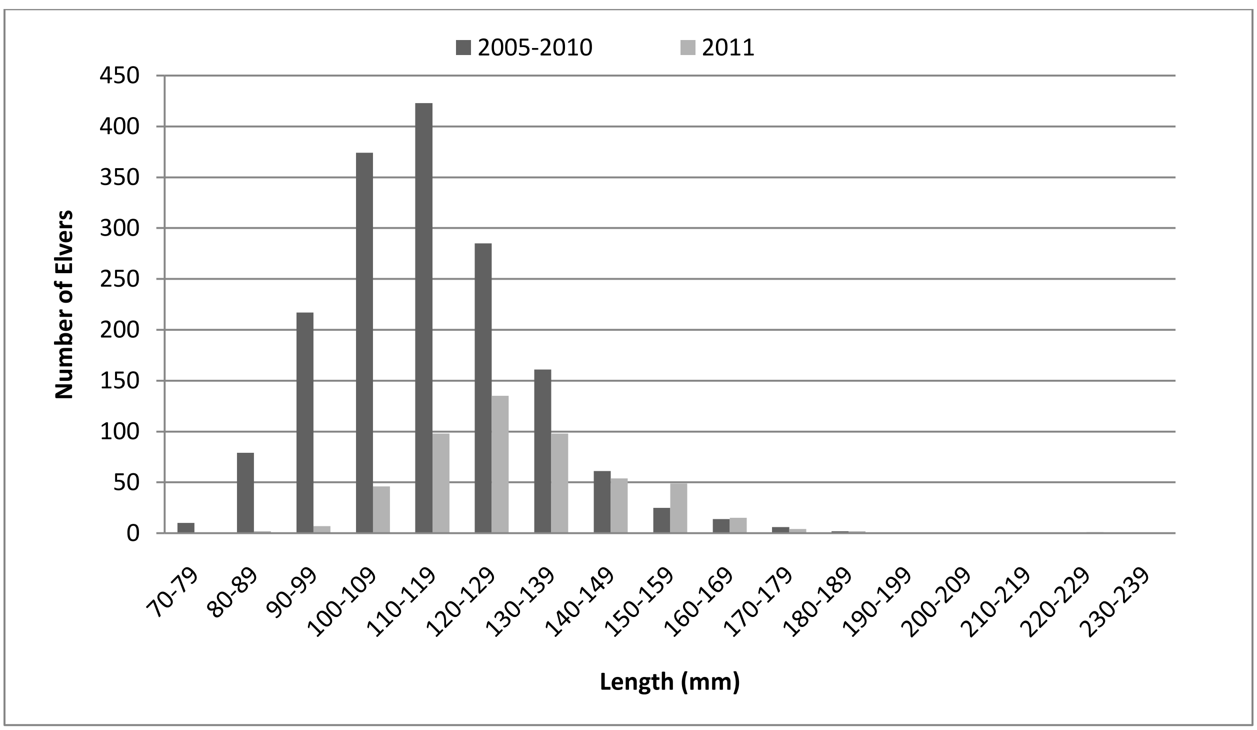

Figure 6. Length frequency of elvers recaptured in Buffalo Creek 2011

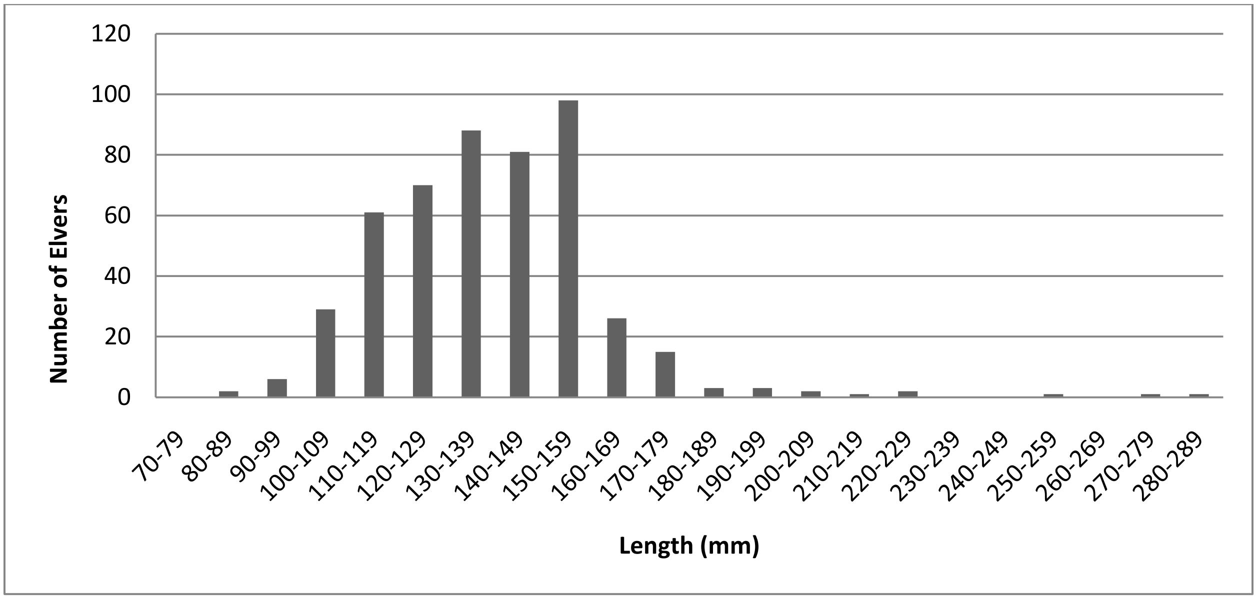

Figure 7. Yearly catch rates of glass eels from Turville Creek and elvers from Conowingo Dam

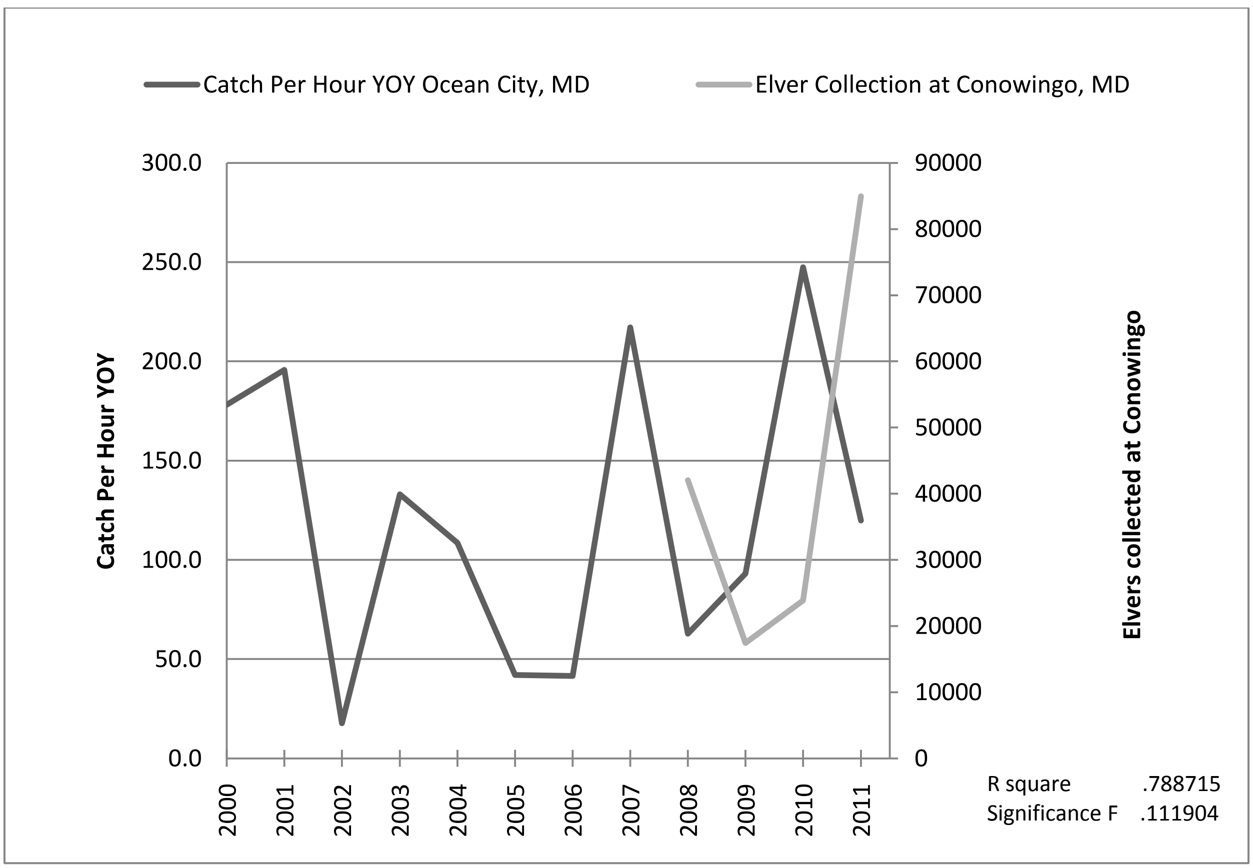

Figure 8. The number of Anguillicola crassus present in different lengths of elvers.

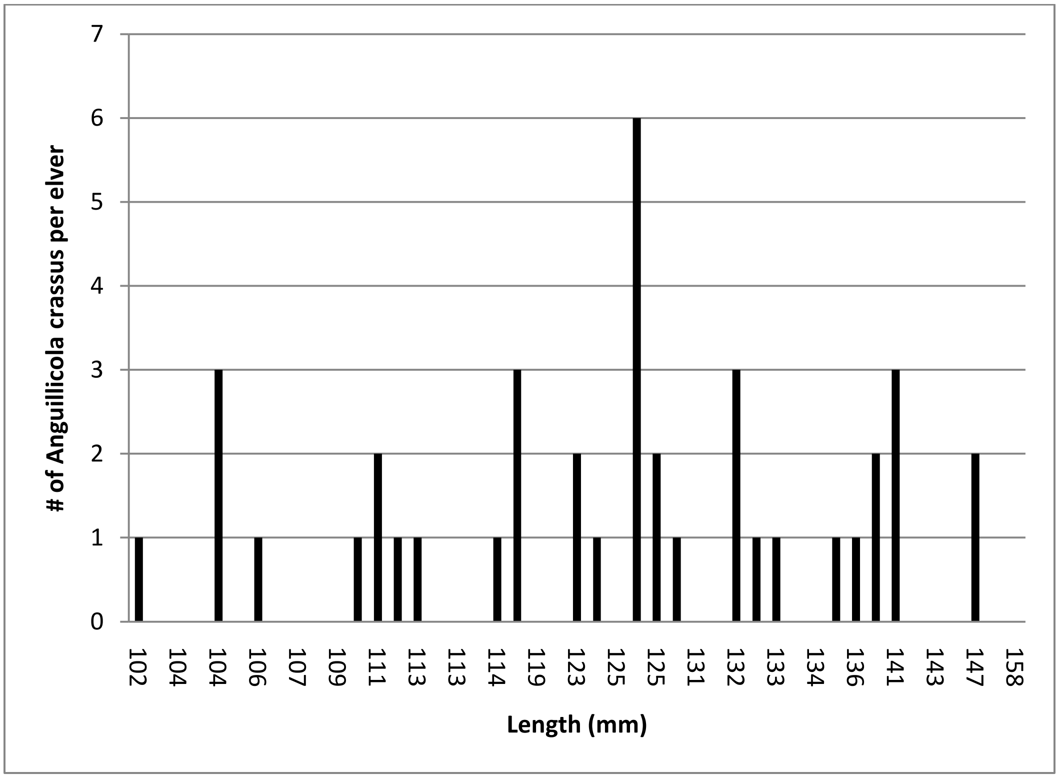

Table 1. Date, location, and number of elvers collected and stocked in 2011

STOCKING DATE	TOTAL ELVERS	STOCKING SITE	Latitude	Longitude	Origin
6/21/2011	16110	Buffalo Creek	40 58.864' N	76.57.081' W	Turville Creek
6/21/2011	16109	Buffalo Creek	40 59.139' N	76 55.930' W	Turville Creek
6/22/2011	10666	Pine Creek	41 44.633' N	77 26.031' W	Turville Creek
6/22/2011	10666	Pine Creek	41 16.285' N	77 19.894' W	Turville Creek
6/22/2011	10666	Pine Creek	41 44.203' N	77 25.822' W	Turville Creek
6/22/2011	1797	Conowingo Creek	39 43.852' N	76 10.701' W	Conowingo Dam
6/30/2011	7222	Pine Creek	41 44.633' N	77 26.031' W	Conowingo Dam
7/14/2011	6326	Buffalo Creek	40 59.139' N	76 55.930' W	Conowingo Dam
7/18/2011	4390	Buffalo Creek	40 59.139' N	76 55.930' W	Conowingo Dam
7/28/2011	3603	Buffalo Creek	40 59.139' N	76 55.930' W	Conowingo Dam
8/22/2011	1528	Pine Creek	41 44.633' N	77 26.031' W	Conowingo Dam
8/31/2011	8940	Pine Creek	41 44.633' N	77 26.031' W	Conowingo Dam
9/2/2011	8084	Pine Creek	41 44.633' N	77 26.031' W	Conowingo Dam
9/7/2011	12205	Pine Creek	41 44.633' N	77 26.031' W	Conowingo Dam
9/8/2011	7844	Conowingo Creek	39 43.852' N	76 10.701' W	Conowingo Dam

Table 2. Number of eels caught **a**t the base of Conowingo Dam on the West side of the dam during 2011.

Date	# of Elvers		Date	# of Elvers
5/23/2011	34		7/20/2011	282
5/25/2011	8		7/22/2011	1380
5/27/2011	1		7/25/2011	2013
5/31/2011	41		7/27/2011	3603
6/3/2011	476		7/29/2011	34
6/6/2011	511		8/1/2011	87
6/8/2011	70		8/2/2011	16
6/10/2011	121		8/5/2011	58
6/13/2011	382		8/8/2011	250
6/15/2011	79		8/10/2011	126
6/17/2011	21		8/12/2011	149
6/20/2011	71		8/15/2011	257
6/22/2011	6		8/17/2011	184
6/24/2011	21		8/19/2011	506
6/27/2011	1217		8/22/2011	928
6/29/2011	4467		8/24/2011	850
6/30/2011	1817		8/26/2011	797
7/1/2011	439		8/29/2011	1344
7/3/2011	378		8/30/2011	2648
7/5/2011	162		8/31/2011	3358
7/7/2011	288		9/1/2011	3548

7/11/2011	1132		9/2/2011	4573
7/12/2011	5514		9/3/2011	3880
7/13/2011	1660		9/4/2011	7250
7/14/2011	2074		9/6/2011	6275
7/15/2011	2340		9/7/2011	6424
7/16/2011	2187		9/8/2011	7844
7/18/2011	780			

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

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

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)*
ID	**2007**	**2008**	**2009**	**2010**	**2011**	
257C63E092	594	617	*	*	*	23
257C6534CA	733	770	*	*	*	37
257C6526C0	463	474	*	*	*	11
257C65EB48	404	510	521	*	*	58.5
257C655F24	426	445	*	*	*	19
257C65F2F2	338	390	505	*	*	83.5
257C63E581	551	589	*	*	*	38
257C65F8B0	475	511	*	*	*	36
257C65E87B	405	471	510	*	*	55
257C65FBAB	377	405	440	*	*	31.5
257C652B3A	466	490	*	*	*	24
257C63C580	391	520	*	557	*	55.3
257C660193	386	428	*	*	*	21
257C63CE9A	458	*	565	*	*	53.5
257C63CF54	484	*	624	*	*	70
257C652735	457	*	590	*	*	66.5
257C6534A4	386	*	478	*	*	46
257C66192F	447	*	580	*	*	66.5

257C63D36E	*	419	433	*	*	14
257C652BF4	*	364	383	395	449	28.3
257C65342C	*	393	516	*	*	123
257C65B1E0	*	479	543	*	*	64
257C660279	*	497	575	*	*	78
257C65E54F	*	454	*	550	*	48
1C2D05239A	*	*	612	626	*	14
1C2D0529B9	*	*	495	578	*	83
257C63D39B	*	*	432	462	470	19
257C6553FB	*	335	*	*	446	37
257C655957	*	321	*	*	377	18.6
1C2D05286B	*	*	476	*	508	16
1C2D052453	*	*	368	*	465	48.5

Table 5. Pearson Correlation performed on number of elvers captured and environmental variables

	# eels	*Lunar Fraction*	*Avg. Att Flow*	*Barometric Pressure*	*Air Temp*	*Precipitation Sum*	*AVG of DO (conc.)*	*AVG of Salinity (ppt)*	*AVG of Temp (°C)*	*AVG of pH*	*AVG of Turbidity (NTU)*	*AVG of Chlorophyll a (µg/l)*
# eels	1											
Lunar Fraction	0.0260	1										
AVG Flow	0.4241	0.0330	1									
Barometric Pressure	0.1454	-0.2805	0.1595	1								
Air Temp	-0.2163	0.0302	-0.2621	-0.4116	1							
Precipitation	0.3088	0.0424	0.2415	0.0207	-0.3217	1						
AVG of DO	-0.0735	-0.1243	0.2647	0.2474	0.0248	-0.1219	1					
AVG of Salinity	-0.2894	-0.0734	-0.5819	-0.1535	0.1199	-0.1368	-0.5397	1				
AVG of Temp	-0.2502	0.0874	-0.6924	-0.2893	0.5639	-0.1738	-0.3882	0.6475	1			
AVG of pH	-0.5675	-0.1282	-0.3780	-0.0321	0.2888	-0.2476	0.6206	-0.0170	0.3254	1		
AVG of Turbidity	0.6111	0.1400	0.8525	0.0083	-0.1800	0.2524	0.0581	-0.4502	-0.4174	-0.4150	1	
AVG of Chlorophyll a	-0.1177	-0.4422	0.2031	0.1431	-0.0758	-0.0637	0.6783	-0.3313	-0.2645	0.6269	0.1055	1

POPULATION ASSESSMENT OF 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

METHODS

Data Collection

Adult American shad were angled from the Conowingo Dam tailrace on the Susquehanna River two to five times per week from 10 May through 18 May 2011 (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 (2004-2011) 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 $\alpha = 0.05$.

Mean length-at-age was calculated by sex for American shad captured by hook and line at the Conowingo Dam. Linear regressions were used to examine trends in American shad mean lengths by age and sex over time (1980-2011) for ages with consistent representation.

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 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 an annually proportional consumption of American shad by striped bass, 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:

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

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 1:2.28. Of the 197 fish sampled by this gear, 172 were successfully scale-aged (Table 1). Males were present in age groups 4-6 and females were found in age groups 4-7. The 2006 year-class (age 5) was the most abundant for both sexes, accounting for 50% of males and 52.5% of females (Table 1). Twenty-eight percent of males and 24.6% of females were repeat spawners. The arcsine-transformed proportion of these repeat spawners (sexes combined) has significantly increased over the time series (1984-2011; $r^2 = 0.46$, $P < 0.001$; Figure 2).

Male American shad generally return to the Susquehanna River at an earlier age than females (1980-2011; Table 2). Mean length-at-age for females is greater than the corresponding mean length-at-age for males (Table 2); mean length has significantly decreased for male American shad at ages 4-6 and for female American shad at ages 4-7 since 1980 (Table 3; Figures 3, 4). The majority of the declines in mean length occurred in the beginning of the time series, with more recent values becoming fairly stable.

Relative Abundance

Sampling at the Conowingo Dam was restricted in 2011 due to heavy rains and high river flows. Only 197 adult American shad were sampled from the Conowingo tailrace over 7 sampling days; 125 of these fish were captured by MDNR staff from a boat and the remaining 72 were captured by shore anglers. MDNR staff tagged 196 (99.5%) of the sampled fish. To remain consistent with historical calculations, only the 125 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.

Operation of the EFL was delayed for most of April 2011 due to river water temperatures being less than 50.0°F and the onset of high river flows in excess of 100,000 cubic feet per second (cfs). The EFL operated for only 15 days between 25 April and 19 May. Exelon ceased EFL operations on 19 May due to the lack of successful American shad passage upstream at the Holtwood Dam facility. Of the 20,571 American shad that passed at the EFL, 87% (17,900 fish) passed between 11 May and 16 May. Peak passage was on 14 May when 5,013 American shad were recorded. Twenty of the American shad counted at the EFL counting windows were identified as being tagged in 2011; only 4 fish passed that were tagged in 2010 (Table 4).

In 2011, the Conowingo WFL operated for 15 days between 13 May and 5 June. The 3,074 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 16 May when 1,185 American shad were collected. Four of the six tagged American shad recaptured by the WFL in 2011 were fish tagged in 2011; the other two recaptured fish were tagged in 2010 (Table 4).

The Petersen statistic estimated 186,330 American shad in the Conowingo Dam tailrace in 2011, and the SPM estimated a population of 103,500 fish. Despite differences in yearly estimates, the overall population trends derived from each method are similar (Figure 5). Specifically, SPM estimates declined from 2001 to 2007 and increased from 2008 to 2011. 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 have significantly increased over the time series (1984-2011; $r^2 = 0.21$, $P = 0.01$), although abundance is variable from 2005-2011 and remains below the high indices observed from 1999 to 2002 (Figure 6). The Conowingo Dam 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 7).

Due to the limited number of sampling days in 2011, we did not obtain enough data from the angler-based roving creel survey at the Conowingo Dam tailrace to calculate CPAH. Data from previous years are included in Table 5. Although American shad CPAH calculated from shad logbook data decreased significantly over the time series (1999-2011; $r^2 = 0.38$, $P = 0.03$), CPAH has remained relatively level since 2008 (Table 6).

Mortality

The Conowingo Dam tailrace total instantaneous mortality estimate from catch curve analysis (using repeat spawning instead of age) resulted in Z = 1.40 (A = 73.5%).

Hickory Shad

Sex and Age Composition

A total of 1,648 hickory shad were sampled in 2011 by the brood stock collection survey in Deer Creek. The male-female ratio was 1.41:1. Of the total fish captured by this survey, 216 were successfully aged. Males were present in age groups 3-7 and females were found in age groups 3-8. The most abundant year-classes by sex were the 2008 year-class (age 3) for males (34.9%) and the 2007 year-class (age 4) for females (33.3%; Table 7). Hickory shad sampled from 2004 to 2011 ranged from 2 to 9 years of age, with ages 3 through 8 present every year (Table 8). The arcsine-transformed proportion of these repeat spawners (sexes combined) has not changed significantly over the time series (2004-2011; $r^2 = 0.028$, $P = 0.69$; Figure 8). However, the percent of repeat spawning males in 2011 (63.6%, Table 7) was lower than the percent of repeat spawning males in 2010 (74.4%), and the total percent of repeat spawners in 2011 (68.5%) was the second lowest total percent from 2004 to 2011 (Table 9).

Relative Abundance

Shad logbook data indicated that hickory shad CPAH did not vary significantly over the time series (1998-2011; $r^2 = 0.11$, $P = 0.25$); however, hickory shad CPAH increased in 2011 and is the highest it has been since 2007 (Table 10).

Mortality

Total instantaneous mortality in the Susquehanna River (Deer Creek) was estimated as Z = 0.67 (A = 48.8%).

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).

American shad abundance has increased at the Conowingo Dam in the Susquehanna River since the 1980s: hook and line CPUE (1984-2011) and combined lift CPUE (1980-2011) have increased over their respective time series. As a cautionary note, hook and line estimates of abundance are not highly sensitive to changes in abundance because this gear can become saturated. In addition, 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. However, the Petersen statistic and SPM estimates of American shad abundance at the Conowingo Dam tailrace (1986-2011) support the observed increasing trends in CPUE. Factors contributing to this increase may include increased adult recruitment from stronger year-classes and reduced fish lift efficiencies (which may decrease the catchability of adult American shad at Conowingo Dam and reduce turbine mortality). Despite the overall increasing trends, a period of decreasing abundance is evident in all estimates between 2002 and 2007, including logbook CPAH.

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, 26% of aged American shad at the Conowingo Dam were repeat spawners in 2011, and, on average, 20% of aged fish were repeat spawners over the past five years. If stock abundance is correlated to the number of repeat spawners, the increase in repeat spawners in the Conowingo Dam tailrace may be related to the abundance increases observed over the time series.

Total instantaneous mortality rate for American shad captured in the Conowingo Dam tailrace in 2011 is within the range of reported Z estimates from other studies (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 (1998-2011), 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. Overall, catch rates have been quite variable, but CPAH in 2011 was the fourth highest CPAH of the 14 year time series.

Hickory shad age structure has remained 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 2004-2011 time series, with the percent of repeat spawners ranging between 67-89%.

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. Since both mature adults and immature sub-adults migrate and overwinter closer to the coast, hickory shad ocean bycatch is minimized compared to the other alosines (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 AND FIGURES

Table 1. Number of adult American shad and repeat spawners by sex and age sampled from the Conowingo Dam tailrace in 2011.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	0	0	0	0	0	0
4	18	0	14	0	32	0
5	25	7	64	10	89	17
6	7	7	40	16	47	23
7	0	0	4	4	4	4
8	0	0	0	0	0	0
Totals	50	14	122	30	172	44
Percent Repeats	28.0%		24.6%		25.6%	

Table 2. Mean length-at-age by sex for American shad sampled at the Conowingo Dam, 1980-2011.

Males

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1980		381	427	462	495					
1981	292	363	417	470						
1982		384	411	460	458					
1983				413						
1984		332	381	434	470					
1985		360	387	426	450					
1986		324	395	430	440					
1987	238	341	379	431	433					
1988	288	332	395	440	490					
1989		347	371	435	473					
1990	250	345	389	419	473	495				
1991	250	343	378	412	445	480	530			
1992	275	319	375	406	430	451				
1993		325	371	414	434	455				
1994		351	381	409	449	505	540			
1995		336	375	412	452	483				
1996		340	379	427	456					
1997		341	378	420	458	472				
1998	280	346	387	411	442	455				
1999	287	338	371	405	427			460		
2000		344	381	417	452	450				
2001		350	394	419	456	476				

2002		346	379	419	454	455				
2003		361	389	415	450	447		480		
2004		350	392	424	440					
2005		355	383	416	447	467	485			
2006		348	388	416	461	468				
2007		358	387	418	448	465	503			
2008		355	383	414	434					
2009		351	380	400	429					
2010		361	392	413	436	445				
2011			384	417	445					

Table 2 continued. Mean length-at-age by sex for American shad sampled at the Conowingo Dam, 1980-2011.

Females

Year	Age									
	2	3	4	5	6	7	8	9	10	11
1980			447	479	528	524				
1981			464	487	512					
1982			436	471	527					
1983			472	459	470					
1984			403	468	492	551				
1985		349	424	457	496	511				
1986		387	431	470	518					
1987		387	413	466	505					

1988		384	428	466	524					
1989		340	421	474	521	526				
1990		360	414	444	493	538				
1991			410	436	471	516	550			
1992			407	434	457	496	540			
1993			399	427	454	476	493			
1994			411	433	470	484				
1995			408	437	471	502	485			
1996		355	416	447	484	499				
1997		362	402	451	481	506	516			
1998			419	439	466	485	525	562		
1999		420	406	440	463	473		540	505	
2000			415	446	478	497	498		540	
2001		359	421	449	479	502	523			
2002			423	455	482	504	509			
2003			420	442	473	500		510		
2004			429	454	473	515	518	520		
2005			427	452	474	498	546			
2006		354	419	446	467	483	494	519		
2007			422	447	471	502	514	526		
2008			419	442	469	484		506		
2009			415	442	467	483	503			
2010			422	444	464	502	515			
2011			417	442	462	485				

Table 3. Regression statistics for American shad mean length by age and sex over time (1980-2011). Only ages with consistent representation over time were considered. Bolded values indicate significant changes in mean length-at-age over time.

	Males				Females			
Age	N	Slope	r^2	*P*	N	Slope	r^2	*P*
3	30	-0.003	< 0.001	0.9925				
4	31	-0.523	0.1431	**0.0359**	32	-0.625	0.1361	**0.0377**
5	32	-1.121	0.4188	**< 0.001**	32	-0.945	0.3688	**< 0.001**
6	30	-0.884	0.2255	**0.0080**	32	-1.607	0.4762	**< 0.001**
7					26	-1.290	0.3403	**0.002**

Table 4. Number of recaptured American shad in 2011 at the Conowingo Dam East and West Fish Lifts by tag color and year.

East Fish Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2011	20
Pink	2010	4
West Fish Lift		
Tag Color	Year Tagged	Number Recaptured
Green	2011	4
Pink	2010	2

Table 5. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2010. Due to sampling limitations, no data were available for 2011.

Year	Number of Interviews	Total Fishing hours	Total Catch of American Shad	Mean Number of American shad caught per hour
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	85.0	120	1.41
2010	36	64.0	114	1.78

Table 6. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for American shad, 1999-2011.

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

Table 7. Numbers of adult hickory shad and repeat spawners by sex and age sampled from the brood stock collection survey in Deer Creek in 2011.

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
3	45	0	20	0	65	0
4	36	35	29	28	65	63
5	36	35	23	23	59	58
6	10	10	9	9	19	19
7	2	2	4	4	6	6
8	0	0	2	2	2	2
Totals	129	82	87	66	216	148
Percent Repeats	63.6%		75.9%		68.5%	

Table 8. Percent of hickory shad by age and number sampled from the brood stock collection survey in Deer Creek by year, 2004-2011.

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	

Table 9. Percent repeat spawning hickory shad (sexes combined) by year from the brood stock collection survey in Deer Creek, 2004-2011.

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

Table 10. Catch (numbers), effort (hours fished) and catch per angler hour from spring logbooks for hickory shad, 1998-2011.

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

Figure 1. Conowingo Dam (Susquehanna River) hook and line sampling location for American shad in 2011.

Figure 2. Arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace, 1984-2011.

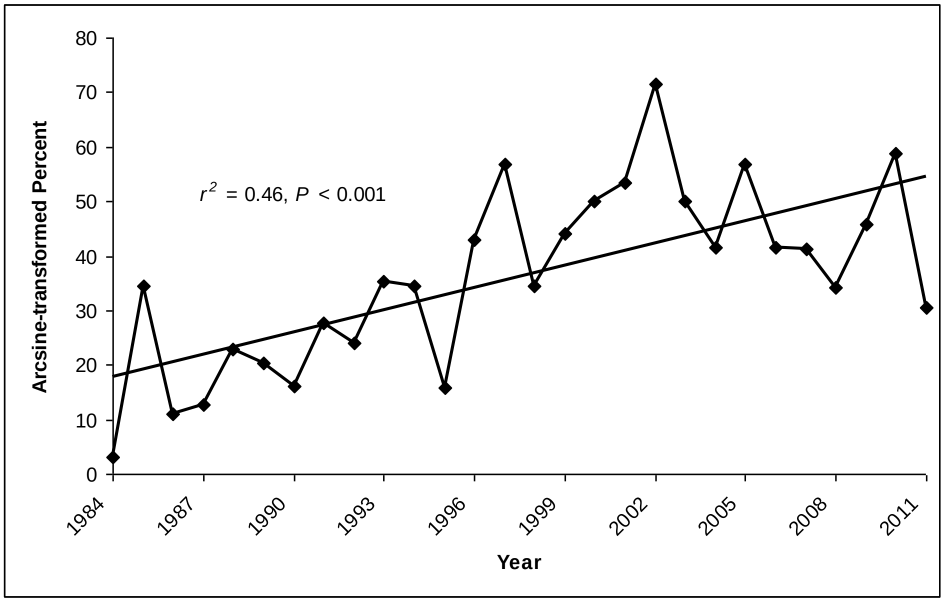

Figure 3. Mean length by age over time for male American shad, 1980-2011. Trend lines are included for ages where mean length varies significantly over time.

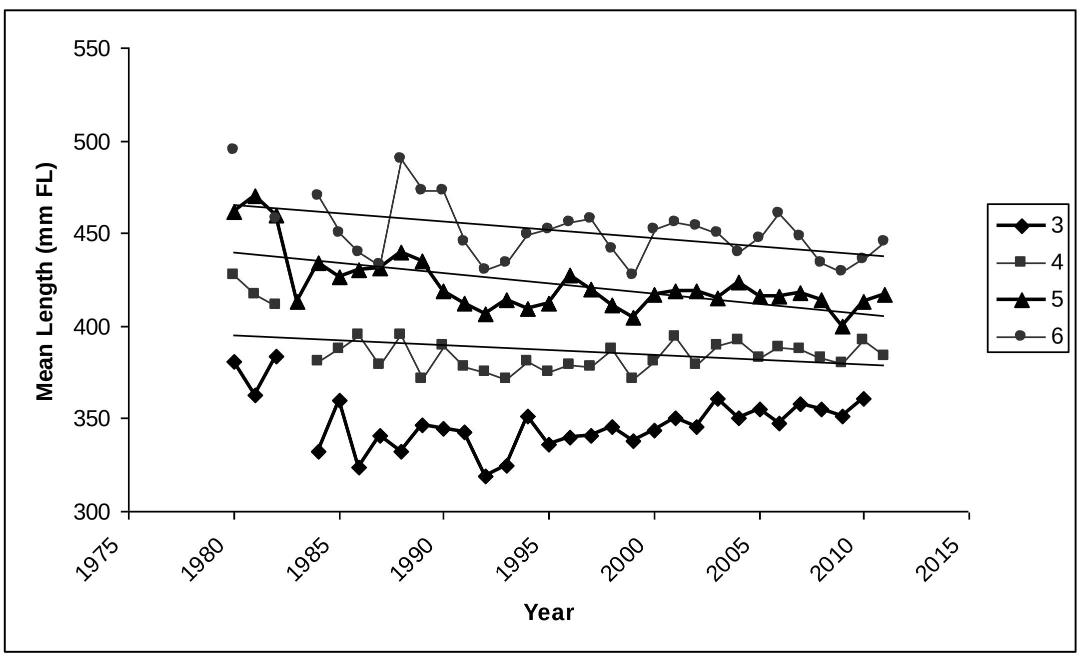

Figure 4. Mean length by age over time for female American shad, 1980-2011. Trend lines are included for ages where mean length varies significantly over time.

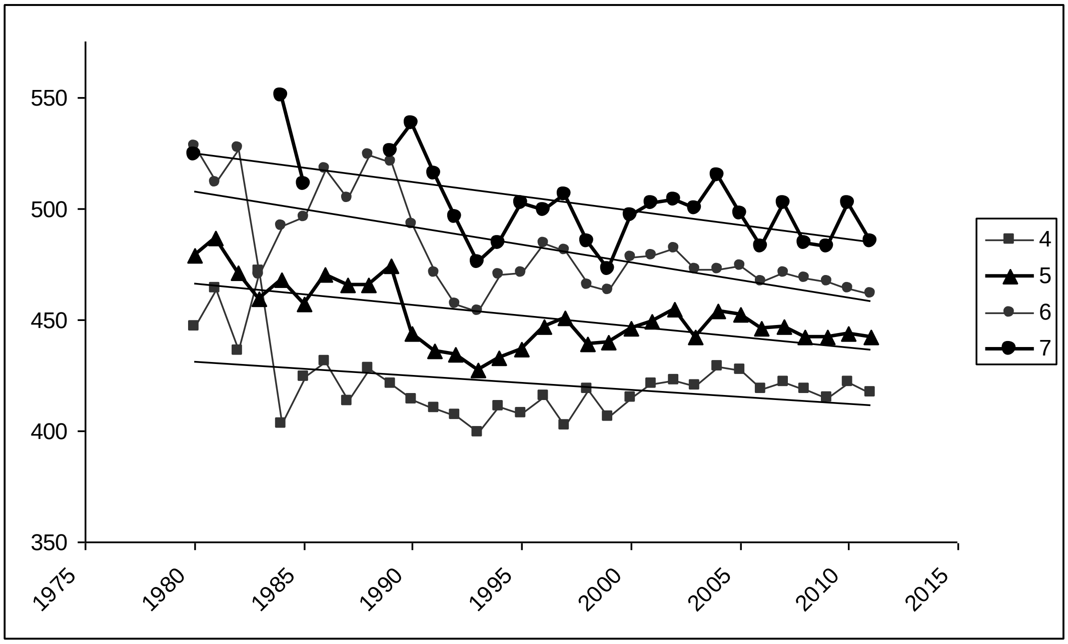

Figure 5. Conowingo Dam tailrace adult American shad abundance estimates from the Petersen statistic and the surplus production model (SPM), 1986-2011.

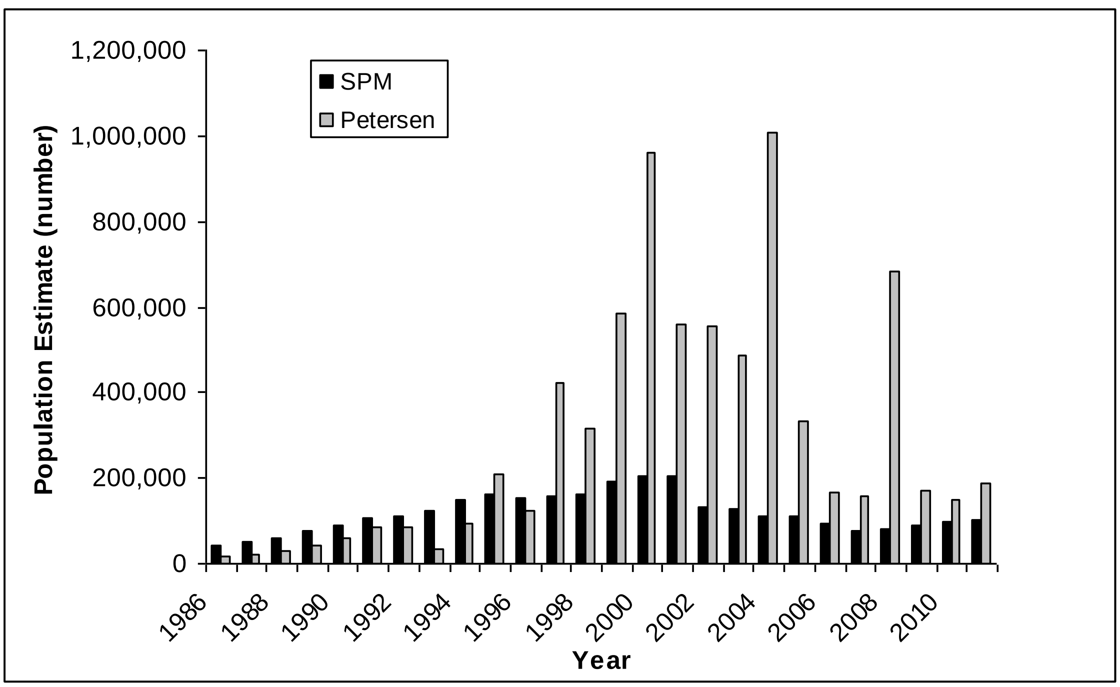

Figure 6. American shad geometric mean CPUE (fish per boat hour) from the Conowingo Dam tailrace hook and line sampling, 1984-2011.

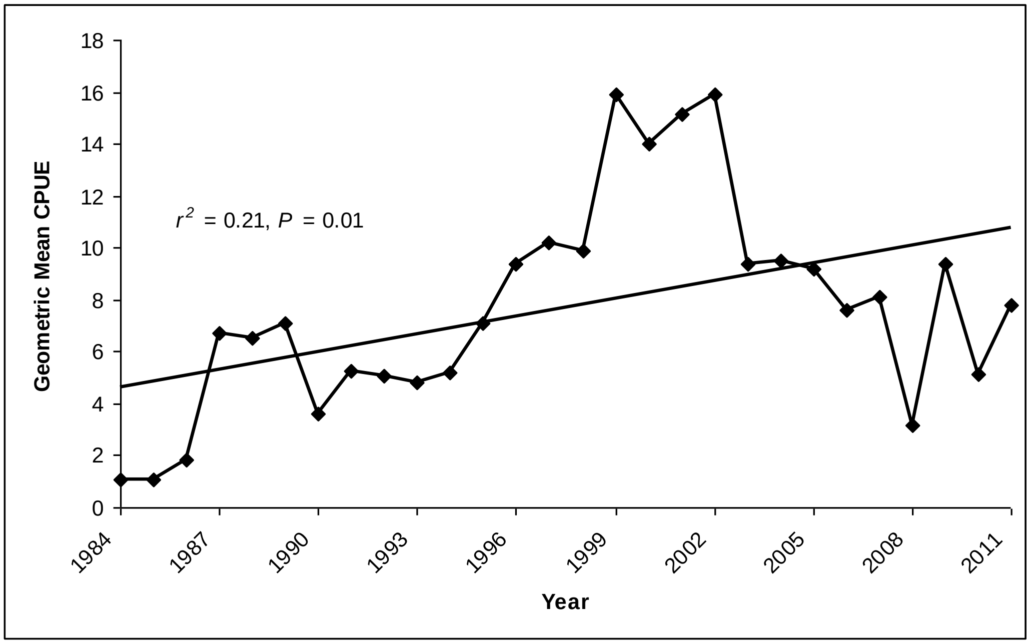

Figure 7. American shad geometric mean CPUE (fish per lift hour) from the East and West Fish Lifts at the Conowingo Dam, 1980-2011.

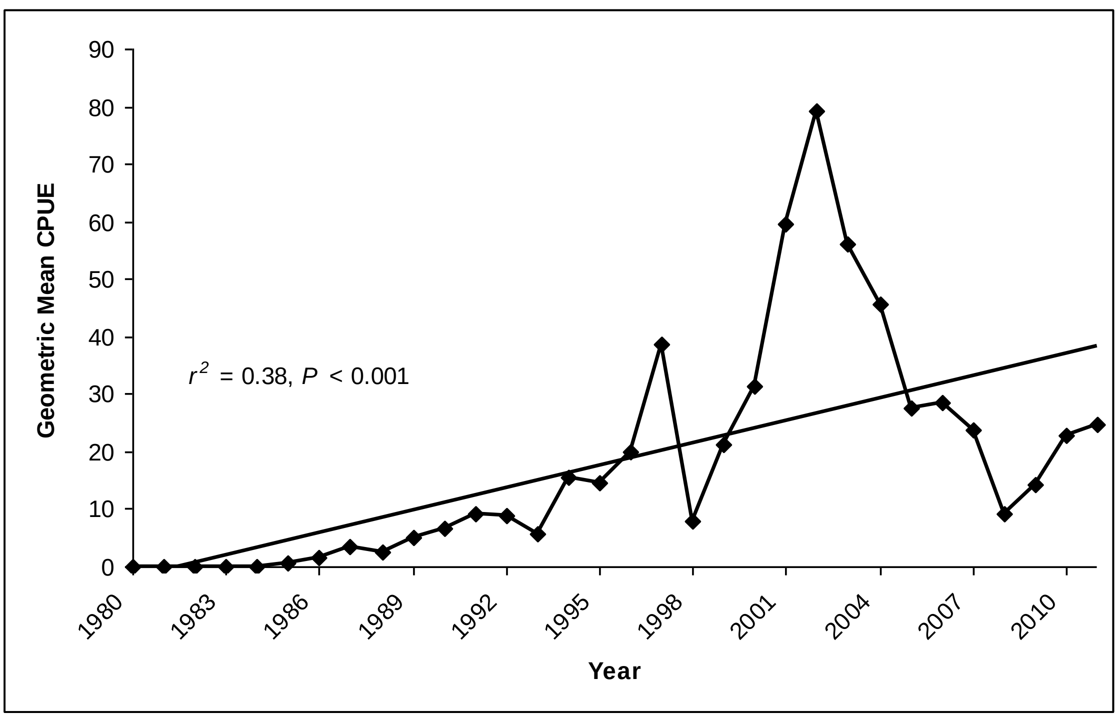

Figure 8. Arcsine-transformed percentages of repeat spawning hickory shad (sexes combined) collected from Deer Creek (Susquehanna River), 2004-2011.