RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER

ANNUAL PROGRESS REPORT

2007

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

February 2011

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2007 EXECUTIVE SUMMARY

This 2007 Executive Summary 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 to return migratory fishes to historic spawning and nursery habitat upstream of dams in the Susquehanna River by all of the SRAFRC parties and their partners.

Conowingo Dam East Fish Lift Operations

The start of operation for the East Fish Lift in 2007 was delayed by cold river temperatures and high river flows. Operation of the lift began on 23 April when river temperature reached 52°F and spill conditions had ended. The first American shad was not caught until 26 April. The passage of over 200 shad on 27 April triggered everyday operation which continued to the end of the season on 31 May. The season ended, when a combination of high water temperatures, dwindling shad numbers (less than 30 shad per day during last three days of operation), and the late season condition of the shad ultimately required operations to cease. The lift operated a total of 39 days during the 2007 season. Mechanical problems experienced during the 2007 season were minor and were resolved quickly to avoid interruptions to lift operations.

A total of 539,203 fish of 29 species and two hybrids was passed upstream into Conowingo Pond. Gizzard shad (508,627), American shad (25,464), white perch (1,434), quillback (1,236), alewife and blueback herring (889), and walleye (695), were the dominant species passed. Gizzard shad and American shad comprised 94.3% and 4.7% respectively of the season total; the two species together accounted for 99% of the total fish passed. Other common fishes included shorthead redhorse (173), striped bass (127), smallmouth bass (123), channel catfish (108), and carp (107). Alosids, (American shad, and river herring comprised 4.9 % of the total catch. Peak passage occurred on 28 April when 49,457 fish, (99.6% gizzard shad), were passed.

The East lift collected and passed 25,464 American shad. The first shad was passed on 26 April. Collection and passage of shad varied daily with 6.6% (1,686) of the shad passed from 26 to 30 April, 52.9% (13,475) passed from 1 to 10 May, 32.7 % (8,331) passed from 11 to 20 May, and 7.7% (1,972)

passed from 21 to 31 May (Figures 1 and 2). On 10 of the 39 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on 8 May when 3,025 American shad were passed. American shad were collected at water temperatures of 55.8 to 79.2°F and at natural river flows of 14,000 to 68,800 cfs. The natural river flow and water temperature during the five highest days of shad passage, (2, 3, 8,12 and 19 May), ranged from 26,600 cfs to 55,800 cfs and 60.9°F to 70.7°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 43,820 cfs. The average daily river flow during the operational season was 40,808 cfs. Peak passage of shad (22,389 or 88% of total passage) occurred between 1000 and 1759 h. The highest hourly shad passage rate, (4,075), was recorded from 1400 to 1459 h. Generally, shad passage increased during the morning hours, peaked and remained steady throughout the day, then sharply declined after 1800 hrs.

Conowingo Dam West Fish Lift Operations

Conowingo Dam West Fish Lift (West Lift) operations began on April 30 and occurred on 29 of the days until May 31. Total fishing effort over this period amounted to 288 lifts and a fishing time of 135.3 hours. Total catch amounted to 159,389 fish (35 taxa). Gizzard shad comprised 92.1% of the total catch and the next four most numerous species, American shad, white perch, walleye, and channel catfish, comprising 6.2% of the total. Alosine catch included 4,272 American shad (2.7% of the total catch), 160 river herring, and no hickory shad. Catch of American shad averaged 147 per operating day with peak day catches of 425 and 668 shad on May 9 and May 20, respectively. Every 50th shad collected throughout the season was killed for otolith analysis and scale samples.

Holtwood Dam Fish Lift Operations

Fishway operations at Holtwood Dam began on May 1, 2007. The tailrace lift was operated for 35 days while the spillway lift operated on 8 days. Lift operations were terminated for the season, with agency concurrence, on 4 June. The tailrace lift operated flawlessly during the passage season, resulting in no lost fishing time and the passage of 10,338 American shad. Although the spillway entrance gate was unable to be repaired prior to or during the season, the spillway lift was operated resulting in the passage of 485 American shad. The 2007 fish passage season marks the eleventh year of operation at Holtwood.

The lifts passed 143,421 fish of 25 taxa. Gizzard and American shad dominated the catch, and comprised 92% of the total fish collected and passed. American shad represented the sole *Alosa* species captured. No river herring were observed at Holtwood in 2007. Collection and passage of shad varied daily with

nearly 60% of total shad (6,188) passed during the 9 day period from 20 through 28 May (immediately after flashboard installation and river flows dropped below station capacity). The highest daily shad catch occurred on 22 May when 966 shad moved upstream during 10.6 hours of operation. On a daily basis, shad passage was consistent through the fishway between 1000 hrs and 1759 hrs.

Fishway operations were conducted at water temperatures ranging from 59.1°F to 79.8°F and river flows between 13,600 and 59,100 cfs. Spillage occurred on 16 days from 1 to 17 May, (prior to flashboard installation). River water temperatures rose quickly this spring reaching 70°F on 12 May, which may have accelerated American shad spawning. American shad of advanced or post-spawned condition were frequently observed during fish passage operations from mid- May to end of season. The 2007 American shad passage total was the third lowest number of fish observed since operations began in 1997. Compared with the Conowingo passage numbers, Holtwood passed 40.6% of the Conowingo catch - the fifth highest passage percentage rate recorded in the eleven years of fish lift operations at Holtwood. A low, stable, river flow appears to be critical for enhancing shad passage rates. Although stable or decreasing river flows were encountered this season, American shad passage numbers at all Susquehanna River fish passage facilities were lower than anticipated. Cold river water temperatures and high river flows in April delayed the start of fish passage operations and a period of warm weather in mid-May caused water temperatures to quickly soar above 70°F resulting in a shorter passage season in Spring 2007.

Safe Harbor Dam Fish Lift Operations

The Safe Harbor fishway began operation on 7 May, with operations ending on 5 June. A total of 112,484 fish of 20 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (84,466) was the dominant species passed and comprised 75% of the catch. Some 7,215 American shad were passed upstream through the fish way and comprised 6% of the catch. Other predominant fishes passed included quillback (12,980), channel catfish (2,462), walleye (1,869), and shorthead redhorse (1,446). Peak passage occurred on 10 May, when 7,589 fish were passed.

The Safe Harbor fishway passed 7,215 American shad in 2007 during 30 days of operation. This year's operating season was much shorter than in recent years and collection and passage of shad varied daily. The Conowingo fishway also had a short season (39 days) and passed 25,464 American Shad, which is their lowest season total since 1993. Having lower numbers of shad in the system and stable river flows, Safe Harbor still managed to pass 7,215 American Shad, or 69.8% of the shad passed at Holtwood Dam

(10,338). Moreover, the Safe Harbor fishway passed 28% of the American Shad passed by Conowingo Dam. Peak shad passage occurred on 26 May when 797 shad were captured and passed during 9.8 hours of operation. American shad were passed at water temperatures of 62.5°F to 79.8°F and river flows of 12,900 to 46,200 cfs (Table 2 and Figures 1and 2). Water temperature and river flow on those 7 days when more than 500 American shad were passed averaged 70.4°F (67.0°F to 74.5°F) and 19,200 cfs, (16,700 cfs to 23,200 cfs), respectively.

York Haven Dam Fish Ladder Operations

The York Haven Fish Ladder was opened on April 2 allowing volitional (unmanned) passage. Manned fishway operation started on 16 May and ended on 6 June. During this 22 day period a total of 31,670 fish of 17 taxa were enumerated as they passed upstream though the ladder into Lake Frederic. Gizzard shad (21,843) was the dominant fish species passed and comprised 70% of the fish passed. Passage varied daily and ranged from 10,045 fish on 6 May to 961 fish on 24 May. American shad were passed at water temperatures of 63.0° F to 79.7° F, and river flows that ranged from 9,300 cfs to 26,300 cfs and East Channel flows of 2,100 cfs to 3,400 cfs. Shad passage varied daily with nearly 92% of total shad passed (176) in May. Passage during May occurred at river flows that declined from 26,300 cfs to 10,300 cfs. Water temperature during this period averaged 70.0° F and ranged from 63.0° F to 78.1° F. East Channel flows averaged 2,334 cfs (2,100 cfs to 3,400 cfs). Passage in June occurred at Rivers flows that averaged 11,667 cfs and ranged from 11,400 cfs to 12,700 cfs. Water temperature during this period averaged 76.5° F (72.5° F to 79.7° F) and East Channel flows were stable at 2,100 cfs.

Potomac River American Shad Egg Collection

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. During April and May, 2007 USFWS used monofilament gill nets to collect 787 viable American shad from the Potomac River (rkm 150). The purpose of sampling was to supply viable 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 183.9 L of American shad eggs (7.5 million) with a 42% fertilization rate resulting in 2.9 million viable eggs. As a proportion of the total catch, ripe and green female American shad were equally represented (25.6% ripe, 26.4% green) and twice that of males (13.5%). The U.S. Fish and Wildlife Service's second attempt to deliver eggs for Susquehanna River American shad restoration resulted in slightly higher numbers of viable eggs despite the reduction of

fishing time and collection location. Results from the Potomac River nearly equaled the viable eggs delivered from the Delaware and Susquehanna Rivers combined (3.0 million eggs).

Delaware River American Shad Egg Collection

The PFBC also collected shad eggs from the Delaware River at Smithfield Beach, PA. A key element in the restoration of American shad 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. Fishing occurred from 9 May through 31 May 2007. Eggs were collected and shipped on 15 of the 16 nights of fishing. A total of 764 adult shad were captured and 135.8 liters of eggs were shipped for a hatchery count of 6.5 million eggs. Overall, the viability for Delaware River American shad eggs was 36.4%. A total of 282 thousand American shad larvae were stocked in the Lehigh River, 541 thousand were stocked in the Schuylkill River, and 48 thousand were stocked in the Delaware River at Smithfield Beach to replenish the Delaware for the adults used for egg-take.

Tank Spawning Trial for American and Hickory Shad

The results of the hickory shad hormone-induced spawning tests at Conowingo Dam in 2007 showed a continuation of the high quality levels achieved from 2005 an 2006. Hormone induced spawning trials with hickory shad at Conowingo Dam began on 23 April and concluded on 1 May, 2007. During this interval, 3 spawning trials were conducted with 384 adult hickory shad. Each trial lasted two days with the largest pulse of eggs produced on the second day. A total of 27.9.1 liters of eggs was collected from the hickory shad trials. Over 25 liters were shipped to the Van Dyke Hatchery and the remaining 2.8 liters were released into the river below Conowingo Dam. The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 69.3%. Water temperature in the spawning tanks ranged from 11.5 to 16.2°C and dissolved oxygen levels ranged from 9.3 to 12.2 ppm. Adult mortality rate for hickory shad during the spawning trials was 3.1%.

This was the seventh year of hormone induced American shad spawning tests at the Conowingo West Fish Lift. A total of 14 on-site spawning trials with 1504 American shad from 1 to 30 May produced 89.6 liters of eggs. Eighty four liters of eggs were shipped to the Van Dyke Hatchery and the remaining 5.6 liters released into the river below Conowingo Dam. Nine of the trials were conducted with pelletized

implants, three with liquid injections and in two trials a combination of pellets and liquid injections was used. The 3:2 sex ratio in favor of males was achieved in most trials as well as a stocking density of 1 fish per 125 liters of water. The total volume of eggs produced per female in individual 2007 trials (0.148 liters) was below the average of 0.363 liter observed for the previous six years. When adjusted for viability, the volume of viable eggs produced per female in the 2007 trials ranged from 0.05 to less than 0.01 liter. Water temperatures and oxygen levels in the spawning tanks were monitored daily and ranged from 17.4 to 24.5°C and 4.7 to 13 ppm. The overall estimated viability of the eggs shipped to VanDyke was 8.9%. Mortality rate for adult American shad during the 2007 trials was 8.3%. Mortality ranged from 2 to 11.5% in previous years.

American shad Hatchery Operations

The PFBC has operated the Van Dyke Research Station for Anadromous Fishes (Van Dyke) since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River Basin. The objectives of Van Dyke were to research culture techniques for American shad and to rear juveniles for release into the Juniata and Susquehanna Rivers. The program goal is to develop a stock of shad imprinted to the Susquehanna drainage, which will subsequently return to the river as spawning adults. As is previous years, production goals for American shad for 2007 were to stock 10-20 million American shad larvae. All Van Dyke hatchery-reared American and hickory 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.

Four shipments of hickory shad eggs (12 million eggs) were received at Van Dyke in 2007. Egg viability was 69% and 8.0 million hickory shad larvae were stocked in Conowingo Reservoir and in Delaware River tributaries, Pennypack Creek and Ridley Creek.

A total of 38 shipments of American shad eggs (21 million eggs) was received at Van Dyke in 2007. Total egg viability was 28% and survival of viable eggs to stocking was 43%, resulting in production of 2.5 million larvae. Larvae were stocked in the Juniata River (1.0 million), the Susquehanna River near Clemson Island (80 thousand), the West Branch Susquehanna River (68 thousand), the North Branch Susquehanna River in Pennsylvania (29 thousand), Conodoguinet Creek (69 thousand), and West Conewago Creek (50 thousand). Delaware River source larvae were stocked in the Lehigh River (282 thousand), the Schuylkill River (541 thousand) and the Delaware River (48 thousand).

Overall survival of larvae was 43%. No episodes of major mortality occurred as a result of larvae lying on the bottom of the tank but high mortalities occurred in many tanks, particularly late in the season. These mortalities are thought to be due to oxygen super-saturation, low pH and/or aluminum toxicity.

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 mark retention specimens examined exhibited tetracycline marks; however the marks did not always appear as intended, presumably due to poor health and growth of the fish. Many mark retention specimens had missing marks or marks that were close together due to poor growth. These marks may be difficult to identify from wild-caught fish. Digital photographs of representative specimens have been archived to aid in future mark evaluation. Hickory shad were marked at 512 ppm on day three. Mark retention for hickory shad was not evaluated because no specimens survived raceway culture.

Abundance and Distribution of Juvenile American Shad

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 oxytetracycline marks to determine hatchery versus wild composition of the samples. Sub-samples of up to 30 juveniles per day were used for otolith analysis. 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 oxytetracycline immersion treatments. A total of 24 juvenile American shad were collected in haul seines, lift nets, Peach Bottom intakes and Conowingo strainers. Of the 24 specimens evaluated for hatchery tags, 25% were wild and 75% were hatchery. Represented in the catch were YOY shad from releases in the Juniata River, Conodoguinet Creek, West Conewago Creek, and the West Branch Susquehanna River. No shad were recaptured from releases in North Branch Susquehanna River. The poor juvenile catch rates in 2007 can be attributed to decreased egg deliveries, poor survival in the hatchery, and poor fish passage.

Analysis of Adult American Shad Otoliths

A total of 158 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2007. Based on oxytetracycline marking and otolith microstructure, 52% of the 155 readable otoliths were identified as wild and 48% 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 1986-2001 year classes, stocking of approximately 306 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 1.31 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.

American Eel Sampling at Conowingo Dam

USFWS staff from Maryland Fishery Resources Office in Annapolis sampled for American immediately downstream for Conowingo Dam. The objective was to determine the best method to reintroduce eels into the Susquehanna River above the Conowingo dam. USFWS collected baseline information on eel abundance, migration timing, catchability, and attraction parameters at the base of the Conowingo Dam since 2005. As in previous years a modified Irish elver ramp was used to sample for elvers, and eel pots with a 6 mm square mesh were also set around the base of the West Fish Lift to catch larger eels. In 2007 an experimental eel passage (elver ramp) was also deployed on the west bank in an attempt to enhance data collection on the population of juvenile eels at the base of Conowingo Dam. The elver ramp was initially operated outside of the West Fish Lift raceway, but due to large fluctuations in the water levels caused by power generation, and a lack of rain, the ramp would become inoperable during periods of low water level. The ramp was moved to the shore adjacent to the West Fish Lift where 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.

Eels were sampled between 30 May and 8 August 2007. Juvenile eel length frequencies ranged from 76 to 169 mm TL, and the length frequency of yellow and silver eels varied from 256 to 734 mm TL. Yellow and silver eels captured were sedated, measured, fin clipped, and had a Passive Integrated Transponder tag (PIT tag) inserted in the dorsal musculature and released. A total of 51 silver or yellow eels was captured and tagged, 28 of which were recaptured at a later sampling date in 2007. Elvers were sedated, measured, counted, and in the occurrence of large numbers, eels were volumetrically counted. Elvers were then transported to Deer Creek and released above Wilson Mill dam. Several methods of collecting elvers were attempted and altered as the sampling season progressed. The Irish elver ramp that was operated on the rip rap by the West Fish Lift was the most successful method of capturing elvers, capturing significantly more elvers than the eel passage pipe. The overflow from water pumped to the west fish lift ran down to an eddy in the river directly below the dam. This may have provided an

attractive flow in the area where elvers were observed concentrating. Yellow eels may become "trap happy" (show an affinity for entering the trap) or set up a confined home range from which they do not emigrate or immigrate since the same individuals were recaptured many times. It appears that elvers reach the base of Conowingo Dam in the first week of May and are found there through the end of June.

In 2007 a marking experiment was conducted to test an age analysis marking technique used on other fish species. A sample of elvers captured at Conowingo Dam was taken to Manning Hatchery in Maryland and marked with oxytetracycline (OTC). The elvers were immersed in an OTC bath at a concentration of 550 ppm for 7 hours. After which the elvers were placed in a small pond on the hatchery grounds and then sampled a year later. A total of 31 elvers were harvested from the pond and sacrificed. Their otoliths were removed and viewed under an ultraviolet light to observe for OTC markings. The results of this experiment indicate that American eel form growth rings on the otolith that can be marked with OTC.

Upper Chesapeake Bay American Shad Population Assessment

Maryland Department of Natural Resources (MD DNR) collected shad for tag and release by angling in the Conowingo tailrace. The 2007 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.70:1. Of the 468 fish sampled by this gear, 449 were scale-aged. Males were present in age groups 3-8 while females were found in age groups 4-9 (Table 1). The 2003 year-class of males (age IV) was the most abundant age group sampled, accounting for 53% of the total catch. For females, the 2002 (age V) was the most abundant age group, accounting for 43%, of the total catch. The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line in 2007 was 14.1% for males and 17.4% for females. The arcsine-transformed proportions of these repeat spawners (sexes combined) had been increasing through 2002 but have been decreasing in recent years. The Conowingo tailrace American shad relative population estimate in 2007 was 158,148 with a 95% confidence interval of 200,377-124,717. No juvenile American shad were caught in the Susquehanna River during the inriver summer seining, in 2007.

Funding Summary

Fish passage facility maintenance, operations, fish counting and reporting were paid by each of the partner hydroelectric project owners 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 PFBC. MD DNR funded the adult shad population assessment, stock analysis, and

juvenile shad seining in the upper Chesapeake Bay. USFWS covered most costs associated with the eel survey at Conowingo. Costs related to Conowingo West Lift operations including tank spawning and hormones were paid from a SRAFRC contributed funds account administered by USFWS. Contributions to the account in 2007 were made by MD DNR and PFBC.

Additional information on activities discussed in this Executive Summary can be obtained from individual Job authors, or by contacting the Susquehanna River Coordinator at:

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1.0 JOB 1, PART 1: SUMMARY OF OPERATIONS AT CONOWINGO DAM EAST FISH PASSAGE FACILITY, 2007

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1.1 INTRODUCTION

Susquehanna Electric Company (SECO), a subsidiary of Exelon Generation, 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 Passage Facility (East lift) at Conowingo Dam. Construction of the East lift 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 East lift has been operated to pass fish directly into Conowingo Pond since spring 1997.

Objectives of 2007 operation were: (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway and trough effectiveness and make modifications as feasible.

1.2 CONOWINGO OPERATION

1.2.1 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.

1.2.2 Fishway Operation

The start of operation for the East Fish Lift in 2007 was delayed by cold river temperatures and high river flows. Operation of the lift began on 23 April when river temperature reached 52°F and spill conditions had ended. The first American shad was not caught until 26 April. The passage of over 200 shad on 27 April triggered everyday operation which continued to the end of the season on 31 May. The season ended, when a combination of high water temperatures, dwindling shad numbers (less than 30 shad per day during last three days of operation), and the late season condition of the shad ultimately required operations to cease. The lift operated a total of 39 days during the 2007 season. Mechanical problems experienced during the 2007 season were minor and were resolved quickly to avoid interruptions to lift operations.

Daily operation times were planned during optimal fish passage parameters. Operational methodologies were influenced by natural river flows, water temperatures, generation schedules, and fish population numbers. Fishway 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 2007 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 was negated or disrupted. Depending on flow, and or generation, entrance C or A was utilized throughout the 2007 season to attract fishes.

1.2.3 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.

1.3 RESULTS

1.3.1 Relative Abundance

The number of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 1. A total of 539,203 fish of 29 species and two hybrids was passed upstream into Conowingo Pond. Gizzard shad (508,627), American shad (25,464), white perch (1,434), quillback (1,236), alewife and blueback herring (889), and walleye (695), were the dominant species passed. Gizzard shad and American shad comprised 94.3% and 4.7% respectively of the season total; the two species together accounted for 99% of the total fish passed. Other common fishes included shorthead redhorse (173), striped bass (127), smallmouth bass (123), channel catfish (108), and carp (107). Alosids, (American shad, and river herring comprised 4.9 % of the total catch. Peak passage occurred on 28 April when 49,457 fish, (99.6% gizzard shad), were passed.

1.3.2 American Shad Passage

The East lift collected and passed 25,464 American shad (Table 1). The first shad was passed on 26 April. Collection and passage of shad varied daily with 6.6% (1,686) of the shad passed from 26 to 30 April, 52.9% (13,475) passed from 1 to 10 May, 32.7 % (8,331) passed from 11 to 20 May, and 7.7% (1,972) passed from 21 to 31 May (Figures 1 and 2). On 10 of the 39 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on 8 May when 3,025 American shad were passed.

American shad were collected at water temperatures of 55.8 to 79.2°F and at natural river flows of 14,000 to 68,800 cfs (Table 2 and Figure 1). The natural river flow and water temperature during the five highest days of shad passage, (2, 3, 8,12 and 19 May), ranged from 26,600 cfs to 55,800 cfs and 60.9°F to 70.7°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 43,820 cfs. The average daily river flow during the operational season was 40,808 cfs.

The hourly passage of American shad for the East lift is given in Table 3. Peak passage of shad (22,389 or 88% of total passage) occurred between 1000 and 1759 h. The highest hourly shad passage rate, (4,075), was recorded from 1400 to 1459 h. Generally, shad passage increased during the morning hours, peaked and remained steady throughout the day, then sharply declined after 1800 hrs.

1.3.3 Alosids

A small number of Alewife (429) and blueback herring (460) were passed during the 2007 season. No hickory shad were collected and passed in spring 2007.

Maryland tag-recapture

During the 2007 season, the East fish lift passed a total of 72 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the MDDNR. Of these floy-tagged fish, 66 tags were pink (2007 hook and line) and 6 were orange (2006 hook and line).

1.4 SUMMARY

East fish lift operation was initiated on 23 April. The first American shad was caught on 26 April. The East fish lift passed 25,464 American shad from 26 April through 31 May. The total number of American shad passed during the 2007 season was the lowest passage total for East lift operations since 1993, and is the third in eight years, (three years in a row) where the lift did not surpass the 100,000 mark (Table 4).

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 114 American shad lift mortalities, (0.45% of the total shad passed), were observed in 2007, 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%).

1.5 RECOMMENDATIONS

Continue to operate the East lift 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.

Continue the use of two fish counters during periods of increased fish passage to accurately reflect the number of fish that pass through the East lift.

Continue to inspect cables, limit switches, and lift components to enhance season operability, and

continue to evaluate effectiveness of fish trough modifications.

1.6 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.

1.7 TABLES AND FIGURES

Table 1: Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2007 (Page 1 of 5)

Date:	*4/23*	*4/24*	*4/25*	*4/26*	*4/27*	*4/28*	*4/29*	*4/30*
Start Fishing Time:	*11:00*	*10:00*	*10:00*	*10:00*	*11:00*	*9:45*	*9:30*	*8:00*
End Fishing Time:	*15:00*	*15:30*	*15:30*	*15:30*	*18:00*	*15:30*	*17:25*	*16:00*
Hours of Operation:	*4.0*	*5.5*	*5.5*	*5.5*	*7.0*	*5.8*	*7.9*	*8.0*
Number of Lifts:	*4*	*7*	*7*	*8*	*13*	*12*	*15*	*12*
Water Temperature (°F):	*53.6*	*57.2*	*56*	*58.1*	*58*	*59*	*58.1*	*59*
American Shad	0	0	0	1	224	55	1,312	94
Blueback herring	0	0	0	0	0	0	0	33
Alewife	0	0	0	0	330	74	0	0
Gizzard shad	806	6,516	10,819	11,761	22,808	49,282	21,927	21,008
Striped bass	0	0	0	0	1	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	0	0	5	24	85	173
Sea lamprey	0	0	0	0	1	4	3	2
Rainbow trout	3	0	1	1	1	0	1	0
Brown trout	0	0	0	0	0	0	1	2
Muskellunge	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	1	1	1	0	0	0	0
Quillback	2	3	2	0	3	1	0	8
White sucker	1	0	0	0	7	0	1	0
Shorthead redhorse	2	32	13	13	7	4	6	12
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	2	0	0	2	0	1
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	1	1	0	0
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0
Smallmouth bass	0	2	0	3	4	1	1	11
Largemouth bass	0	0	0	0	0	0	0	0
White Crappie	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	1	2	1	2	0	9	16	19
Longnose gar	0	0	0	0	0	0	0	0
TOTAL	815	6,556	10,839	11,782	23,392	49,457	23,353	21,363

Table 1: Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2007 (Page 2 of 5)

Date:	*5/1*	*5/2*	*5/3*	*5/4*	*5/5*	*5/6*	*5/7*	*5/8*
Start Fishing Time:	*7:30*	*7:50*	*7:40*	*7:30*	*11:30*	*7:20*	*7:45*	*7:30*
End Fishing Time:	*17:20*	*18:15*	*18:15*	*17:15*	*18:30*	*18:15*	*18:30*	*17:55*
Hours of Operation:	*9.8*	*10.4*	*10.6*	*9.8*	*7.0*	*10.9*	*10.8*	*10.4*
Number of Lifts:	*14*	*17*	*14*	*12*	*12*	*15*	*15*	*19*
Water Temperature (°F):	*60*	*60.5*	*62.6*	*63*	*64.4*	*63.5*	*64.4*	*65*
American Shad	169	1,748	2,323	1,319	403	929	280	3,025
Blueback herring	157	70	14	2	0	0	28	126
Alewife	0	23	0	2	0	0	0	0
Gizzard shad	20,501	17,541	7,285	13,136	13,750	15,202	18,778	21,516
Striped bass	1	1	1	2	2	2	1	3
Hybrid striped bass	0	0	0	0	0	0	0	3
White perch	83	27	23	8	119	760	42	20
Sea lamprey	0	2	0	1	0	1	0	2
Rainbow trout	2	0	0	0	0	0	0	0
Brown trout	0	1	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	1	0	0	3	2	0	2
Quillback	0	2	14	9	11	2	3	4
White sucker	0	3	0	0	0	0	0	0
Shorthead redhorse	16	12	2	4	11	4	5	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	1
Channel catfish	1	2	0	5	7	3	7	8
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	3	1	1	0	2	2	0	0
Green sunfish	0	1	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	1	0	2	0	0	0	1	0
Smallmouth bass	6	15	16	8	8	3	4	7
Largemouth bass	0	0	0	0	2	0	0	0
White Crappie	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Yellow perch	1	0	0	0	0	0	0	0
Walleye	42	14	13	4	115	177	23	9
Longnose gar	0	0	0	0	0	0	0	0
TOTAL	20,983	19,464	9,694	14,500	14,433	17,087	19,172	24,726

Table 1: Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2007 (Page 3 of 5)

Date:	*5/9*	*5/10*	*5/11*	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*
Start Fishing Time:	*7:30*	*7:30*	*7:40*	*7:50*	*7:10*	*7:00*	*7:30*	*7:30*
End Fishing Time:	*18:20*	*18:30*	*17:00*	*18:30*	*18:00*	*16:00*	*17:00*	*17:00*
Hours of Operation:	*10.8*	*11.0*	*9.3*	*10.7*	*10.8*	*9.0*	*9.5*	*9.5*
Number of Lifts:	*15*	*15*	*15*	*26*	*23*	*11*	*13*	*15*
Water Temperature (°F):	*66.2*	*68*	*68*	*69.9*	*70*	*71.6*	*71.1*	*73.4*
American Shad	1,557	1,722	789	2,108	1,169	48	305	401
Blueback herring	8	2	2	0	2	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	11,830	17,626	21,280	16,291	13,828	8,556	13,189	21,417
Striped bass	1	1	5	1	13	2	7	8
Hybrid striped bass	0	1	0	0	0	0	0	0
White perch	11	1	8	5	26	0	0	0
Sea lamprey	0	0	0	2	0	0	0	1
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	1	0	1	1	3	0	1	1
Muskellunge	0	0	0	1	0	0	0	0
Tiger musky	0	0	0	0	1	0	0	0
Carp	6	11	11	5	4	4	4	13
Quillback	41	61	11	22	22	119	35	35
White sucker	0	1	0	0	0	0	0	0
Shorthead redhorse	2	3	9	5	4	0	0	1
Yellow bullhead	0	0	0	2	0	0	0	0
Brown bullhead	3	0	0	1	63	0	3	5
Channel catfish	3	3	0	1	10	1	4	4
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	4	0	1	1
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	1
Bluegill	0	1	2	0	0	3	1	0
Smallmouth bass	1	10	8	1	3	1	0	2
Largemouth bass	0	0	0	0	1	0	0	1
White Crappie	1	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Yellow perch	0	1	0	0	0	0	1	0
Walleye	13	14	23	10	28	4	7	20
Longnose gar	0	1	0	0	0	0	0	0
TOTAL	13,478	19,459	22,149	18,456	15,181	8,738	13,558	21,911

Table 1: Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2007 (Page 4 of 5)

Date:	*5/17*	*5/18*	*5/19*	*5/20*	*5/21*	*5/22*	*5/23*	*5/24*
Start Fishing Time:	*7:30*	*7:45*	*7:40*	*7:30*	*7:30*	*7:30*	*7:45*	*7:30*
End Fishing Time:	*17:00*	*17:10*	*17:00*	*16:20*	*16:00*	*16:00*	*16:00*	*16:00*
Hours of Operation:	*9.5*	*9.4*	*9.3*	*8.8*	*8.5*	*8.5*	*8.3*	*8.5*
Number of Lifts:	*13*	*14*	*13*	*16*	*8*	*11*	*9*	*10*
Water Temperature (°F):	*74.3*	*71.6*	*70.7*	*69.9*	*70*	*71.6*	*71.6*	*71.6*
American Shad	513	280	1,936	782	46	364	369	410
Blueback herring	1	15	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	23,066	18,736	12,119	11,890	7,838	9,554	9,151	4,499
Striped bass	3	9	1	1	1	6	4	6
Hybrid striped bass	1	0	0	0	0	0	0	1
White perch	2	1	0	0	0	6	1	0
Sea lamprey	0	0	1	0	1	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	1	1	0	0	0	0	2	1
Muskellunge	0	1	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	7	2	0	0	7	1	1	0
Quillback	3	4	0	5	15	1	170	7
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	4	2	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	1	2
Channel catfish	5	6	1	0	3	3	4	3
Flathead catfish	1	0	0	0	0	0	0	0
Rock bass	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	1	2	1	0	1	0	0	1
Smallmouth bass	2	1	0	0	1	1	0	0
Largemouth bass	0	0	0	1	0	2	0	1
White Crappie	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Yellow perch	1	0	0	1	0	0	0	0
Walleye	12	34	8	3	7	17	16	5
Longnose gar	1	0	0	0	0	0	0	0
TOTAL	23,623	19,094	14,067	12,683	7,920	9,955	9,719	4,936

Table 1: Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2007 (Page 5 of 5)

Date:	*5/25*	*5/26*	*5/27*	*5/28*	*5/29*	*5/30*	*5/31*	***Season***
Start Fishing Time:	*7:50*	*7:30*	*7:30*	*7:30*	*7:00*	*7:45*	*7:30*	***Total***
End Fishing Time:	*16:00*	*16:00*	*16:00*	*16:00*	*15:00*	*15:00*	*13:30*	
Hours of Operation:	*8.2*	*8.5*	*8.5*	*8.5*	*8.0*	*7.3*	*6.0*	***335.25***
Number of Lifts:	*8*	*10*	*9*	*10*	*8*	*6*	*5*	***479***
Water Temperature (°F):	*72.5*	*75.4*	*77*	*75.2*	*77.9*	*79.7*	*80.1*	
American Shad	194	156	196	158	28	29	22	**25,464**
Blueback herring	0	0	0	0	0	0	0	**460**
Alewife	0	0	0	0	0	0	0	**429**
Gizzard shad	3,386	6,869	1,786	1,672	716	600	92	**508,627**
Striped bass	4	6	7	5	12	8	2	**127**
Hybrid striped bass	0	0	0	0	0	0	0	**6**
White perch	0	0	0	1	2	1	0	**1,434**
Sea lamprey	0	0	1	0	0	0	0	**22**
Rainbow trout	0	1	0	0	0	0	0	**10**
Brown trout	0	0	0	0	0	0	0	**17**
Muskellunge	0	0	0	0	0	0	0	**2**
Tiger musky	0	0	0	0	0	0	0	**1**
Carp	0	0	4	5	10	1	0	**107**
Quillback	17	10	449	84	20	14	27	**1,236**
White sucker	0	0	0	0	0	0	0	**13**
Shorthead redhorse	0	0	0	0	0	0	0	**173**
Yellow bullhead	0	0	0	0	0	0	0	**2**
Brown bullhead	1	0	0	0	0	0	0	**80**
Channel catfish	1	2	2	3	7	3	1	**108**
Flathead catfish	0	0	0	0	0	0	0	**1**
Rock bass	0	0	0	0	0	0	0	**17**
Green sunfish	0	0	0	0	0	0	0	**1**
Pumpkinseed	0	0	0	1	0	0	0	**2**
Bluegill	2	1	3	0	3	0	1	**27**
Smallmouth bass	1	0	0	1	1	0	0	**123**
Largemouth bass	0	0	2	1	0	0	0	**11**
White Crappie	0	0	0	0	0	0	0	**1**
Black Crappie	0	0	0	1	0	0	0	**1**
Yellow perch	0	0	0	0	0	0	0	**5**
Walleye	2	9	7	4	2	2	1	**695**
Longnose gar	0	0	0	0	0	0	0	**1**
TOTAL	3,608	7,054	2,457	1,936	801	658	146	**539,203**

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 2007 (Page 1 of 2)

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
23-Apr	0	*0*	99,800	*52.2*	12	11	C	310	23.5-24.3	108.2	2
24-Apr	0	*0*	84,000	*55.0*	6	11	C	310	23.3-23.7	108.5	1
25-Apr	0	*0*	72,600	*57.4*	12	10	C	310	22.5	105.9	0
26-Apr	1	*1O*	66,400	*58.2*	12-18	11	C	310	23.0	107.2	0
27-Apr	224	*0*	64,700	*56.9*	18	11	C	310	23.0	108.6	0
28-Apr	55	*0*	68,800	*55.8*	18	10	C	310	22.0-22.5	106.9	0
29-Apr	1,312	*0*	65,400	*56.1*	18	8	C,A	310	20.0-21.0	107.5	0
30-Apr	94	*0*	62,800	*57.3*	18	11	C	310	23.0-23.4	106.8	0
1-May	169	*0*	56,500	*59.1*	18	11	C	310	21.9-24.5	108.3	1
2-May	1,748	*0*	55,800	*60.9*	24	11	C	310	21.0-22.5	107.0	0
3-May	2,323	*0*	53,700	*62.4*	24	11	C,A	310	20.0-23.6	106.9	0
4-May	1,319	*0*	59,100	*63.2*	24	11	C,A,C	310	20.0-23.6	107.4	0
5-May	403	*0*	57,500	*63.2*	24	8	C	310	22.0-23.0	107.4	0
6-May	929	*1O*	53,700	*63.1*	28	8	C	310	20.5-22.5	107.6	0
7-May	280	*0*	46,200	*62.5*	18	11	C	310	21.5-23.6	107.4	0
8-May	3,025	*3P,1O*	41,100	*62.7*	25	11	C,A,C	310	19.0-23.5	107.0	0
9-May	1,557	*4P*	37,400	*63.9*	25	10	C,A,C	310	20.0-23.0	107.3	0
10-May	1,722	*8P,1O*	32,800	*66.0*	25	11	C,A	310	19.5-23.0	107.1	0
11-May	789	*0*	33,500	*68.3*	27	11	C,A	310	19.6-23.6	107.5	0
12-May	2,108	*10P, 2O*	33,200	*70.7*	28	5	C	310	21.0	107.7	0
13-May	1,169	*9P*	34,100	*71.9*	26	7	A,C	310	17.0-21.0	107.5	0
14-May	48	*0*	35,100	*71.7*	28	7	C	310	22.5-23.0	106.8	0
15-May	305	*1P*	33,800	*70.3*	28	11	C	310	22.0-23.5	107.1	0
16-May	401	*1P*	32,700	*69.4*	24	11	C	310	21.6-23.6	107.3	0
17-May	513	*3P*	30,100	*69.1*	26	11	C	310	21.0-23.4	107.8	0

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 2007 (Page 2 of 2)

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
18-May	280	*0*	27,800	*69.5*	22	7	C	310	21.0-22.4	107.2	0
19-May	1,936	*8P*	25,600	*68.8*	28	2	A	310	17.7-18.3	108.1	0
20-May	782	*5P*	25,600	*67.8*	24	2	A	310	18.0	107.7	0
21-May	46	*0*	24,700	*66.7*	28	7	A,C	310	20.4-22.5	108.7	0
22-May	364	*4P*	23,200	*67.0*	28	7	A,C	310	19.4-22.5	108.3	0
23-May	369	*2P*	20,700	*67.4*	25	7	A,C	310	18.0-22.9	108.2	0
24-May	410	*5P*	19,300	*69.0*	25	7	A,C	310	17.0-22.0	107.4	0
25-May	194	*1P*	18,300	*70.7*	28	7	A,C	310	17.9-22.6	107.9	0
26-May	156	*2P*	16,700	*72.5*	28	4	A,C	310	17.0-18.5	107.6	0
27-May	196	*0*	17,100	*74.5*	28	5	A,C	310	17.0-20.5	107.9	0
28-May	158	*0*	16,800	*76.0*	28	6	A,C	310	18.4-21.5	107.8	0
29-May	28	*0*	16,300	*77.1*	30	4	A,C	310	18.5-21.9	107.5	0
30-May	29	*0*	14,600	*78.4*	30	7	A	310	18.0-20.0	106.8	0
31-May	22	*0*	14,000	*79.2*	30	2	A	310	17.8	106.0	0

* Tag color: P = pink, O = orange.

Table 3: Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2007 (Page 1 of 2)

Date:	*4/23*	*4/24*	*4/25*	*4/26*	*4/27*	*4/28*	*4/29*	*4/30*	*5/1*	*5/2*	*5/3*	*5/4*
Observation Time-Start:	*12:15*	*10:50*	*10:45*	*10:15*	*11:00*	*10:15*	*9:45*	*8:45*	*8:20*	*8:20*	*8:10*	*8:00*
Observation Time-End:	*16:00*	*16:00*	*16:00*	*16:00*	*18:30*	*16:00*	*18:00*	*16:35*	*18:00*	*18:45*	*18:50*	*17:59*
Military Time (hrs)												
0700 to 0759												
0800 to 0859								30	0	3	16	70
0900 to 0959								32	3	43	79	21
1000 to 1059		0	0	0		44	1	17	10	83	62	12
1100 to 1159		0	0	0	0	5	0	6	19	68	75	93
1200 to 1259	0	0	0	0	2	3	0	3	45	91	54	329
1300 to 1359	0	0	0	0	3	1	3	3	21	290	317	249
1400 to 1459	0	0	0	1	20	1	342	0	36	323	577	227
1500 to 1559	0	0	0	0	18	1	361	2	12	371	504	137
1600 to 1659					76		309	1	15	211	323	110
1700 to 1759					79		296		8	190	221	71
1800 to 1859					26					75	95	
1900 to 1959												
Total	0	0	0	1	224	55	1,312	94	169	1,748	2,323	1,319

Date:	*5/5*	*5/6*	*5/7*	*5/8*	*5/9*	*5/10*	*5/11*	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*
Observation Time-Start:	*12:20*	*8:00*	*8:05*	*8:00*	*8:00*	*8:00*	*8:15*	*8:15*	*8:00*	*8:00*	*8:05*	*8:00*
Observation Time-End:	*19:00*	*18:45*	*18:50*	*18:30*	*19:00*	*19:00*	*17:30*	*18:53*	*18:30*	*16:30*	*17:30*	*17:30*
Military Time (hrs)												
0700 to 0759												
0800 to 0859		31	6	17	11	17	87	7	93	8	1	6
0900 to 0959		44	9	32	34	117	46	56	170	8	5	5
1000 to 1059		12	21	17	86	102	88	375	171	6	48	3
1100 to 1159		15	6	6	137	225	124	415	114	5	108	30
1200 to 1259	17	39	27	223	119	285	126	335	111	2	22	69
1300 to 1359	10	39	59	430	235	264	91	246	74	9	22	74
1400 to 1459	10	170	33	944	333	127	56	232	148	4	38	67
1500 to 1559	17	302	78	615	272	152	102	166	108	4	39	45
1600 to 1659	65	127	21	450	144	218	52	103	154	2	13	48
1700 to 1759	132	104	14	256	162	147	17	134	9		9	54
1800 to 1859	152	46	6	35	24	68		39	17			
1900 to 1959												
Total	403	929	280	3,025	1,557	1,722	789	2,108	1,169	48	305	401

Table 3: Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2007 (Page 2 of 2)

Date:	*5/17*	*5/18*	*5/19*	*5/20*	*5/21*	*5/22*	*5/23*	*5/24*	*5/25*	*5/26*	*5/27*	*5/28*
Observation Time-Start:	*8:00*	*8:10*	*8:00*	*8:00*	*8:00*	*8:10*	*8:00*	*8:00*	*8:30*	*8:00*	*8:00*	*8:00*
Observation Time-End:	*17:30*	*17:40*	*17:30*	*16:40*	*16:30*	*16:30*	*16:30*	*16:30*	*16:30*	*16:30*	*16:30*	*16:15*
Military Time (hrs)												
0700 to 0759												
0800 to 0859	36	34	76	74	3	14	11	23	14	22	51	37
0900 to 0959	102	41	271	127	1	38	68	61	42	57	82	73
1000 to 1059	90	63	321	194	7	111	124	99	46	24	34	26
1100 to 1159	36	29	309	137	16	81	80	96	45	22	20	14
1200 to 1259	72	34	311	103	6	52	33	69	30	17	6	4
1300 to 1359	21	27	261	74	12	36	30	37	4	8	1	3
1400 to 1459	47	18	227	42	0	12	8	20	6	1	2	1
1500 to 1559	50	13	100	27	0	13	12	4	3	5	0	0
1600 to 1659	42	10	44	4	1	7	3	1	4	0	0	0
1700 to 1759	17	11	16									
1800 to 1859												
1900 to 1959												
Total	513	280	1,936	782	46	364	369	410	194	156	196	158

Date:	*5/29*	*5/30*	*5/31*	***Season***
Observation Time-Start:	*8:00*	*8:00*	*8:00*	***Total***
Observation Time-End:	*15:30*	*15:15*	*14:00*	
Military Time (hrs)				
0700 to 0759				
0800 to 0859	10	0	2	**810**
0900 to 0959	9	3	3	**1,682**
1000 to 1059	5	1	4	**2,307**
1100 to 1159	3	7	5	**2,351**
1200 to 1259	0	11	8	**2,658**
1300 to 1359	1	2	0	**2,957**
1400 to 1459	0	2		**4,075**
1500 to 1559	0	3		**3,536**
1600 to 1659				**2,558**
1700 to 1759				**1,947**
1800 to 1859				**583**
1900 to 1959				
Total	28	29	22	**25,464**

Table 4: Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2007

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**

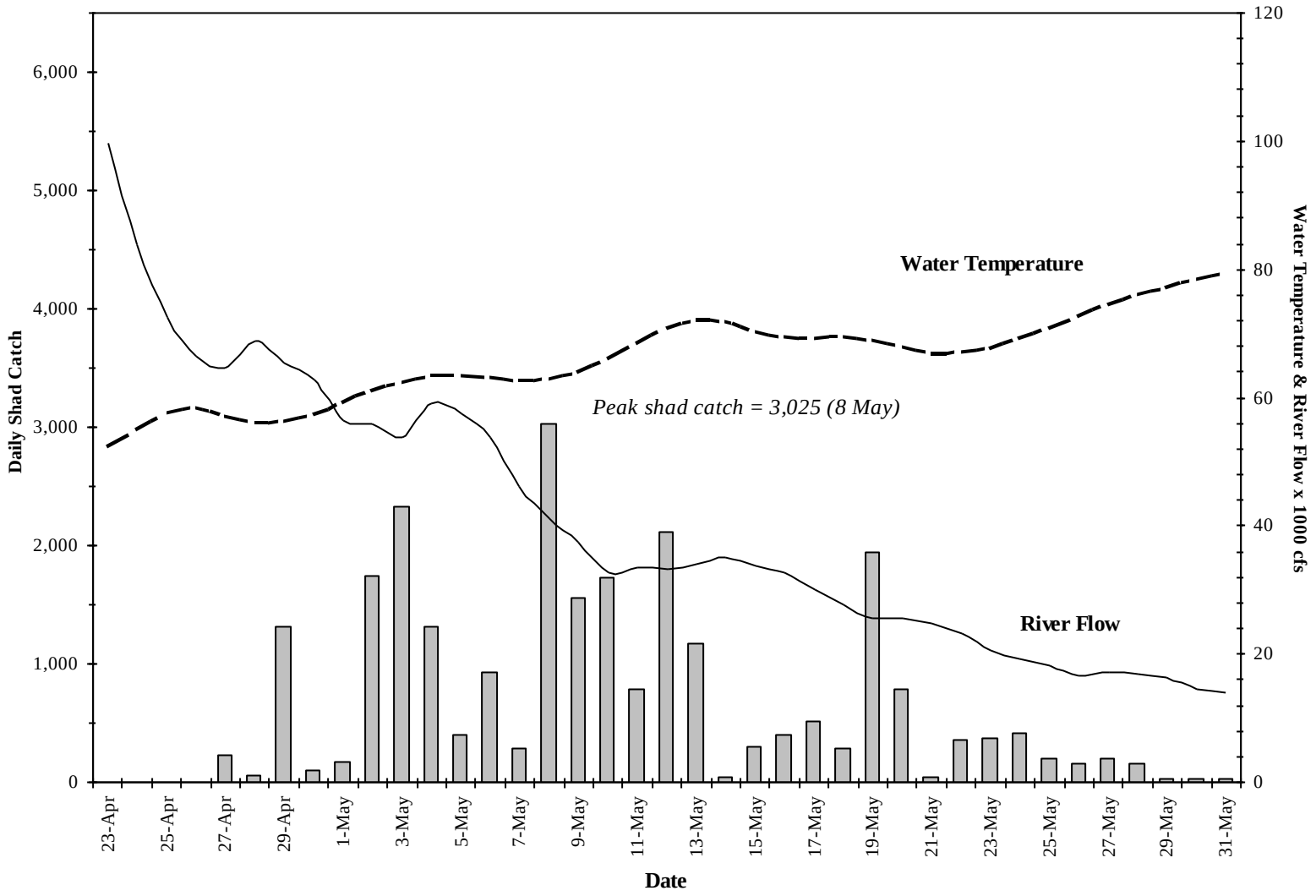

Figure 1: A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the daily American shad catch at the Conowingo East Fish Lift, spring 2007

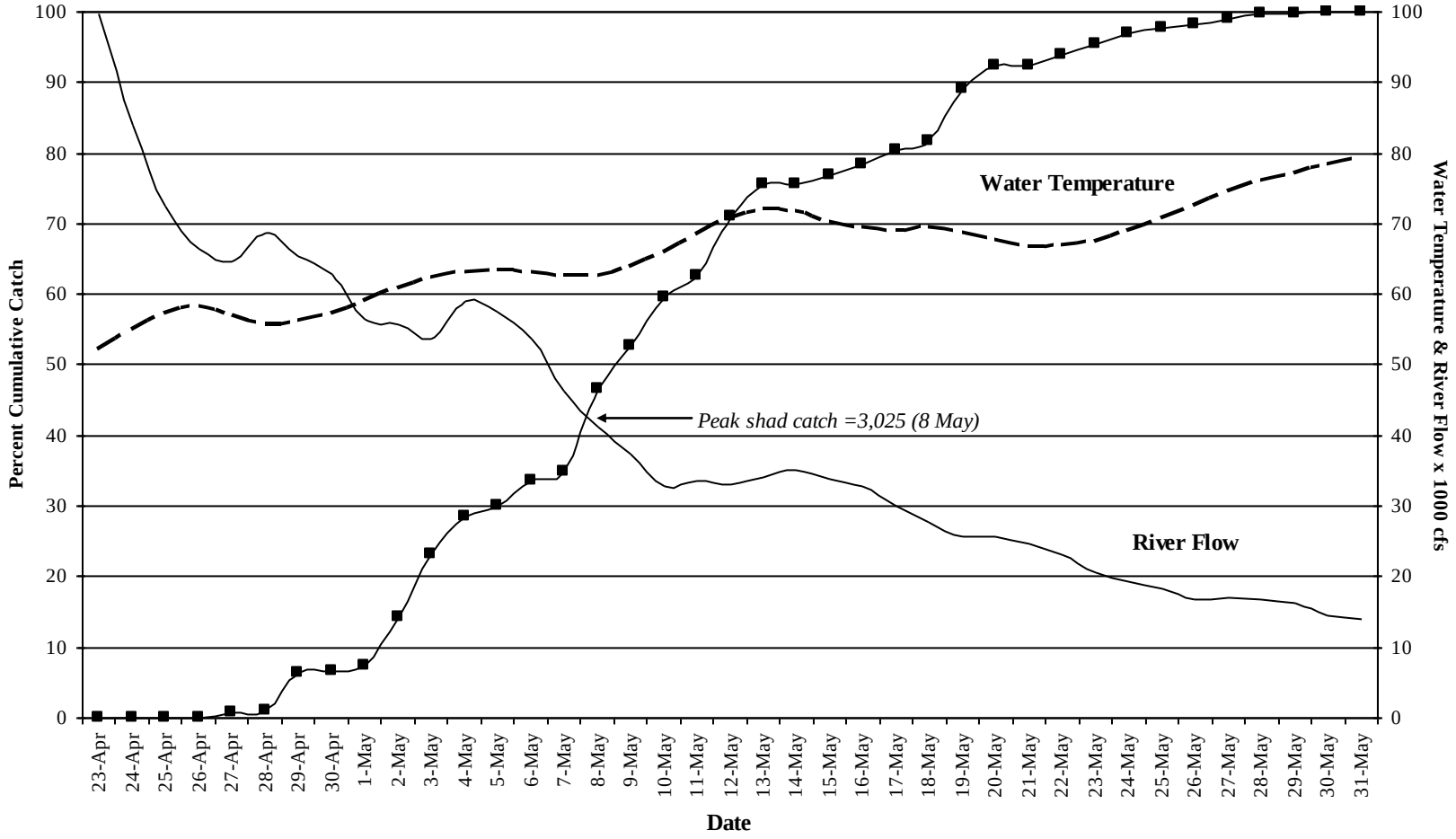

Figure 2: A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the percent cumulative American shad catch at the Conowingo East Fish Lift, spring 2007.

2.0 JOB 1, PART 2: SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS, 2007

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2.1 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 capturing and counting American shad, river herring, other migratory species and resident fishes in the tailrace. From 1985 through 1996, most shad collected at the West Fish Lift have been sorted from the daily catch, placed into circular transport tanks, and stocked into suitable spawning waters above 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 functional fish passage available at Holtwood and Safe Harbor dams in 1997, the Conowingo East Fish Lift has been operated to pass all lifted fish directly into the Conowingo Hydroelectric Project head pond (see Job 1, Part 1). Upstream hydroelectric project operators are no longer obligated under the settlement agreement to pay for trap and transport activities from the Conowingo fish lifts; however Exelon Power (Exelon) has agreed to maintain and operate the West Fish Lift, and to enter into an annual contract with a consultant for West Fish Lift trapping, egg taking, and data collection operations. Annual West Fish Lift operational details are coordinated with state, regional, and federal resource agencies through the Susquehanna River Technical Committee (SRTC) which oversees fish passage operations efforts at the Conowingo Hydroelectric Project. Funding to reimburse Exelon for contractor expenses for West Fish Lift operations, as well as shad tank spawning trials in 2008 was derived from annual contributions by the Pennsylvania Fish and Boat Commission (PFBC) and the Maryland Department of Natural Resources (MD DNR) to the Susquehanna River Anadromous Fish Restoration Cooperative's (SRAFRC) contributed funds account. These contributed funds have been administered by the U.S. Fish and Wildlife Service (USFWS), Susquehanna River Coordinator (Coordinator).

The objectives of Conowingo West Fish Lift operations in 2007 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. Shad taken here are also monitored for MD DNR tags and sex ratios, and scale and head samples are taken for age and otolith analysis. No fish were trucked for release upstream of the hydroelectric dams during 2007.

2.2 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 hours). Within these parameters the West Fish Lift was operated as in past years, maintaining appropriate entrance velocities and curbing use of adjacent hydroelectric generation Units 1 and 2, whenever river flow dropped below 60,000 cfs. Normandeau Associates (NA) was contracted by Exelon to conduct fish lift and/or passage operations at both the Conowingo Hydroelectric Project East and West fish lifts, and to conduct American shad tank spawning trials for delivery of eggs to PFBC Van Dyke shad hatchery.

American shad collected in the trap 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 MDNR for tank spawning in 2007. 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.

2.3 RESULTS

Figure 1 shows daily West Fish Lift shad catch, river flow and water temperatures for the 2007 season. Average daily river flow at Conowingo during the West Fish Lift operating period declined steadily from a high of about 63,000 cfs at the end of April to a low of 14,000 cfs by May 31. Water temperature during the same period increased more or less rapidly from 58 to 70° F by May 15, and hovered around 70° F May 25 after which they rose steadily to a temperature of 76° F to May 31 when the fish lift was shut down for the season.

Lift operations began on April 30 and occurred on 29 of the next 32 days through May 31 (Table 2). Total fishing effort over this period amounted to 288 lifts and a fishing time of 135.3 hours. Total catch at the West Fish Lift amounted to 159,389 fish of 35 taxa, including hybrids (Table 1). Gizzard shad comprised 92% of the total catch and, channel catfish, walleye, and white perch comprised 3.4% of the total. Alosine catch included 4,272 American shad (2.6% of the total catch), 160 river herring, and no hickory shad. Catch of American shad averaged 147 per operating day with peak day catches of 668 and 425 shad on May 20 and 9, respectively. Daily operating parameters and catch by major species is shown in Table 2. Overall male to female sex ratio of shad in the West Fish Lift in 2007 was 1.0 to 1.7 (Table 3).

West Fish Lift catch per effort of 31.6 shad per fishing hour, 15 shad per lift, and 147 shad per day were higher than that reported for the two previous years (Table 4). Operations and fish catch at the West Fish Lift during 1985-2007 are summarized in Table 5.

2.4 DISCUSSION

Spring 2007 water temperatures during West Fish Lift operations were initially cooler, but increased more quickly to a higher level than in 2006 (58-77 vs. 63-72 ° F) and river flows decreased gradually in 2007 compared to 2006. Peak day catches occurred on May 9 and 20 and overall, daily shad abundance was higher in 2007 and overall annual catch was higher despite there being a 27% decrease in the number of lifts and eight fewer operational days in 2007. Most shad collected in 2007 were released alive back to the tailrace.

2.5 TABLES AND FIGURES

Table 1: Catch of fishes at the Conowingo Dam West Fish Lift, 2007

Number of Days	**29**
Number of Lifts	**288**
Fishing Time (hours : minutes)	**135 h:20 min**
Number of Taxa	**34 + 1 hybrid**
AMERICAN SHAD	4,272
HICKORY SHAD	0
BLUEBACK HERRING	153
ALEWIFE	7
GIZZARD SHAD	146,821
STRIPED BASS	263
Hybrid Striped Bass	2
White Perch	2,276
American Eel	27
Brook Trout	13
Brown Trout	6
Rainbow Trout	1
Northern Pike	1
Carp	372
Comely Shiner	45
Spotfin Shiner	986
Mimic Shiner	1
Quillback	73
White Sucker	4
Shorthead Redhorse	144
White Catfish	5
Brown Bullhead	237
Channel Catfish	1,480
Flathead Catfish	13
Rock Bass	30
Redbreast Sunfish	53
Green Sunfish	1
Pumpkinseed	8
Bluegill	85
Smallmouth Bass	140
Largemouth Bass	34
Black Crappie	2
Yellow Perch	49
Walleye	1,776
Atlantic Needlefish	3
Sea Lamprey	6
Total	159,389

Table 2: Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 30 April - 31 May, 2007 (Page 1 of 2)

Date:	30-Apr	1-May	2-May	3-May	4-May	5-May	6-May	7-May
Day:	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY
Number of Lifts:	11	17	21	22	18	10	10	7
Time of First Lift:	11:25	9:15	10:05	9:55	10:15	10:15	10:15	13:15
Time of Last lift:	15:35	15:00	16:40	16:50	15:45	15:50	15:55	16:25
Operating time (hours):	4:10	5:45	6:35	6:55	5:30	5:35	5:40	3:10
Average Water Temperature (°F):	58.28	58.91	60.62	62.06	62.69	63.86	63.8	63.6
American shad	0	2	21	72	46	330	103	73
Blueback herring	2	0	3	0	4	38	74	1
Alewife	0	0	1	0	5	0	0	1
Gizzard shad	10,400	16,700	16,200	18,800	14,500	3,250	4,200	3,400
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	0	0	1	0	1	0	0	1
Carp	3	0	1	6	3	1	0	0
Other species	670	214	146	106	206	139	113	312
Total	11,075	16,916	16,373	18,984	14,765	3,758	4,490	3,788

Date:	8-May	9-May	10-May	11-May	13-May	15-May	16-May	17-May
Day:	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY	TUESDAY	WEDNESDAY	THURSDAY
Number of Lifts:	19	11	12	11	6	9	12	8
Time of First Lift:	9:55	12:45	10:05	12:15	12:15	12:35	9:45	11:05
Time of Last lift:	15:45	16:40	15:40	15:45	14:45	15:45	14:50	16:30
Operating time (hours):	5:50	3:55	5:35	3:30	2:30	3:10	5:05	5:25
Average Water Temperature (°F):	64.2	64.7	64.9	65.8	68.1	70.5	71.6	71.8
American shad	161	425	152	186	266	115	179	106
Blueback herring	1	0	1	23	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	17,500	5,000	6,700	4,800	1,400	4,050	7,510	3,900
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	0	4	11	5	1	12	57	4
Carp	0	2	1	1	1	159	11	106
Other species	533	399	405	348	54	218	401	121
Total	18,195	5,830	7,270	5,363	1,722	4,554	8,158	4,237

Table 2: Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 30 April - 31 May, 2007 (Page 2 of 2)

Date:	18-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May
Day:	FRIDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Number of Lifts:	10	8	7	7	5	5	5	5
Time of First Lift:	9:45	11:00	9:55	13:55	11:20	14:05	10:50	13:25
Time of Last lift:	16:20	17:00	15:00	16:00	15:30	15:45	14:55	15:55
Operating time (hours):	6:35	6:00	5:05	2:05	4:10	1:40	4:05	2:30
Average Water Temperature (°F):	70.4	69.3	70.2	70.7	69.7	69.2	70.2	71.2
American shad	64	668	84	376	113	213	195	100
Blueback herring	5	0	0	0	0	1	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	2,050	650	725	0	1,640	1,155	282	125
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	39	0	14	4	25	7	22	7
Carp	5	0	7	1	0	5	1	3
Other species	125	70	155	61	151	119	380	116
Total	2,288	1,388	985	442	1,929	1,500	880	351

Date:	27-May	28-May	29-May	30-May	31-May	
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	**Total for the Year**
Number of Lifts:	7	6	7	6	6	**288**
Time of First Lift:	9:50	11:00	10:20	12:10	9:55	
Time of Last lift:	15:50	15:45	15:45	15:45	15:00	
Operating time (hours):	6:00	4:45	5:25	3:35	5:05	**135:20:00**
Average Water Temperature (°F):	72.1	72.7	74.0	77.0	76.0	
American shad	114	74	8	24	2	**4,272**
Blueback herring	0	0	0	0	0	**153**
Alewife	0	0	0	0	0	**7**
Gizzard shad	106	55	385	1,322	16	**146,821**
Hickory shad	0	0	0	0	0	**0**
Striped bass	9	12	13	9	5	**263**
Carp	5	0	8	40	2	**372**
Other species	166	173	550	550	500	**7,501**
Total	400	314	964	1,945	525	**159,389**

Table 3: American shad sex ratio information, Conowingo West Fish Lift, 2007. No operation on 12, 14, and 19 May

Date	Sample size	Males	Females	Male:Female Ratio	
30-Apr	0	0	0	0	
1-May	2	1	1	1:	1.0
2-May	21	10	11	1:	1.1
3-May	72	43	29	1:	0.7
4-May	45	20	25	1:	1.3
5-May	149	85	64	1:	0.8
6-May	3	2	1	1:	0.5
7-May	73	46	27	1:	0.6
8-May	102	56	46	1:	0.8
9-May	114	64	50	1:	0.8
10-May	101	57	44	1:	0.8
11-May	142	71	71	1:	1.0
13-May	137	53	84	1:	1.6
15-May	101	46	55	1:	1.2
16-May	106	49	57	1:	1.2
17-May	103	41	62	1:	1.5
18-May	64	33	31	1:	0.9
20-May	474	120	354	1:	3.0
21-May	84	28	56	1:	2.0
22-May	215	65	150	1:	2.3
23-May	107	30	77	1:	2.6
24-May	213	49	164	1:	3.3
25-May	195	51	144	1:	2.8
26-May	100	25	75	1:	3.0
27-May	114	32	82	1:	2.6
28-May	74	20	54	1:	2.7
29-May	8	1	7	1:	7.0
30-May	24	5	19	1:	3.8
31-May	2	0	2	0	
Total	**2,945**	**1,103**	**1,842**	**1:**	**1.7**

Table 4: Catch and effort of American shad taken at the Conowingo Dam west Fish Lift during primary collection periods,* 1985-2007

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**

*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 - 2007

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**	**34**	**4,272**	**0**	**7**	**153**

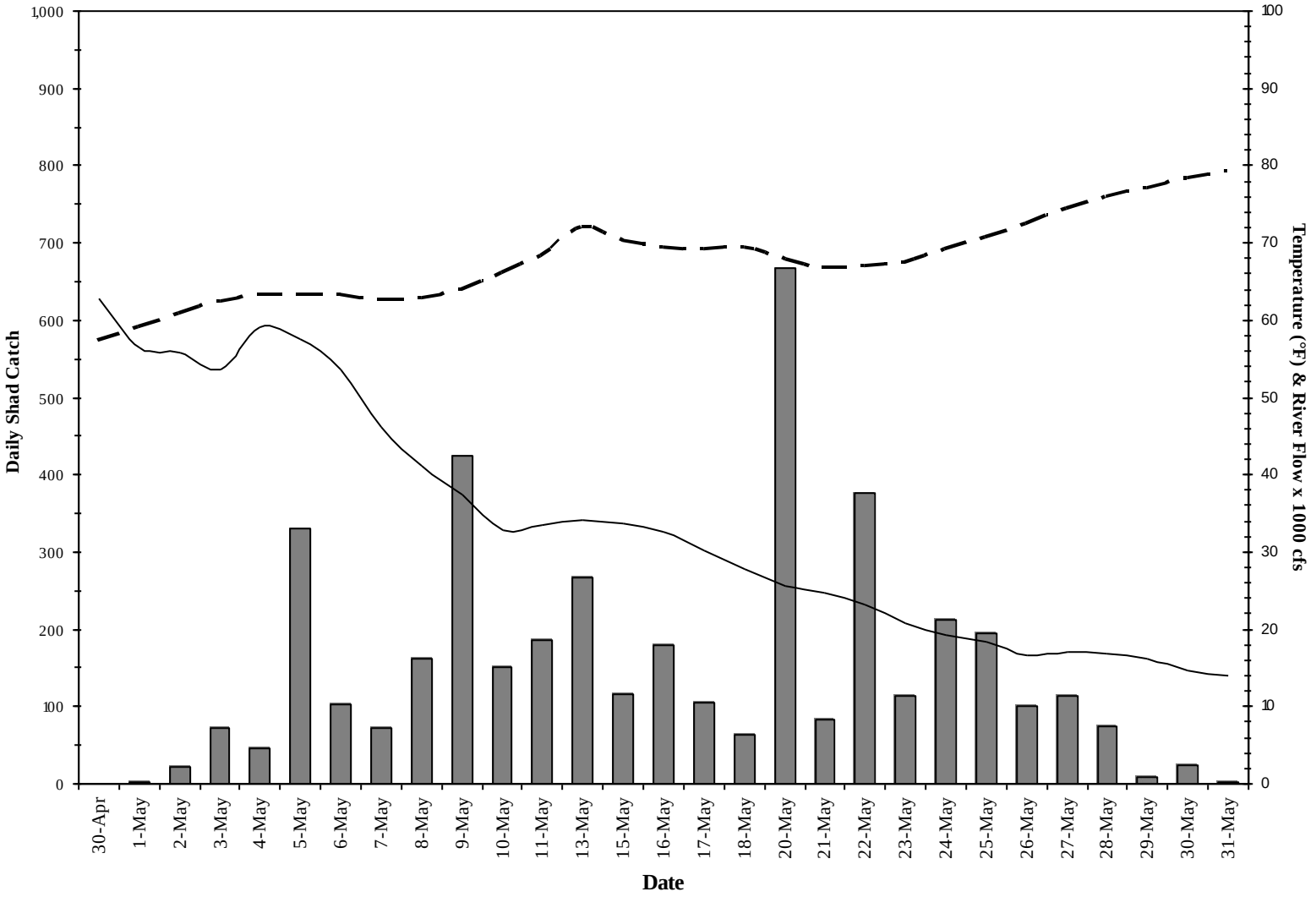

Figure 1: A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 2007. The West Lift was not operated on 12, 14 and 19 May.

3.0 JOB 1, PART 3: SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY, 2007

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3.1 EXECUTIVE SUMMARY

Fishway operations at Holtwood Dam began on 1 May 2007 the second latest start date at Holtwood since fish passage operations began in 1997. The tailrace lift was operated for 35 days while the spillway lift operated on 8 days. We terminated lift operations for the season, with agency concurrence, on 4 June. The tailrace lift operated flawlessly during the passage season, resulting in no lost fishing time and the passage of 10,338 American shad. Although the spillway entrance gate was unable to be repaired prior to or during the season, the spillway lift was operated resulting in the passage of 485 American shad. The 2007 fish passage season marks the eleventh year of operation at Holtwood.

The lifts passed 143,421 fish of 25 taxa. Gizzard and American shad dominated the catch, and comprised 92% of the total fish collected and passed. American shad represented the sole *Alosa* species captured. No river herring were observed at Holtwood in 2007.

A total of 9,853 American shad (95% of total shad catch) was passed in the tailrace lift while the spillway lift accounted for 485 American shad (5% of total shad catch). Collection and passage of shad varied daily with nearly 60% of total shad (6,188) passed during the 9 day period from 20 through 28 May (immediately after flashboard installation and river flows dropped below station capacity). The highest daily shad catch occurred on 22 May when 966 shad moved upstream during 10.6 hours of operation. On a daily basis, shad passage was consistent through the fishway between 1000 hrs and 1759 hrs.

Fishway operations were conducted at water temperatures ranging from 59.1°F to 79.8°F and river flows between 13,600 and 59,100 cfs. Spillage occurred on 16 days from 1 to 17 May, (prior to flashboard installation). River water temperatures rose quickly this spring reaching 70°F on 12 May, which may have accelerated American shad spawning. American shad of advanced or post-spawned condition were frequently observed during fish passage operations from mid-May to end of season.

Stable river flows and minimal rainfall this season resulted in excellent water clarity, which allowed the viewing technicians to identify several American shad with attached Maryland DNR floy tags. The number of floy tags observed at Holtwood in 2007 included 36 pink tags, (2007 Hook & Line), and 4 orange tags, (2006 Hook & Line).

The 2007 American shad passage total was the third lowest number of fish observed since operations began in 1997. Compared with the Conowingo passage numbers, Holtwood passed

40.6% of the Conowingo catch - the fifth highest passage percentage rate recorded in the eleven years of fish lift operations at Holtwood.

A low, stable, river flow appears to be critical for enhancing shad passage rates. Although stable or decreasing river flows were encountered this season, American shad passage numbers at all Susquehanna River fish passage facilities were lower than anticipated. Cold river water temperatures and high river flows in April delayed the start of fish passage operations and a period of warm weather in mid-May caused water temperatures to quickly soar above 70°F resulting in a shorter passage season in Spring 2007. Future operations of the fishway will build on the past eleven years of operation experience.

3.2 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 2007. This year marked the eleventh operational season.

Objectives of 2007 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.

3.3 HOLTWOOD OPERATION

3.3.1 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 32,000 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, operation of four rubber dams installed as part of the fishway project, and operation of the Safe Harbor Hydroelectric Station.

In spring 2007, rubber dams 2 and 3 were inoperable (not inflated) due to problems that occurred in March and April, and only nine turbines were available for generation due to the extended outage of Unit #10 for turbine replacement. Cold water temperatures and high river flows delayed the passage of American shad at Conowingo Dam until 29 April, resulting in a delayed start for fishway operations at Holtwood until 1 May. Due to damaged flashboards, inoperability of two rubber dams, and river flows greater than station capacity, spill occurred at Holtwood everyday except one, (8 May), from 1 to 17 May. On 8 May, power generation was reduced at Safe Harbor to allow rescue workers time to search for a drowning victim downstream of the Holtwood dam. New flashboards were installed 18 and 19 May, and with decreasing river flows, no additional spill events were observed during fish lift operations through the end of season. Passage operations ended on 4 June, with agency concurrence, due to an extended period of high water temperatures and a lack of pre-spawned shad available for passage.

3.4 FISHWAY DESIGN AND OPERATION

3.4.1 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.

Four inflatable rubber dams, operated from the hydro control room, are an integral component of effective spillway lift operation. During fish lift operations in 2007, only two of the four rubber crest dams were operational and flashboards were installed upstream of the two damaged rubber dams when river flows permitted, (18 and 19 May).

Design guidelines for fishway operation include three entrance combinations. These are: (1) entrance A, B, and C; (2) entrance A and B; and (3) 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 2007, entrance gate A was used exclusively in the tailrace to attract American shad, while spillway gate C was operated on a limited basis. Sustained high river flow events had prevented

the repair of the spillway gate and the removal of debris from the spillway crowder channel prior to the 2007 passage season. The debris was successfully removed after spill over the dam was stopped allowing the entranceway to be used. The spillway lift is also used less frequently when flashboard sections are missing or rubber dams are deflated because spillage may mask or interfere with the attraction flow from the spillway entrance gate.

3.4.2 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, and were completed before season start-up. A meeting of the Holtwood Fish Passage Technical Advisory Committee, (HFPTAC), was held in April 2007 to discuss the annual fish lift operational plan.

The catch of shad at Conowingo Dam triggered the start of Holtwood operations on 1 May. This year we recorded 35 days of continuous operation. As mentioned previously in this report, the spillway lift was operated on a limited basis (8 days) in spring 2007. The tailrace lift was operated everyday during this year's fish passage operation and encountered only minor mechanical problems which were quickly resolved without any loss of operational time.

The 2007 American shad passage rate at Holtwood versus Conowingo (40.6% of fish passing Conowingo passed Holtwood) was above the 10-year average of 33%. 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, supervising biologist, and biological technician manned the lifts daily. A detailed description of the fishway's major components and their operation are found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

3.4.3 Fish Counts

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

Fish passage data is handled by a single system that records and processes the data. The data (species and numbers passed) is recorded on a worksheet by the biologist or biological technician

as fish pass the viewing window. At the end of each hour, fish passage data is entered into a Microsoft Excel spreadsheet and saved. Data processing and reporting is PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheet software.

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

3.5 RESULTS

3.5.1 Relative Abundance

We present the diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2007 operational period in Table 1. A total of 143,421 fish of 25 taxa passed upstream into Lake Aldred. Gizzard shad (121,927) and American shad (10,338) comprised 92% of the fishes passed. The 2007 American shad passage total was the third lowest observed based on actual numbers of fish. But, based on Conowingo results, this was the fifth highest passage percentage rate recorded in the eleven years of fish lift operations (Tables 1, 5, and 6). Other abundant fishes passed included spotfin shiner (3,640), shorthead redhorse (2,305), walleye (2,167), and quillback (2,150). The peak one-day passage of all species occurred on 9 May, when 11,067 fish were passed, comprised mostly of gizzard shad (10,327), American shad (323), and shorthead redhorse (284).

Stable river flows and minimal rainfall this season resulted in excellent water clarity, which allowed the viewing technicians to identify several American shad with attached Maryland DNR floy tags. The number of floy tags observed at Holtwood in 2007 included 36 pink tags, (2007 Hook & Line), and 4 orange tags, (2006 Hook & Line).

3.5.2 American Shad Passage

A total of 10,338 American shad were passed at Holtwood during 2007; 9,853 American shad (95% of the total shad catch) passed in the tailrace lift while the spillway lift accounted for 485 American shad (5% of total shad catch) (Table 4). Collection and passage of shad varied daily with nearly 60% of total shad (6,188) passed during the 9 day period from 20 through 28 May, (immediately after flashboard installation and river flows dropped below station capacity). The highest daily shad catch occurred on 22 May when 966 shad moved upstream during 10.6 hours of operation. On a daily basis, shad passage was consistent through the fishway between 1000 hrs and 1759 hrs with the highest passage occurring from 1300 hrs to 1559 hrs (Table 3). Fishway operations were conducted at water temperatures ranging from 59.1°F to 79.8°F and river flows between 13,600 and 59,100 cfs, (Table 2). Spillage occurred on 16 days from 1 to 17 May, (prior to flashboard installation). River water temperatures rose quickly this spring reaching 70°F on 12 May, which may have accelerated American shad spawning. American shad of advanced or post-spawned condition were frequently observed during fish passage operations from mid-May

to the end of season.

The capture of shad at the fishway occurred over a wide range of station operation and discharge conditions (Table 2). Shad were attracted to the tailrace lift at water elevations ranging from 109 ft. to 118 ft. Tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2007, tailrace fishway operation generally coincided with a nine turbine operation/generation scenario due to the replacement of the Unit 10 turbine. Spillway lift operation usually occurred during periods of no or minimal spillage, (spillway water elevation 116 ft), or when the forebay level was high enough to allow simultaneous operation of both the spillway and tailrace fish lifts. Spillage occurred during 16 of the 35 days of operation, with the spill events occurring before installation of new flashboards.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 163.5 ft to 171 ft (Table 2). Visual observations indicated that shad passed through the fishway into Lake Aldred at this range of forebay elevations. After the new flashboards were installed, river flows decreased steadily and forebay elevations during passage operations generally ranged between 168 ft to 169 ft.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Most shad, (8,713 or 84% of shad passage total) passed through the fishway between 1000 hrs and 1759 hrs. Generally, shad passage was consistent from 1000 hrs to 1759 hrs, then gradually declined until operation was ended each evening. The highest hourly passage rates occurred from 1100 hrs to 1559 hrs, accounting for the passage of 6,022 American shad.

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 eight 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, 9,853 and 485 shad were captured in the tailrace and spillway lifts over the total operating period in 2007, respectively (Table 4).

3.5.3 Passage Evaluation

In spring 2007, 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 2007, spill events occurred during 16 of the 35 days of fishway operation. We documented 92.3% of American shad passed at river flows less than 40,000 cfs, with 7.6% passing at river flows greater than 40,000 cfs but less than 60,000 cfs, (Table 5 and Figure 2). During fish lift operations in 2007, river flows ranged from 13,600 cfs to 59,100 cfs. The 2007 American shad passage rate at Holtwood versus Conowingo (40.6% of American shad passed at Conowingo

were passed by Holtwood), was above the 10-year average of 33% observed at Holtwood from 1997 to 2006.

We hope to optimize future fishway operations by utilizing knowledge gained through these eleven 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 6 mortalities, less than 0.1% of total American shad passage.

3.6 RECOMMENDATIONS

1. Continue 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. As river flow conditions permit install the "Slick Bar" in front of the fishway exit channel to reduce the amount of debris entering and accumulating at the exit/entrance of the trough. After the "slick bar" is installed implement protocols/guidelines to spill trash through gates 7 and 9. This should be done on an as needed basis prior to the scheduled start of fishway operations.

3.7 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.

3.8 TABLES AND FIGURES

Table 1: Summary of the daily number of fish passed by the Holtwood fish passage facility in 2007 (Page 1 of 4)

Date:	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*
Hours of Operation - Tailrace:	*5.3*	*5.8*	*9.8*	*9.5*	*7.6*	*7.0*	*8.0*	*5.5*	*9.7*	*9.6*
Number of Lifts - Tailrace:	*9*	*9*	*15*	*12*	*11*	*9*	*11*	*7*	*16*	*15*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*58.7*	*60.0*	*61.6*	*62.3*	*62.5*	*62.6*	*62.3*	*62.2*	*63.8*	*65.7*
American shad	38	30	295	226	127	50	18	5	323	588
Gizzard shad	5,091	4,409	5,134	3,154	2,768	1,832	2,757	1,674	10,327	5,265
Sea lamprey	0	0	0	0	0	0	0	0	1	0
Rainbow trout	1	1	0	0	0	1	0	0	0	0
Brown trout	4	0	0	1	0	0	0	1	1	0
Muskellunge	0	0	0	0	0	0	0	0	0	0
Carp	0	12	5	2	4	3	5	7	15	4
Quillback	13	31	32	19	3	2	1	0	62	16
Northern hogsucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	58	141	101	92	83	45	34	0	284	260
Channel catfish	0	2	8	4	1	9	1	0	0	3
Brown bullhead	0	0	0	0	0	0	0	0	1	0
Flathead catfish	0	0	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	2	3	9	3	4	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0	1	1
Smallmouth bass	15	12	18	13	8	4	4	0	10	3
Largemouth bass	1	1	0	2	3	0	0	0	3	0
Black crappie	1	2	0	0	0	0	0	0	0	0
Yellow perch	0	1	0	0	0	0	0	0	0	0
Walleye	12	19	18	26	19	15	8	0	39	20
Spotfin shiner	0	0	0	0	0	0	0	0	0	0
Total	***5,236***	***4,664***	***5,620***	***3,542***	***3,020***	***1,961***	***2,828***	***1,687***	***11,067***	***6,160***

Table 1: Summary of the daily number of fish passed by the Holtwood fish passage facility in 2007 (Page 2 of 4)

Date:	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*
Hours of Operation - Tailrace:	*10.1*	*10.2*	*9.0*	*9.7*	*8.3*	*8.3*	*9.2*	*7.8*	*8.8*	*10.3*
Number of Lifts - Tailrace:	*15*	*17*	*15*	*16*	*11*	*13*	*11*	*10*	*12*	*17*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*67.9*	*70.3*	*72.0*	*71.8*	*70.1*	*69.6*	*68.8*	*69.6*	*68.7*	*67.7*
American shad	801	582	334	205	28	74	50	18	34	919
Gizzard shad	5,133	8,196	3,660	5,219	4,062	3,974	2,987	2,615	2,685	5,180
Sea lamprey	0	1	0	0	0	0	0	0	0	0
Rainbow trout	1	0	0	2	1	0	0	0	0	0
Brown trout	0	2	0	0	0	0	0	0	0	1
Muskellunge	0	0	0	0	0	1	0	0	0	0
Carp	25	20	6	9	3	5	12	1	0	1
Quillback	387	251	65	33	18	92	17	1	1	1
Northern hogsucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	154	93	27	33	15	10	2	2	0	7
Channel catfish	26	15	7	4	2	2	0	0	0	11
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Flathead catfish	0	1	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	13	3	0	0	0	0	0	0	0	4
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	2	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	1	0	0	0	0
Bluegill	1	1	0	0	0	0	0	2	0	1
Smallmouth bass	1	4	1	0	1	3	0	0	0	0
Largemouth bass	0	1	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	1	0	0	0	0	0	0
Walleye	34	32	16	36	42	50	44	4	2	125
Spotfin shiner	0	0	0	0	0	0	0	0	0	0
Total	***6,576***	***9,204***	***4,116***	***5,542***	***4,172***	***4,212***	***3,112***	***2,643***	***2,722***	***6,250***

Table 1: Summary of the daily number of fish passed by the Holtwood fish passage facility in 2007 (Page 3 of 4)

Date:	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Hours of Operation - Tailrace:	*10.3*	*10.6*	*10.1*	*10.8*	*10.5*	*10.6*	*9.7*	*10.5*	*9.6*
Number of Lifts - Tailrace:	*17*	*17*	*16*	*18*	*18*	*18*	*16*	*18*	*15*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	*9.5*	*10.2*	*8.1*	*8.3*	*6.1*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*7*	*14*	*8*	*8*	*4*
Water Temperature (°F):	*66.4*	*66.4*	*66.9*	*68.2*	*69.5*	*71.8*	*73.6*	*75.5*	*76.4*
American shad	569	966	484	718	935	822	468	307	136
Gizzard shad	5,956	4,360	4,190	3,555	5,159	5,049	2,242	2,589	1,334
Sea lamprey	1	0	0	0	0	0	0	0	0
Rainbow trout	1	1	0	0	0	2	0	2	0
Brown trout	0	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	1	0	0
Carp	1	0	13	2	14	50	9	7	2
Quillback	0	1	6	4	6	162	105	378	127
Northern hogsucker	0	0	0	0	0	0	0	0	0
Shorthead redhorse	2	1	3	8	16	88	88	132	160
Channel catfish	0	0	0	0	5	28	10	28	0
Brown bullhead	0	0	0	0	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	0	0	1	1	0
Redbreast sunfish	0	0	0	0	0	0	0	1	0
Green sunfish	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	1	0	0
Bluegill	0	0	0	0	2	5	4	5	3
Smallmouth bass	2	0	1	0	4	2	3	3	1
Largemouth bass	0	0	0	0	0	1	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0
Walleye	107	81	27	42	238	285	264	136	187
Spotfin shiner	0	0	0	0	0	0	0	0	0
Total	***6,639***	***5,410***	***4,724***	***4,329***	***6,379***	***6,494***	***3,196***	***3,589***	***1,950***

Table 1: Summary of the daily number of fish passed by the Holtwood fish passage facility in 2007 (Page 4 of 4)

Date:	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*8.5*	*7.7*	*7.3*	*7.2*	*5.7*	***306.7***
Number of Lifts - Tailrace:	*9*	*10*	*9*	*8*	*7*	***458***
Hours of Operation - Spillway:	*0.0*	*7.0*	*6.0*	*0.0*	*5.7*	***60.9***
Number of Lifts - Spillway:	*0*	*5*	*5*	*0*	*5*	***56***
Water Temperature (°F):	*79.3*	*79.2*	*78.9*	*79.7*	*79.5*	
American shad	21	45	37	23	6	**10,338**
Gizzard shad	202	243	429	101	187	**121,927**
Sea lamprey	0	0	0	0	0	**3**
Rainbow trout	0	0	0	1	0	**14**
Brown trout	0	0	0	0	0	**10**
Muskellunge	0	0	0	0	0	**2**
Carp	2	4	51	139	3	**437**
Quillback	31	73	86	73	4	**2,150**
Northern hogsucker	0	0	1	0	0	**1**
Shorthead redhorse	58	44	87	114	13	**2,305**
Channel catfish	0	2	17	13	10	**208**
Brown bullhead	0	0	0	0	0	**1**
Flathead catfish	0	0	0	0	0	**1**
Striped bass	0	1	1	1	0	**3**
Rock bass	0	0	1	0	0	**44**
Redbreast sunfish	0	0	0	0	0	**1**
Green sunfish	0	0	0	0	0	**2**
Pumpkinseed	0	0	0	0	0	**2**
Bluegill	0	0	3	1	0	**30**
Smallmouth bass	1	0	2	0	0	**118**
Largemouth bass	0	0	0	0	0	**12**
Black crappie	0	0	0	0	0	**3**
Yellow perch	0	0	0	0	0	**2**
Walleye	14	41	72	31	46	**2,167**
Spotfin shiner	0	0	1,490	0	2,150	**3,640**
Total	***329***	***453***	***2,277***	***497***	***2,419***	**143,421**

Table 2: Summary of daily average river flow, water temperature, unit operation, fishway weir operation, and project water elevations during operation of the Holtwood fish passage facility in 2007 (Page 1 of 2)

	River Flow	Water	Secchi	Number	Weir Gate Operation			Elevation (ft)		
Date	(cfs)	Temp. (°F)	(in)	of Units	A	B*	C**	Tailrace	Spillway	Forebay
1 May	56,500	59.09	18	9	X			118	Spill	169
2 May	55,800	60.91	18	9	X			118	Spill	169
3 May	53,700	62.36	22	9	X			118	Spill	169
4 May	59,100	63.18	20	9	X			118	Spill	169
5 May	57,500	63.24	20	9	X			116-118	Spill	168
6 May	53,700	63.13	20	9	X			117-118	Spill	169
7 May	46,200	62.48	20	9	X			118	Spill	168-169
8 May	41,100	62.70	28	9	X			117	116	163.5
9 May	37,400	63.90	28	9	X			117	Spill	167
10 May	32,800	65.99	28	9	X			117	Spill	166
11 May	33,500	68.33	30	9	X			118	Spill	167
12 May	33,200	70.66	36	9	X			117	Spill	167-168
13 May	34,100	71.94	36	9	X			116-117	Spill	165-166
14 May	35,100	71.69	36	9	X			117	Spill	166-167
15 May	33,800	70.28	30	9	X			117	Spill	167
16 May	32,700	69.44	30	9	X			114-117	Spill	166-167
17 May	30,100	69.08	30	9	X			116-117	Spill	166
18 May	27,800	69.46	30	9	X			117	116	164
19 May	25,600	68.78	30	9	X			117	116	164
20 May	25,600	67.75	30	9	X			116	116-117	168-170
21 May	24,700	66.72	30	9	X			116-117	116-117	169-170
22 May	23,200	67.01	30	9	X			117	116	168
23 May	20,700	67.45	28	9	X			116	116	169
24 May	19,300	69.04	28	9	X			114-117	116	168-169
25 May	18,300	70.69	28	5-9	X		X	112-117	116-118	168-171
26 May	16,700	72.53	28	7-9	X		X	113-116	116	168-169

Table 2: Summary of daily average river flow, water temperature, unit operation, fishway weir operation, and project water elevations during operation of the Holtwood fish passage facility in 2007 (Page 2 of 2)

	River Flow	Water	Secchi	Number	Weir Gate Operation			Elevation (ft)		
Date	(cfs)	Temp. (°F)	(in)	of Units	A	B	C	Tailrace	Spillway	Forebay
27 May	17,100	74.47	30	9	X		X	116	116	168
28 May	16,800	76.04	36	7-9	X		X	113-116	116	168-169
29 May	16,300	77.05	36	9	X		X	115	116-117	168-170
30 May	14,600	78.38	36	5-9	X			109-117	116	168-169
31 May	14,000	79.22	36	6-9	X			113-117	116	169
1 Jun	14,400	79.49	36	9	X		X	113-117	116	168-169
2 Jun	13,900	79.36	36	0/5-9	X		X	107-117	116	169
3 Jun	13,600	79.80	36	0/5/9	X			107-115	116	169
4 Jun	13,600	79.46	36	9	X		X	115	116	169

* Tailrace gate B not utilized during 2007.

** Spillway entrance gate C damaged by flooding prior to 2005 season.

Table 3: Hourly summary of American shad passage at the Holtwood fish passage facility in 2007
(Page 1 of 3)

Date:	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*
Observation Time (Start):	*11:45*	*9:45*	*8:45*	*8:45*	*8:00*	*8:00*	*8:15*
Observation Time (End):	*17:00*	*15:44*	*18:35*	*17:35*	*16:00*	*15:00*	*16:25*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	--	--	2	29	12	9	4
0900 to 0959	--	--	18	19	14	2	1
1000 to 1059	--	13	10	8	17	11	0
1100 to 1159	0	4	15	8	11	10	2
1200 to 1259	11	5	29	6	13	5	2
1300 to 1359	14	1	30	26	27	8	2
1400 to 1459	2	3	52	53	12	5	4
1500 to 1559	8	4	49	34	21	--	2
1600 to 1659	3	--	54	36	--	--	1
1700 to 1759	--	--	26	7	--	--	--
1800 to 1859	--	--	10	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**38**	**30**	**295**	**226**	**127**	**50**	**18**

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*
Observation Time (Start):	*9:00*	*8:30*	*8:15*	*8:45*	*8:00*	*9:00*	*8:05*
Observation Time (End):	*15:06*	*18:15*	*18:00*	*19:00*	*18:25*	*18:20*	*18:00*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	--	0	1	1	27	--	13
0900 to 0959	1	12	45	32	81	14	4
1000 to 1059	1	9	19	59	47	34	38
1100 to 1159	0	40	69	83	57	58	37
1200 to 1259	1	37	39	144	49	32	32
1300 to 1359	1	38	127	89	73	57	14
1400 to 1459	1	62	118	77	65	16	31
1500 to 1559	--	39	105	71	59	23	14
1600 to 1659	--	30	50	91	64	32	17
1700 to 1759	--	45	15	101	47	52	5
1800 to 1859	--	11	--	53	13	16	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**5**	**323**	**588**	**801**	**582**	**334**	**205**

Table 3: Hourly summary of American shad passage at the Holtwood fish passage facility in 2007
(Page 2 of 3)

Date:	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*
Observation Time (Start):	*8:15*	*8:00*	*8:10*	*8:40*	*8:00*	*8:00*	*8:15*
Observation Time (End):	*17:00*	*16:40*	*17:30*	*16:37*	*16:45*	*18:45*	*18:45*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	0	2	0	1	0	33	14
0900 to 0959	4	16	0	4	1	98	17
1000 to 1059	2	9	0	2	2	116	49
1100 to 1159	4	8	8	1	0	73	32
1200 to 1259	4	9	9	3	10	122	43
1300 to 1359	4	7	4	1	3	134	117
1400 to 1459	8	8	4	3	6	104	96
1500 to 1559	1	8	13	1	5	98	51
1600 to 1659	1	7	6	2	7	57	70
1700 to 1759	--	--	6	--	--	53	38
1800 to 1859	--	--	--	--	--	31	42
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**28**	**74**	**50**	**18**	**34**	**919**	**569**

Date:	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*
Observation Time (Start):	*8:05*	*8:00*	*8:20*	*8:25*	*8:00*	*8:00*	*8:00*
Observation Time (End):	*19:00*	*18:20*	*19:05*	*19:00*	*18:45*	*18:00*	*18:30*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	24	21	15	7	65	5	42
0900 to 0959	6	64	50	49	52	46	34
1000 to 1059	30	90	59	109	78	66	25
1100 to 1159	34	37	50	144	95	69	41
1200 to 1259	62	48	96	98	98	83	29
1300 to 1359	84	14	103	76	83	69	13
1400 to 1459	162	61	94	147	113	33	23
1500 to 1559	235	48	54	102	81	41	48
1600 to 1659	115	38	56	12	81	19	28
1700 to 1759	135	45	61	126	47	37	10
1800 to 1859	79	18	73	65	29	--	14
1900 to 1959	--	--	7	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**966**	**484**	**718**	**935**	**822**	**468**	**307**

Table 3: Hourly summary of American shad passage at the Holtwood fish passage facility in 2007
(Page 2 of 3)

	29	*30*	*31*					
Date:	*May*	*May*	*May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	
Observation Time (Start):	*8:00*	*8:00*	*8:15*	*8:15*	*8:00*	*8:10*	*8:30*	
Observation Time (End):	*17:50*	*16:20*	*16:45*	*16:15*	*15:30*	*15:32*	*14:30*	***Total***
Military Time (hrs)								
0700 to 0759	--	--	--	--	--	--	--	***0***
0800 to 0859	21	8	1	2	0	1	0	***360***
0900 to 0959	27	2	0	6	5	12	1	***737***
1000 to 1059	15	9	0	8	15	7	0	***957***
1100 to 1159	14	7	2	9	11	2	1	***1,036***
1200 to 1259	11	14	8	4	2	1	0	***1,159***
1300 to 1359	10	6	5	1	2	0	1	***1,244***
1400 to 1459	13	7	0	9	1	0	3	***1,365***
1500 to 1559	2	3	5	6	1	0	--	***1,218***
1600 to 1659	11	0	0	0	--	--	--	***871***
1700 to 1759	12	--	--	--	--	--	--	***863***
1800 to 1859	--	--	--	--	--	--	--	***454***
1900 to 1959	--	--	--	--	--	--	--	***7***
2000 to 2059	--	--	--	--	--	--	--	***0***
Total	**136**	**56**	**21**	**45**	**37**	**23**	**6**	***10,338***

Table 4: Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2007

	Shad	Number Collected		Percent Collected	
Date	Catch	Tailrace	Spillway*	Tailrace	Spillway
1-May	38	38	--	100%	0%
2-May	30	30	--	100%	0%
3-May	295	295	--	100%	0%
4-May	226	226	--	100%	0%
5-May	127	127	--	100%	0%
6-May	50	50	--	100%	0%
7-May	18	18	--	100%	0%
8-May	5	5	--	100%	0%
9-May	323	323	--	100%	0%
10-May	588	588	--	100%	0%
11-May	801	801	--	100%	0%
12-May	582	582	--	100%	0%
13-May	334	334	--	100%	0%
14-May	205	205	--	100%	0%
15-May	28	28	--	100%	0%
16-May	74	74	--	100%	0%
17-May	50	50	--	100%	0%
18-May	18	18	--	100%	0%
19-May	34	34	--	100%	0%
20-May	919	919	--	100%	0%
21-May	569	569	--	100%	0%
22-May	966	966	--	100%	0%
23-May	484	484	--	100%	0%
24-May	718	718	--	100%	0%
25-May	935	700	235	75%	25%
26-May	822	672	150	82%	18%
27-May	468	400	68	85%	15%
28-May	307	282	25	92%	8%
29-May	136	134	2	99%	1%
30-May	56	56	--	100%	0%
31-May	21	21	--	100%	0%
1-Jun	45	40	5	89%	11%
2-Jun	37	37	0	100%	0%
3-Jun	23	23	--	100%	0%
4-Jun	6	6	0	100%	0%
Total	***10,338***	***9,853***	***485***	***95%***	***5%***

* Spillway entrance gate severely damaged by Hurricane Ivan flooding in September 2004.
Operation of Spillway lift during 2007 occurred without the use of a functional entrance gate.

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

	1997	1998*	1999	2000*	2001	2002*	2003*	2004*	2005	2006	2007
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr	26 Apr	27 Apr	11 Apr	01 May
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun	03 Jun	10 Jun	06 Jun	04 Jun
Season duration (days)	58	47	40	40	43	55	36	39	45	57	35
Number of days of operation	55	41	40	36	42	35	34	39	36	57	35
American shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135	109,360	68,926	56,899	25,464
American shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254	3,428	34,189	35,968	10,338
River flow ≤40,000 cfs											
Number of days	48	22	34	19	40	19	15	2	33	48	27
Percent of season	87%	54%	85%	53%	95%	54%	44%	5%	92%	84%	77%
Number of American shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229	2	34,060	35,302	9,549
Daily average of American shad passed	546	341	1,002	1,037	2,733	543	1,348	1	1,032	735	354
Percent of total passage	93%	91%	98%	67%	99%	59%	80%	0%	99.6%	98.1%	92.3%
River flow 40,001 to 60,000 cfs											
Number of days	7	2	6	12	2	14	18	20	3	5	8
Percent of season	13%	5%	15%	33%	5%	40%	53%	51.3%	8%	9%	23%
Number of American shad passed	1,862	230	633	9,536	634	7,029	5,019	1,943	129	566	789
Daily average of American shad passed	266	115	106	795	317	502	279	97	43	113	99
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.8%	56.7%	0.4%	1.6%	7.6%
River flow >60,000 cfs											
Number of days	0	17	0	5	0	2	1	17	0	4	0
Percent of season	0%	41%	0%	14%	0%	6%	3%	43.6%	0%	7%	0%
Number of American shad passed	0	493	0	173	0	171	6	1,483	0	100	0
Daily average of American shad passed	0	29	0	35	0	86	6	87	0	25	0
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%	43.3%	0.0%	0.3%	0.0%

* Denotes seasons of high river flow.

Table 6: Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2007

		Holtwood		Safe Harbor		York Haven	
	Conowingo East	**Number**	**Passed**	**Number**	**Passed**	**Number**	**Passed**
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%	4,675	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%**

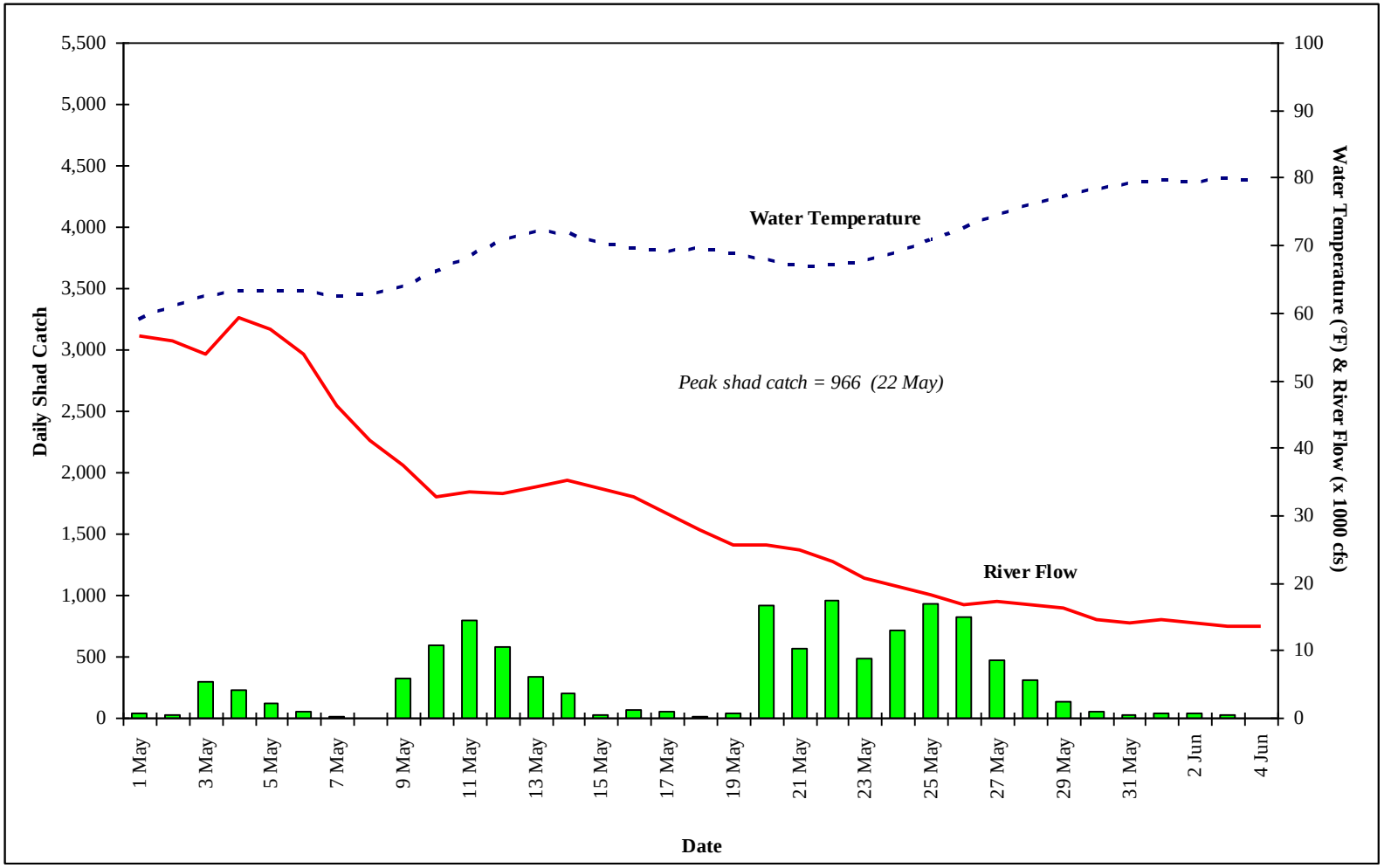

Figure 1: A plot of river flow (x1000) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2007

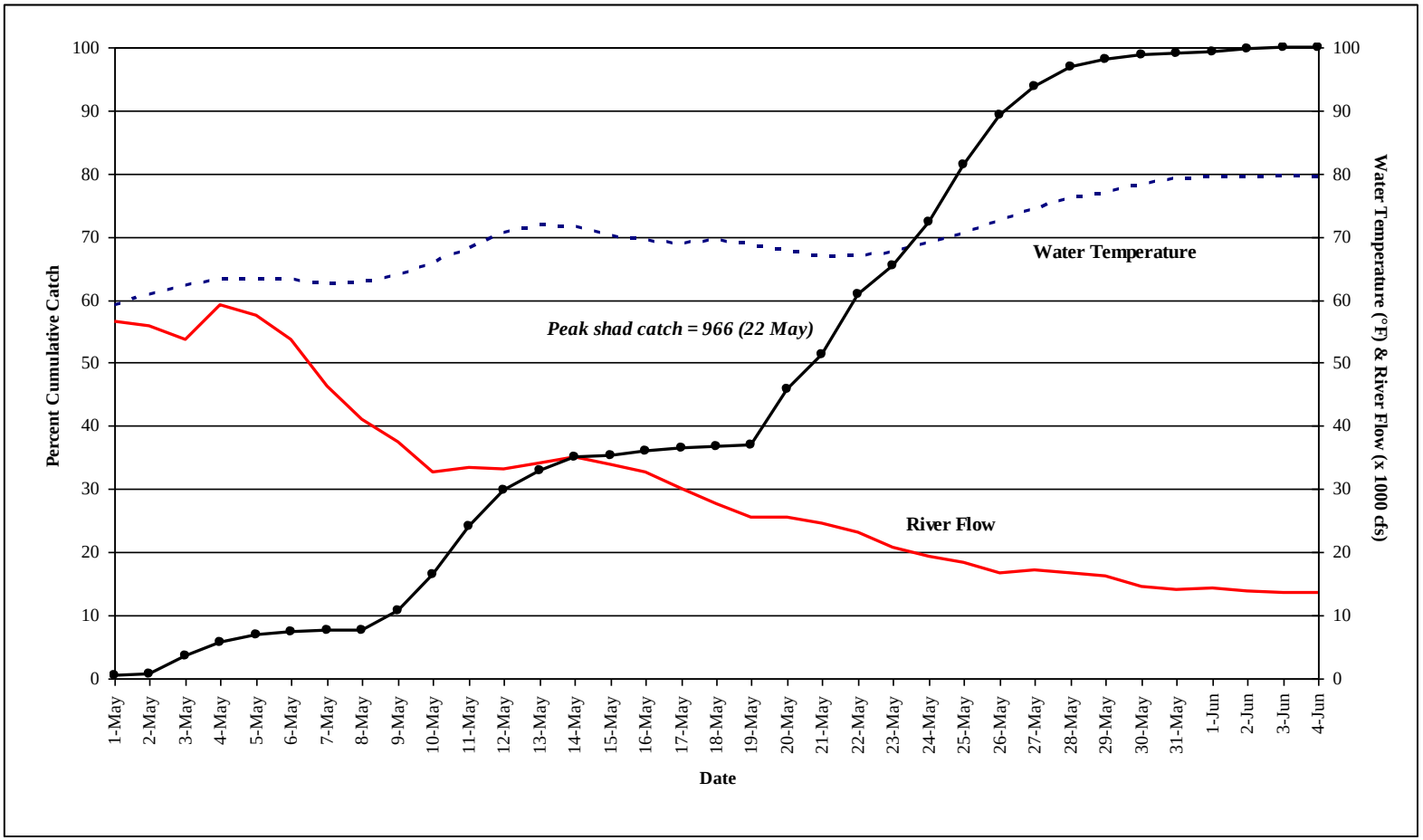

Figure 2: A plot of river flow (x1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Holtwood Fish Passage Facility, spring 2007

4.0 JOB 1, PART 4: SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY, 2007

NORMANDEAU ASSOCIATES, INC.
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Drumore, Pennsylvania 17518

4.1 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 2007 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

4.2 SAFE HARBOR OPERATION

4.2.1 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.

4.3 FISHWAY DESIGN AND OPERATION

4.3.1 Fishway Design

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

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

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; (3) entrance A and C, and (4) entrance A, B, and C individually. Operation during the 2007 season utilized a combination of entrances A and C (Table 2).

4.3.2 Fishway Operation

Safe Harbor fishway operation commences soon after passage of approximately 500 American shad via the Holtwood fishway. In 2007, due to high river flows in April, operations did not commence until early May. Passage of 500 American shad from the Holtwood fishway into Lake Aldred occurred on 4 May.

The Safe Harbor fishway began operation on 7 May, with operations ending on 5 June. No shut downs of the facility occurred during operations in spring, 2007. Lift operations ended due to the dwindling fish catch and rising water temperatures; indications that the migration run was ending.

Throughout the 2007 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

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

4.3.3 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 passage from 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 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 members of the SHFPTAC and other cooperators.

4.4 RESULTS

4.4.1 Relative Abundance

The relative abundance of fishes collected and passed in 2007 by the Safe Harbor fish way is presented in Table 1. A total of 112,484 fish of 20 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (84,466) was the dominant species passed and comprised 75% of the catch. Some 7,215 American shad were passed upstream through the fish way and comprised 6% of the catch. Other predominant fishes passed included quillback (12,980), channel catfish (2,462), walleye (1,869), and shorthead redhorse (1,446). Peak passage occurred on 10 May, when 7,589 fish were passed.

4.4.2 American Shad Passage

The Safe Harbor fishway passed 7,215 American shad in 2007 during 30 days of operation (Table 1). This year's operating season was much shorter than in recent years and collection and

passage of shad varied daily. The Conowingo fishway also had a short season (39 days) and passed 25,464 American Shad, which is their lowest season total since 1993. Having lower numbers of shad in the system and stable river flows, Safe Harbor still managed to pass 7,215 American Shad, or 69.8% of the shad passed at Holtwood Dam (10,338). Moreover, the Safe Harbor fishway passed 28% of the American Shad passed by Conowingo Dam. Peak shad passage occurred on 26 May when 797 shad were captured and passed during 9.8 hours of operation.

American shad were passed at water temperatures of 62.5°F to 79.8°F and river flows of 12,900 to 46,200 cfs (Table 2 and Figures 1and 2). Water temperature and river flow on those 7 days when more than 500 American shad were passed averaged 70.4°F (67.0°F to 74.5°F) and 19,200 cfs, (16,700 cfs to 23,200 cfs), respectively.

The number of American shad observed passing through the trough by hour is shown in Table 3. With the season's shad catch broken down based on hours of observation, passage rates showed a morning peak from 0800 to 1100 hr, followed by a slight reduction in rates from 1100 to 1359hr. Another peak was then observed from 1400 to 1500hr. with a steady decrease in catch from 1500 to 1859 hr. The peak passage hour for American Shad during the entire season was observed between 0800-0859 hrs, with a total of 1,047 American shad passed. The highest hourly passage (141) occurred between 1300 and 1359 hr on 26 May.

During the 2007 season, the Safe Harbor fishway passed a total of 25 tagged American shad that had been passed by downstream fish lift facilities. All 25 floy tags observed were pink in color indicating that all were caught in 2007 by hook and line, tagged and released downstream of Conowingo dam by the MD DNR.

4.4.3 Other Alosids

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2007.

4.5 SUMMARY

The 2007 Safe Harbor fishway operating season was successful with no disruptions to operations due to mechanical problems. The thirty days of operation in 2007 marks the shortest migration season at Safe Harbor since 1999 when 29 days of operation were completed. A total of 7,215 American shad were passed into Lake Clarke, or 69.8% of the American shad that were passed into Lake Aldred by the Holtwood fishway (Table 4). Future operations of the fishway will build on the past eleven years of experience.

4.6 RECOMMENDATIONS

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.

4.7 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.

4.8 TABLES AND FIGURES

Table 1: Number and disposition of fish passed by the Safe Harbor fishway in 2007 (Page 1 of 3)

	7-May	*8-May*	*9-May*	*10-May*	*11-May*	*12-May*	*13-May*	*14-May*	*15-May*	*16-May*
Date:										
Hours of Operation:	*8.0*	*7.0*	*8.4*	*8.5*	*8.3*	*7.0*	*8.3*	*8.2*	*8.3*	*6.7*
Viewing Start Time:	*9:00*	*8:00*	*8:00*	*8:00*	*7:30*	*8:00*	*8:00*	*8:00*	*8:00*	*8:25*
Viewing End Time:	*15:25*	*15:15*	*15:30*	*15:50*	*15:50*	*16:10*	*15:50*	*15:45*	*15:50*	*15:25*
Number of Lifts:	*5*	*6*	*5*	*9*	*9*	*8*	*8*	*9*	*8*	*7*
Water Temperature (°F):	*62.0*	*62.6*	*63.0*	*65.0*	*68.0*	*70.0*	*71.0*	*71.0*	*70.0*	*67.3*
American Shad	297	83	64	116	313	377	207	290	189	97
Gizzard shad	3,096	3,821	2,175	4,948	2,933	5,062	4,475	4,470	3,510	1,877
Striped bass	0	0	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	1	1	0	0	0	0	0
Brown trout	1	1	2	0	0	0	0	0	0	1
Brook trout	0	0	1	0	1	0	0	0	0	0
Carp	3	54	55	142	116	483	19	13	3	6
Quillback	322	615	830	1,654	2,208	1,038	664	310	186	130
Shorthead redhorse	8	104	122	408	352	225	40	20	6	2
Channel catfish	29	6	7	45	104	59	198	228	46	20
Rock bass	1	3	4	10	13	3	14	8	8	3
Pumpkinseed	0	0	1	0	0	0	4	0	0	0
Bluegill	3	1	1	4	2	4	5	3	5	7
Smallmouth bass	116	104	160	131	72	46	10	3	4	0
Largemouth bass	1	8	0	7	3	2	7	0	1	0
White Crappie	0	0	0	0	1	0	0	1	0	0
Black Crappie	0	0	0	1	0	0	0	0	0	0
Yellow perch	0	1	0	0	0	0	0	0	0	0
Walleye	12	11	23	122	153	212	155	102	93	29
Total	**3,889**	**4,812**	**3,445**	**7,589**	**6,272**	**7,511**	**5,798**	**5,448**	**4,051**	**2,172**

Table 1: Number and disposition of fish passed by the Safe Harbor fishway in 2007 (Page 2 of 3)

Date:	*17-May*	*18-May*	*19-May*	*20-May*	*21-May*	*22-May*	*23-May*	*24-May*	*25-May*	*26-May*
Hours of Operation:	*8.8*	*8.4*	*7.8*	*6.4*	*8.3*	*10.0*	*9.5*	*10.0*	*9.0*	*9.8*
Viewing Start Time:	*8:00*	*7:40*	*7:30*	*8:00*	*7:45*	*8:05*	*8:05*	*7:30*	*8:00*	*8:00*
Viewing End Time:	*15:50*	*15:25*	*15:25*	*16:00*	*15:35*	*17:15*	*17:15*	*17:20*	*17:05*	*17:45*
Number of Lifts:	*9*	*8*	*8*	*7*	*8*	*11*	*10*	*10*	*11*	*11*
Water Temperature (°F):	*70.0*	*69.3*	*69.0*	*68.5*	*67.3*	*65.0*	*67.8*	*70.0*	*70.0*	*72.0*
American Shad	156	52	49	43	383	657	507	391	511	797
Gizzard shad	3,204	1,673	2,264	2,516	3,217	4,585	3,830	3,470	4,190	5,723
Striped bass	0	0	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Sea lamprey	0	0	0	0	0	0	0	0	0	1
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Brown trout	0	0	1	0	0	1	0	0	0	0
Brook trout	0	0	0	0	0	0	0	0	0	0
Carp	5	57	1	1	0	4	16	7	1	2
Quillback	413	419	33	30	3	11	16	100	130	399
Shorthead redhorse	8	3	0	0	0	0	0	10	4	27
Channel catfish	40	37	28	34	49	8	50	21	74	76
Rock bass	1	1	0	0	2	0	1	4	1	1
Pumpkinseed	0	0	0	0	0	1	0	0	0	0
Bluegill	2	1	0	1	5	2	3	4	9	2
Smallmouth bass	1	0	0	0	1	1	0	1	1	1
Largemouth bass	0	0	0	0	0	0	4	1	0	0
White Crappie	0	0	0	0	0	0	0	0	0	1
Black Crappie	0	0	0	0	0	1	2	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	33	19	24	26	34	19	15	18	38	142
Total	**3,863**	**2,262**	**2,400**	**2,651**	**3,694**	**5,290**	**4,444**	**4,027**	**4,959**	**7,172**

Table 1: Number and disposition of fish passed by the Safe Harbor fishway in 2007 (Page 3 of 3)

Date:	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	**Totals**
Hours of Operation:	*9.5*	*8.8*	*9.3*	*8.0*	*9.0*	*8.8*	*8.6*	*8.6*	*8.0*	*7.9*	***253.0***
Viewing Start Time:	*8:00*	*7:40*	*7:30*	*7:45*	*7:45*	*8:00*	*8:00*	*8:00*	*7:45*	*7:45*	
Viewing End Time:	*17:30*	*16:45*	*16:50*	*15:20*	*16:40*	*16:30*	*16:30*	*16:30*	*15:50*	*15:45*	
Number of Lifts:	*13*	*10*	*12*	*8*	*9*	*9*	*9*	*9*	*7*	*8*	***261***
Water Temperature (°F):	*75.0*	*76.0*	*78.0*	*78.0*	*78.8*	*80.0*	*81.0*	*81.0*	*81.7*	*81.7*	
American Shad	516	345	218	119	196	74	102	29	18	19	**7,215**
Gizzard shad	3678	2041	3145	660	1369	408	1334	507	241	44	**84,466**
Striped bass	0	0	0	0	0	0	0	0	2	0	**2**
Hybrid striped bass	0	0	0	0	0	0	1	0	0	0	**1**
Sea lamprey	0	0	0	0	0	0	0	0	0	0	**1**
Rainbow trout	0	0	0	0	0	0	0	0	0	0	**2**
Brown trout	0	0	0	0	0	0	0	0	0	0	**7**
Brook trout	0	0	0	0	0	0	0	0	0	0	**2**
Carp	11	7	8	10	20	63	13	25	5	8	**1,158**
Quillback	349	679	752	270	151	363	421	408	66	10	**12,980**
Shorthead redhorse	31	17	7	5	2	2	16	22	5	0	**1,446**
Channel catfish	119	79	158	85	75	108	102	203	245	129	**2,462**
Rock bass	0	0	2	0	0	0	0	0	0	0	**80**
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	**6**
Bluegill	2	4	5	1	3	2	2	1	3	0	**87**
Smallmouth bass	1	0	0	1	1	0	0	0	0	0	**655**
Largemouth bass	1	0	0	1	0	0	0	0	0	0	**36**
White Crappie	0	0	1	0	0	0	0	0	0	0	**4**
Black Crappie	0	0	0	0	0	0	0	0	0	0	**4**
Yellow perch	0	0	0	0	0	0	0	0	0	0	**1**
Walleye	254	86	36	6	20	11	77	58	26	15	**1,869**
Total	**4,962**	**3,258**	**4,332**	**1,158**	**1,837**	**1,031**	**2,068**	**1,253**	**611**	**225**	**112,484**

Table 2: Summary of daily average river flow and water temperature as measured at Holtwood Dam, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Safe Harbor fish passage facility in 2007

Date	River Flow[1] (mcfs)	Water Temp (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
07 May	46.2	62.5	20	12	1 to 12	A & C	500	172.2	225.7
08 May	41.1	62.7	30	4	1 to 4	A & C	500	168.0	225.9
09 May	37.4	63.9	36	10	1 to 10	A & C	500	169.4	226.7
10 May	32.8	66.0	36	10	1 to 10	A & C	500	170.4	226.4
11 May	33.5	68.3	36	10	1 to 10	A & C	500	169.3	226.2
12 May	33.2	70.7	36	10	1 to 10	A & C	500	169.4	226.4
13 May	34.1	71.9	30	7	2 to 8	A & C	500	169.0	226.6
14 May	35.1	71.7	28	10	1 to 9, 12	A & C	500	170.7	226.3
15 May	33.8	70.3	22	7	1 to 7	A & C	500	170.4	226.4
16 May	32.7	69.4	30	7	1 to 7	A & C	500	171.6	226.0
17 May	30.1	69.1	26	10	1-5, 7-10, 12	A & C	500	169.4	226.2
18 May	27.8	69.5	26	4	1 to 4	A & C	500	174.7	225.8
19 May	25.6	68.8	22	4	2, 4, 5, 7	A & C	500	169.1	225.6
20 May	25.6	67.8	21	6	2 to 7	A & C	500	170.1	226.5
21 May	24.7	66.7	20	5	1, 2, 5 to7	A & C	500	170.7	226.3
22 May	23.2	67.0	30	5	1, 2, 4, 5, 7	A & C	500	169.8	226.5
23 May	20.7	67.4	36	5	1, 2, 4, 5, 7	A & C	500	170.3	226.0
24 May	19.3	69.0	36	3	1, 2, 5	A & C	500	169.6	226.3
25 May	18.3	70.7	36	2	1, 2	A & C	500	171.2	225.7
26 May	16.7	72.5	36	6	2, 3-5, 7, 9	A & C	500	169.4	226.4
27 May	17.1	74.5	36	6	2 to 5, 7, 12	A & C	500	169.3	226.8
28 May	16.8	76.0	36	6	2 to 5, 7, 12	A & C	500	170.0	226.9
29 May	16.3	77.1	32	6	2 to 5, 7, 12	A & C	500	171.4	225.9
30 May	14.6	78.4	34	5	2 to 5, 7, 12	A & C	500	169.3	226.3
31 May	14.0	79.2	38	2	1, 2	A & C	500	169.8	226.4
01 Jun	14.4	79.5	36	5	1 to 3, 5, 7	A & C	500	170.5	226.3
02 Jun	13.9	79.4	36	4	2, 3, 5, 7	A & C	500	169.7	226.2
03 Jun	13.6	79.8	36	1	2	A & C	500	169.1	226.2
04 Jun	13.6	79.5	20	5	2, 3, 5, 9, 12	A & C	500	169.1	226.1
05 Jun	12.9	79.1	24	1	12	A & C	500	170.7	225.8

[1] River flow and temperature measured at Holtwood Dam.

Table 3: Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2007 (Page 1 of 2)

Date:	*7-May*	*8-May*	*9-May*	*10-May*	*11-May*	*12-May*	*13-May*	*14-May*	*15-May*	*16-May*	*17-May*	*18-May*
Observation Time-Start:	*9:00*	*8:00*	*8:00*	*8:00*	*7:30*	*8:00*	*8:00*	*8:00*	*8:00*	*8:25*	*8:00*	*7:40*
Observation Time-End:	*15:25*	*15:15*	*15:30*	*15:50*	*15:50*	*16:10*	*15:50*	*15:45*	*15:50*	*15:25*	*15:50*	*15:25*
Military Time (hrs)												
0700 to 0759					30							
0800 to 0859		40	20	32	73	72	44	71	29	13	40	18
0900 to 0959	57	1	10	26	56	97	25	39	20	8	23	8
1000 to 1059		5	11	16	36	52	29	32	16	15	25	6
1100 to 1159	60	4	6	16	34	27	20	22	28	13	4	5
1200 to 1259	35	1	9	2	25	55	24	20	30	10	9	2
1300 to 1359	13	15	5	7	22	14	33	39	19	13	13	6
1400 to 1459	100	2	2	8	21	40	25	36	29	9	24	7
1500 to 1559	32	15	1	9	16	20	7	31	18	16	18	
1600 to 1659												
1700 to 1759												
1800 to 1859												
1900 to 1959												
Total	**297**	**83**	**64**	**116**	**313**	**377**	**207**	**290**	**189**	**97**	**156**	**52**

Date:	*19-May*	*20-May*	*21-May*	*22-May*	*23-May*	*24-May*	*25-May*	*26-May*	*27-May*	*28-May*	*29-May*	*30-May*
Observation Time-Start:	*7:30*	*8:00*	*7:45*	*8:05*	*8:05*	*7:30*	*8:00*	*8:00*	*8:00*	*7:40*	*7:30*	*7:45*
Observation Time-End:	*15:25*	*16:00*	*15:35*	*17:15*	*17:15*	*17:20*	*17:05*	*17:45*	*17:30*	*16:45*	*16:50*	*15:20*
Military Time (hrs)												
0700 to 0759			1			6				1	3	17
0800 to 0859	9	4	53	104	85	82	23	36	78	17	53	8
0900 to 0959	10	10	38	118	65	53	26	58	85	25	31	17
1000 to 1059	1	4	40	60	63	27	99	138	93	103	17	
1100 to 1159	12	5	61	54	57	41	69	39	54	54	11	22
1200 to 1259	2	1	39	32	50	27	83	110	61	43	12	7
1300 to 1359		6	53	63	53	48	30	141	23	27	10	27
1400 to 1459	9	3	64	74	40	35	116	127	31	36	21	14
1500 to 1559	6	10	34	48	53	45	37	77	52	20	27	7
1600 to 1659				82	27	12	23	54	23	19	33	
1700 to 1759				22	14	15	5	17	16			
1800 to 1859												
1900 to 1959												
Total	**49**	**43**	**383**	**657**	**507**	**391**	**511**	**797**	**516**	**345**	**218**	**119**

Table 3: Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2007 (Page 1 of 2)

Date:	*31-May*	*1-Jun*	*2-Jun*	*3-Jun*	*4-Jun*	*5-Jun*	
Observation Time-Start:	*7:45*	*8:00*	*8:00*	*8:00*	*7:45*	*7:45*	***Season***
Observation Time-End:	*16:40*	*16:30*	*16:30*	*16:30*	*15:50*	*15:45*	***Total***
Military Time (hrs)							
0700 to 0759	20				1	1	**80**
0800 to 0859	23	7	7	2	1	3	**1,047**
0900 to 0959	16	8	14	2	1	0	**947**
1000 to 1059	20		16	4	1	2	**931**
1100 to 1159	19	9	20	3	6	2	**777**
1200 to 1259	8	23	18	4	4	3	**749**
1300 to 1359	22	9	11	4	1	0	**727**
1400 to 1459	32	10	7	3		5	**930**
1500 to 1559	20	5	3	4	3	3	**637**
1600 to 1659	16	3	6	3			**301**
1700 to 1759							**89**
1800 to 1859							**0**
1900 to 1959							**0**
Total	**196**	**74**	**102**	**29**	**18**	**19**	**7,215**

Table 4: Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2007

		Holtwood		Safe Harbor		York Haven	
	Conowingo East	Number	Passed	Number	Passed	Number	Passed
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%	4,675	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	6.9%
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%**

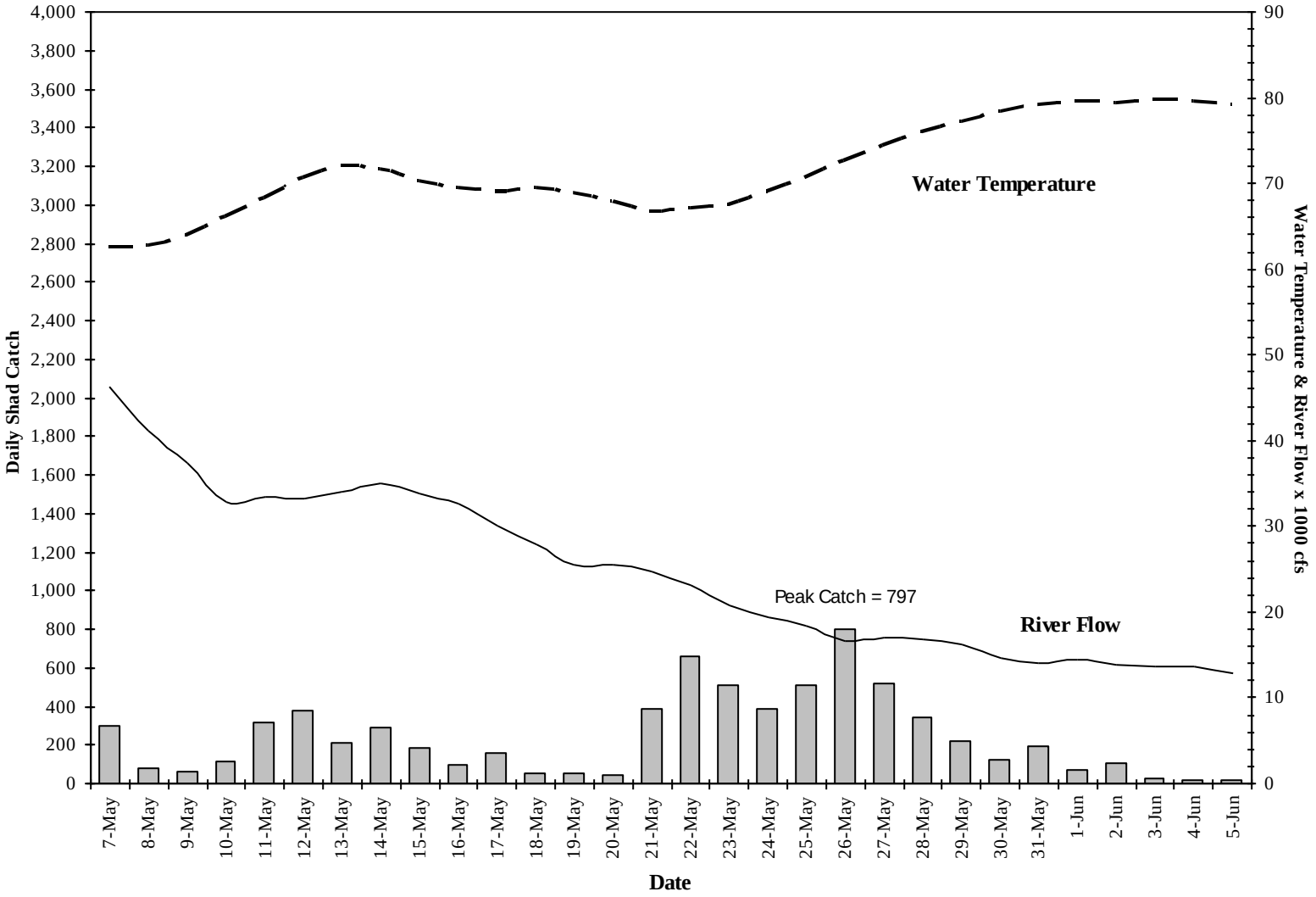

Figure 1: A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the daily American shad catch at the Safe Harbor fish passage facility, spring 2007

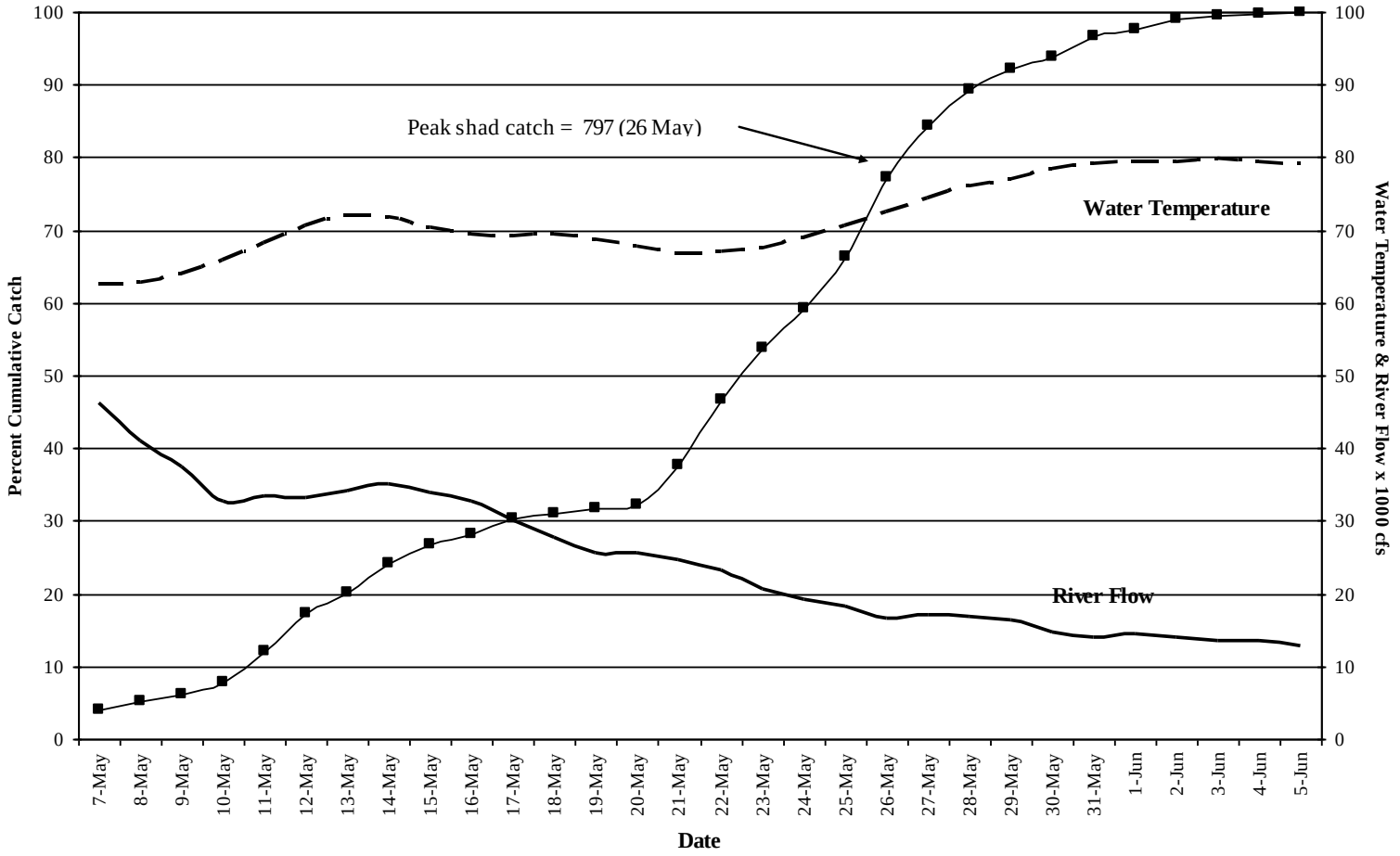

Figure 2: A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam, in relationship to the percent cumulative American shad catch at the Safe Harbor fish passage facility, spring 2007

5.0 JOB 1, PART 5: FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT, 2007

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Middletown, Pennsylvania 17057

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5.1 EXECUTIVE SUMMARY

The fish ladder was opened on 2 April allowing volitional (unmanned) passage. Manned Fishway operation started on 16 May and ended on 6 June. During this 22 day period a total of 31,670 fish of 17 taxa were enumerated as they passed upstream though the ladder into Lake Frederic. Gizzard shad (21,843) was the dominant fish species passed and comprised 70% of the fish passed. Passage varied daily and ranged from 10,045 fish on 6 May to 961 fish on 24 May. American shad were passed at water temperatures of 63.0° F to 79.7° F, and River flows that ranged from 9,300 cfs to 26,300 cfs and East Channel flows of 2,100 cfs to 3,400 cfs (Tables 2 and 3, Figures 3 and 4). Shad passage varied daily with nearly 92% of total shad passed (176) in May. Passage during May occurred at Rivers flows that declined from 26,300 cfs to 10,300 cfs. Water temperature during this period averaged 70.0° F and ranged from 63.0° F to 78.1° F. East Channel flows averaged 2,334 cfs (2,100 cfs to 3,400 cfs). Passage in June occurred at Rivers flows that averaged 11,667 cfs and ranged from 11,400 cfs to 12,700 cfs. Water temperature during this period averaged 76.5° F (72.5° F to 79.7° F) and East Channel flows were stable at 2,100 cfs.

The hourly passage of American shad through the fish ladder is given in Table 4. Over 44% of the shad (86) passed between 0800 hrs and 1100 hrs; hourly passage varied from no shad to 8 shad. Some 54 shad passed from 1101 hrs to 1300 hrs. A total of 52 shad passed between 1301 hrs and 1600 hrs. The peak hourly passage of shad (8) occurred on 30 May between 0800 hrs and 0859 hrs.

YHPC will continue working with members of the FPTAC to develop and implement practical changes to Fishway operation that are geared toward improving passage through the Fishway. Future operations of the Fishway will build on the past eight years of experience.

As in previous years YHPC agreed to make periodic observations for adult shad in the forebay and open the trash gate if/when large numbers of adults were observed. No adult shad were observed by Station Personnel that made periodic observations of the forebay area from June1 1 through August 31.

The station also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC. Daily monitoring of the York Haven forebay for the presence of fish began on 17 September when water temperature was 68.0° F. Monitoring

continued through 13 November. River flow during this period ranged varied daily and ranged from 3,680 cfs to 25,900 cfs. The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity. Given that fish activity was non-existent there was no need to implement "Downstream Operation."

5.2 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.

Following the electronic (e-mail) distribution of the Draft 2006 Fishway Operation Report on December 16, 2006 and the Draft 2007 Fishway Operating Procedure on January 18, 2007 resource agency members of the FPTAC indicated they had no comments, questions or concerns regarding the Draft 2006 Report and/or the Draft Fishway Operation Plan for 2007 to warranted a meeting prior to the start of spring Fishway operation. Since there were no comments both documents were finalized. As in previous years, YHPC agreed to conduct periodic observations for adults in the forebay and would open the trash gate if/when large numbers of adults were observed. They also planned to the implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC.

5.3 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.

Operation in 2007, the eight year of Fishway operation incorporated experience gained during the first six seasons, along with FPTAC recommendations. Objectives of 2007 operation were to monitor passage of migratory and resident fishes through the Fishway and continue to assess operation and the springtime minimum flow release.

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 was less than 23,000 cfs, a nominal minimum spill of 4,000 cfs was maintained over the Main Dam during daily Fishway operation.

5.4 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 five 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.

5.5 FISHWAY DESIGN AND OPERATION

5.5.1 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).

5.5.2 Fishway Operation

Fishway preparations for the 2007 season began in Late March enabling volitional fish passage (unmanned) through the ladder to commence on 2 April. Only the entrance and exit gate(s) were open the during the 22 day unmanned period of Fishway operation.

Manned Fishway operation, commenced on 16 May, 9 days after the Safe Harbor Fish Lift was placed in service and had passed 1,936 American shad. Fish were counted and allowed to pass upstream daily between 0800 hrs and 1600 hrs from 16 May to 6 June; a 22 day period. The decision to stop manned Fishway operation on 6 June was mutually agreed to by members of the FPTAC.

During manned Fishway operation, both fixed wheel gates and the diffuser gate were opened. These gates remained opened throughout the spawning migration. The entrance gate was the

only gate that was adjusted throughout the season. This gate was adjusted manually throughout the season maintaining a 0.25-ft to 0.5-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 to 6 ft/sec at the entrance to the ladder. The 7-ft wide stop gate, located between the weir and the fish ladder entrance, remained closed during the entire period of operation.

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

After manned Fishway operation ended on 6 June, the South fixed wheel gate was closed. On 8 June, the fish ladder and North fixed wheel gate were set to deliver a minimum flow of 400 cfs into the East Channel. As agreed to, the fish ladder and the North wheel gate remained open through 30 June.

5.5.3 Fish Counts

Fish that passed through the ladder were identified to species and enumerated as they passed the counting window by a biologist 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. This gate was closed nightly at 1600 hrs based on shad passage. The stop gate was usually opened each morning the Fishway was manned at 0800 hrs. Occasionally, it was closed for brief periods of time as needed each day to enable the person manning the Fishway to 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 varied from 8 in to 24 in depending on river conditions.

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 and GPU personnel on a daily basis. In addition, weekly passage information was supplied electronically to YHPC and GPU personnel and members of the FPTAC.

Each day a permanent record (video tape) of daily fish passage was made. The video system was the same system used in 2000 and it was set-up identical to that reported in Kleinschmidt (2000). Fish passage was recorded in 12 hour time-lapse mode. During recording, the recorder imprinted the time and date on each frame of video tape, providing a record for fish that passed the viewing window. No tape review of 2007 passage was conducted, as hourly shad passage never reached the minimum passage requirement of 1,000 shad/hr.

5.6 RESULTS

5.6.1 Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 31,670 fish of 17 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (21,843) was the dominant fish species passed and comprised almost 70% of the fish passed. Some 192 American shad were counted as they passed through the ladder. Other predominant fishes passed included channel catfish (4,192), quillback (3,425) walleye (879), carp (597), and smallmouth bass (378). Passage varied daily and ranged from 3,184 fish on 16 May to 727 fish on 5 June.

5.6.2 American Shad Passage

A total of 192 American shad passed upstream through the ladder in 2007 (Table 1). Some 176 shad passed in May while 16 passed in June. Peak shad passage occurred on 21 May when 22 shad passed.

American shad were passed at water temperatures of 63.0° F to 79.7° F, and River flows that ranged from 9,300 cfs to 26,300 cfs and East Channel flows of 2,100 cfs to 3,400 cfs (Tables 2 and 3, Figures 3 and 4). Shad passage varied daily with nearly 92% of total shad passed (176) in May. Passage during May occurred at Rivers flows that declined from 26,300 cfs to 10,300 cfs. Water temperature during this period averaged 70.0° F and ranged from 63.0° F to 78.1° F. East Channel flows averaged 2,334 cfs (2,100 cfs to 3,400 cfs). Passage in June occurred at Rivers flows that averaged 11,667 cfs and ranged from 11,400 cfs to 12,700 cfs. Water temperature during this period averaged 76.5° F (72.5° F to 79.7° F) and East Channel flows were stable at 2,100 cfs.

The hourly passage of American shad through the fish ladder is given in Table 4. Over 44% of the shad (86) passed between 0800 hrs and 1100 hrs; hourly passage varied from no shad to 8 shad. Some 54 shad passed from 1101 hrs to 1300 hrs. A total of 52 shad passed between 1301 hrs and 1600 hrs. The peak hourly passage of shad (8) occurred on 30 May between 0800 hrs and 0859 hrs.

5.6.3 Other Alosids

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

5.6.4 Observations

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

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

5.7 SUMMARY

The ladder was opened on 2 April allowing unmanned passage. Manned Fishway operation started on 16 May and ended on 6 June. During this 22 day period a total of 31,670 fish of 17 taxa were enumerated as they passed upstream though the ladder into Lake Frederic.

A total of 192 shad were observed as they passed upstream through the ladder. American shad were passed at water temperatures of 63.0° F to 79.7° F, and River flows that ranged from 9,300 cfs to 26,300 cfs and East Channel flows of 2,100 cfs to 3,400 cfs. Some 176 shad passed in May while 16 passed in June. Peak shad passage occurred on 21 May when 22 shad passed. Most shad (86) passed through the ladder between 0800 hrs and 1100 hrs.

YHPC will continue working with members of the FPTAC to develop and implement practical changes to Fishway operation that are geared toward improving passage through the Fishway. Future operations of the Fishway will continue to build on the previous eight years of experience.

5.8 DOWNSTREAM FISH PASSAGE

As in previous years, YHPC agreed to make periodic observations for adult shad in the forebay and open 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.

5.8.1 Adult Passage

No observations of post-spawned adult shad were noted by Station personnel that made periodic observations of the forebay area from June through mid-August, 2007. During this period (1 June to 31 August) station personnel opened the trash sluice opened on 26 days. This observation process will continue in 2008.

5.8.2 Juvenile Passage

The Juvenile Downstream Passage Protocol provides for:

- Monitoring the forebay to determine when outmigrating juveniles arrive at the project
- Starting "Downstream Operation" when juveniles arrive at York Haven; Downstream Operation begins each evening at sunset and continue until about 11:30 p.m. Downstream Operation includes:
    - Turning on temporary lighting at the trash sluiceway and opening the sluiceway
    - Operating only Units 1-6 when river flow is insufficient for operation of any of the remaining units

  - Operating Units 7-20 only when river flow exceeds the hydraulic capacity of available Units 1-6; the operating priority for Units 7-20 is Unit 7, Unit 8, Unit 9 etc.
- Monitoring and sampling in the forebay as river water temperatures drop and/or River flows increase to determine when the juvenile shad emigration has ended for the season
- Ceasing "Downstream Operation" at the end of the run, in consultation with members of the FPTAC.

In accordance with the protocol, monitoring of the York Haven forebay for the presence of juvenile American shad began on 17 September when water temperature was 68.0° F and River flow at Harrisburg was 5,260 cfs. Monitoring continued through 13 November. River flow during this period varied daily and ranged from 3,680 cfs to 25,900 cfs (Figure 5). The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity.

Given that fish activity was non-existent there was no need to implement "Downstream Operation". As a means of ensuring the downstream migration wasn't occurring without being noticed routine contact was maintained with others conducting juvenile shad sampling programs in the lower River. According to personnel conducting these sampling programs juvenile shad abundance was extremely low again in 2007. Only two juvenile shad were collected at Columbia while haul seining and no juvenile shad had been collected in the lift net at the Holtwood station through mid-November.

5.9 LITERATURE CITED

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

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

White. D.K., and J. Larson. 1998. Model study of the fish passage facility at the East Channel Dam York Haven Project. Alden Research Laboratory, Inc. August, 39 pp.

5.10 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 2007 (Page 1 of 3)

Date	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May
Observation Time (hrs.)	8.0	8.0	8.0	8.0	7.5	8.0	8.0	8.0	8.0	8.0
Water Temperature (^{o}F)	68.9	67.1	64.4	63.0	63.5	63.5	65.3	68.9	70.7	72.5
AMERICAN SHAD	5	9	13	7	9	22	10	10	12	19
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	1,566	1,997	1,130	1,029	1,203	1,337	625	905	906	1,199
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	1	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	1
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	22	14	30	32	25	22	60	50	34	23
QUILLBACK	1,314	124	154	85	83	63	257	140	26	43
WHITE SUCKER	3	0	0	0	0	0	0	0	1	1
SHORTHEAD REDHORSE	44	18	22	0	0	1	7	5	2	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	177	195	112	118	129	21	41	133	114	118
ROCK BASS	0	0	1	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	0	0	1	0
SMALLMOUTH BASS	2	11	8	0	0	14	33	63	57	28
LARGEMOUTH BASS	2	9	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	1	0
WALLEYE	49	33	39	49	43	19	24	18	33	70
TIGER MUSKELLUNGE	0	0	0	0	0	0	1	1	0	0
Total	3,184	2,411	1,509	1,320	1,492	1,499	1,058	1,325	1,187	1,502

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 2007 (Page 2 of 3)

Date	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun	4-Jun
Observation Time (hrs.)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Water Temperature (^{o}F)	73.5	75.5	70.7	77.0	76.9	78.1	78.8	79.7	76.5	75.2
AMERICAN SHAD	6	7	7	16	15	9	5	4	2	2
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	1058	805	1502	1090	699	927	527	450	682	768
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	1	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	44	59	19	17	24	11	26	40	28	4
QUILLBACK	189	34	36	51	59	507	79	16	27	16
WHITE SUCKER	0	0	0	0	0	0	0	0	0	0
SHORTHEAD REDHORSE	4	5	4	1	0	5	1	1	2	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	1
CHANNEL CATFISH	190	370	364	160	140	466	385	474	304	68
ROCK BASS	1	1	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	28	19	25	15	18	20	11	9	3	4
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	93	86	86	46	35	46	47	27	4	15
NORTHERN HOG SUCKER	0	0	0	0	0	0	0	0	0	0
Total	1,614	1,386	2,043	1,396	990	1,991	1,081	1,021	1,052	878

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 2007 (Page 3 of 3)

Date	5-Jun	6-Jun	Total
Observation Time (hrs.)	8.0	8.0	175.5
Water Temperature (^{o}F)	76.1	72.5	
AMERICAN SHAD	2	1	192
ALEWIFE	0	0	0
BLUEBACK HERRING	0	0	0
GIZZARD SHAD	552	886	21,843
HICKORY SHAD	0	0	0
STRIPED BASS	0	0	0
WHITE PERCH		0	0
AMERICAN EEL	0	0	0
RAINBOW TROUT	0	0	2
BROWN TROUT	0	0	1
MUSKELLUNGE	0	0	0
CARP	10	3	597
QUILLBACK	64	58	3,425
WHITE SUCKER	0	0	5
SHORTHEAD REDHORSE	6	5	133
BROWN BULLHEAD	3	1	5
CHANNEL CATFISH	79	34	4,192
ROCK BASS	0	0	3
BLUEGILL	0	0	1
SMALLMOUTH BASS	5	5	378
LARGEMOUTH BASS	0	0	11
YELLOW PERCH	0	0	1
WALLEYE	6	11	879
TIGER MUSKELLUNGE	0	0	2
Total	727	1,004	31,670

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 elevation during operation of the York Haven fishway complex in 2007

	River	East	Main Dam	Water				Stop	Elevation (ft)					
	Flow	Channel	Flow	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	(cfs)	(oF)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
16-May	29,700	3,400	26,300	68.9	12	12	12	Closed	279.6	279.5	279.6	274.2	274.2	274.2
17-May	26,800	3,200	23,600	67.1	13	12	16	Closed	279.2	279.1	279.4	273.9	273.8	274.3
18-May	25,700	3,000	22,700	64.4	12	12	12	Closed	279.2	279.2	279.2	273.9	273.8	273.9
19-May	24,400	2,200	22,200	63.0	12	12	12	Closed	279.1	279.1	279.1	273.2	273.1	273.2
20-May	23,100	2,200	20,900	63.5	12	12	12	Closed	279.1	279.1	279.1	273.2	273.1	273.2
21-May	22,300	2,200	20,100	63.5	12	12	12	Closed	279.1	279.0	279.3	273.5	273.5	273.5
22-May	20,700	2,175	18,525	65.3	12	12	12	Closed	279.0	278.9	279.1	273.3	273.3	273.4
23-May	18,700	2,150	16,550	68.9	12	12	12	Closed	278.8	278.8	278.8	273.5	273.4	273.5
24-May	17,100	2,125	14,975	70.7	12	12	12	Closed	278.8	278.7	278.9	273.5	273.5	273.5
25-May	16,200	2,100	14,100	72.5	24	24	24	Closed	278.6	278.6	278.6	273.4	273.4	273.5
26-May	15,500	2,100	13,400	73.5	12	12	12	Closed	278.6	278.6	278.6	273.5	273.5	273.5
27-May	15,000	2,100	12,900	75.5	12	12	12	Closed	278.6	278.6	278.6	273.5	273.5	273.5
28-May	14,500	2,100	12,400	70.7	12	12	12	Closed	278.6	278.6	278.6	273.5	273.5	273.5
29-May	14,100	2,100	12,000	77.0	22	20	24	Closed	278.6	278.6	278.6	273.5	273.5	273.5
30-May	13,500	2,100	11,400	76.9	24	24	24	Closed	278.6	278.6	278.6	273.5	273.5	273.5
31-May	12,400	2,100	10,300	78.1	12	12	12	Closed	278.6	278.6	278.6	273.5	273.5	273.5
1-Jun	11,600	2,100	9,500	78.8	12	12	12	Closed	278.6	278.6	278.6	273.5	273.5	273.5
2-Jun	11,500	2,100	9,400	79.7	10	8	12	Closed	278.6	278.6	278.6	273.6	273.5	273.6
3-Jun	11,400	2,100	9,300	76.5	12	12	12	Closed	278.6	278.6	278.6	273.6	273.6	273.6
4-Jun	11,400	2,100	9,300	75.2	14	12	18	Closed	278.6	278.6	278.6	273.5	273.5	273.5
5-Jun	11,400	2,100	9,300	76.1	18	18	18	Closed	278.6	278.6	278.6	273.5	273.5	273.5
6-Jun	12,700	2,100	10,600	72.5	12	12	12	Closed	278.6	278.6	278.6	273.4	273.4	273.4

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2007

		Elevation (ft)																				
	River Flow	Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
Date	(cfs)	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
16-May	29,700	279.6	279.5	279.6	274.2	274.2	274.2	274.4	274.2	274.6	277.8	277.8	277.8	278.4	278.3	278.5	277.7	277.6	277.7	278.2	278.1	278.3
17-May	26,800	279.2	279.1	279.4	273.9	273.8	274.3	274.0	273.9	274.0	277.6	277.6	277.7	279.0	278.9	279.2	277.6	277.5	277.6	278.5	278.0	278.8
18-May	25,700	279.2	279.2	279.2	273.9	273.8	273.9	273.8	273.7	273.8	277.6	277.6	277.6	278.8	278.8	278.9	277.5	277.5	277.6	278.5	278.4	278.5
19-May	24,400	279.1	279.1	279.1	273.2	273.1	273.2	273.3	273.2	273.3	277.5	277.5	277.5	278.6	278.6	278.7	277.6	277.5	277.6	278.4	278.4	278.5
20-May	23,100	279.1	279.1	279.1	273.2	273.1	273.2	273.7	273.7	273.7	277.6	277.4	277.8	278.7	278.6	278.9	277.5	277.4	277.7	278.3	278.3	278.3
21-May	22,300	279.1	279.0	279.3	273.5	273.5	273.5	273.7	273.7	273.7	277.6	277.4	277.8	278.7	278.6	278.9	277.5	277.4	277.7	278.3	278.3	278.3
22-May	20,700	279.0	278.9	279.1	273.3	273.3	273.4	273.5	273.5	273.5	277.5	277.5	277.5	278.5	278.4	278.5	277.4	277.4	277.4	278.4	278.4	278.4
23-May	18,700	278.8	278.8	278.8	273.5	273.4	273.5	273.4	273.3	273.5	277.5	277.5	277.5	278.5	278.4	278.5	277.4	277.3	277.4	278.3	278.2	278.3
24-May	17,100	278.8	278.7	278.9	273.5	273.5	273.5	273.3	273.6	273.7	277.4	277.4	277.4	278.6	278.3	278.8	277.3	277.3	277.3	278.2	278.2	278.2
25-May	16,200	278.6	278.6	278.6	273.4	273.4	273.5	273.6	273.6	273.6	277.3	277.3	277.3	278.4	278.4	278.4	277.2	277.2	277.2	278.2	278.1	278.3
26-May	15,500	278.6	278.6	278.6	273.5	273.5	273.5	273.5	273.5	273.6	277.4	277.4	277.4	278.3	278.3	278.4	277.2	277.2	277.2	278.0	278.0	278.0
27-May	15,000	278.6	278.6	278.6	273.5	273.5	273.5	273.5	273.5	273.5	277.4	277.4	277.4	278.2	278.1	278.3	277.3	277.2	277.3	278.0	278.0	278.0
28-May	14,500	278.6	278.6	278.6	273.5	273.5	273.5	273.5	273.5	273.5	277.4	277.4	277.4	278.1	278.1	278.1	277.3	277.3	277.3	278.0	278.0	278.0
29-May	14,100	278.6	278.6	278.6	273.5	273.5	273.5	273.5	273.5	273.5	277.4	277.3	277.4	278.3	278.1	278.4	277.3	277.3	277.3	278.1	277.8	278.2
30-May	13,500	278.6	278.6	278.6	273.5	273.5	273.5	273.5	273.5	273.5	277.4	277.4	277.5	278.4	278.3	278.4	277.3	277.3	277.3	278.2	278.2	278.2
31-May	12,400	278.6	278.6	278.6	273.5	273.5	273.5	273.4	273.4	273.4	277.4	277.4	277.4	278.4	278.3	278.4	277.3	277.2	277.3	278.1	278.1	278.1
1-Jun	11,600	278.6	278.6	278.6	273.5	273.5	273.5	273.4	273.4	273.4	277.4	277.4	277.4	278.4	278.3	278.4	277.3	277.2	277.3	278.1	278.1	278.1
2-Jun	11,500	278.6	278.6	278.6	273.6	273.5	273.6	273.6	273.5	273.6	277.2	277.2	277.3	278.2	278.2	278.2	277.2	277.2	277.2	278.1	278.1	278.1
3-Jun	11,400	278.6	278.6	278.6	273.6	273.6	273.6	273.6	273.5	273.6	277.3	277.3	277.3	278.4	278.3	278.4	277.3	277.3	277.3	278.2	278.1	278.3
4-Jun	11,400	278.6	278.6	278.6	273.5	273.5	273.5	273.6	273.6	273.6	277.3	277.3	277.3	278.4	278.4	278.4	277.3	277.3	277.3	278.2	278.2	278.3
5-Jun	11,400	278.6	278.6	278.6	273.5	273.5	273.5	273.6	273.6	273.6	277.3	277.2	277.3	278.4	278.4	278.4	277.3	277.3	277.3	278.2	278.2	278.2
6-Jun	12,700	278.6	278.6	278.6	273.4	273.4	273.4	273.6	273.7	273.6	277.3	277.3	277.3	278.4	278.3	278.4	277.2	277.2	277.2	278.0	278.0	278.1

Table 4. Hourly summary of American shad passage through the serpentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2007 (Page 1 of 2)

Date	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May
Observation Time (Start)	0800	0800	0800	0800	0830	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)									
0801 - 0900	1	0	2	6	4	5	1	5	0
0901 - 1000	0	0	5	0	3	0	0	1	0
1001 - 1100	2	0	0	0	1	1	0	2	2
1101 - 1200	0	4	0	0	0	4	1	1	4
1201 - 1300	0	2	1	0	0	5	5	1	3
1301 - 1400	0	2	1	0	1	3	0	0	1
1401 - 1500	0	0	1	1	0	2	1	0	1
1501 - 1600	2	1	3	0	0	2	2	0	1
Total Catch	5	9	13	7	9	22	10	10	12

Date	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	800	1600	1600
Military Time (Hours)									
0801 - 0900	0	1	3	0	0	8	2	1	0
0901 - 1000	3	2	1	2	6	4	1	1	0
1001 - 1100	3	2	0	0	0	1	0	0	0
1101 - 1200	4	0	1	1	1	0	1	0	1
1201 - 1300	6	0	1	2	2	0	1	0	0
1301 - 1400	2	1	0	2	0	1	2	1	0
1401 - 1500	1	0	0	0	4	0	0	1	1
1501 - 1600	0	0	1	0	3	1	2	1	2
Total Catch	19	6	7	7	16	15	9	5	4

Table 4. Hourly summary of American shad passage through the serpentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2007 (Page 2 of 2)

Date	3-Jun	4-Jun	5-Jun	6-Jun		
Observation Time (Start)	0800	0800	0800	0800		
Observation Time (End)	1600	1600	1600	1600	Total	Percentage
Military Time (Hours)						
0801 - 0900	1	0	0	0	40	20.8
0901 - 1000	1	0	0	0	30	15.6
1001 - 1100	0	0	2	0	16	8.3
1101 - 1200	0	0	0	1	24	12.5
1201 - 1300	0	1	0	0	30	15.6
1301 - 1400	0	0	0	0	17	8.9
1401 - 1500	0	0	0	0	13	6.8
1501 - 1600	0	1	0	0	22	11.5
Total Catch	2	2	2	1	192	100.0

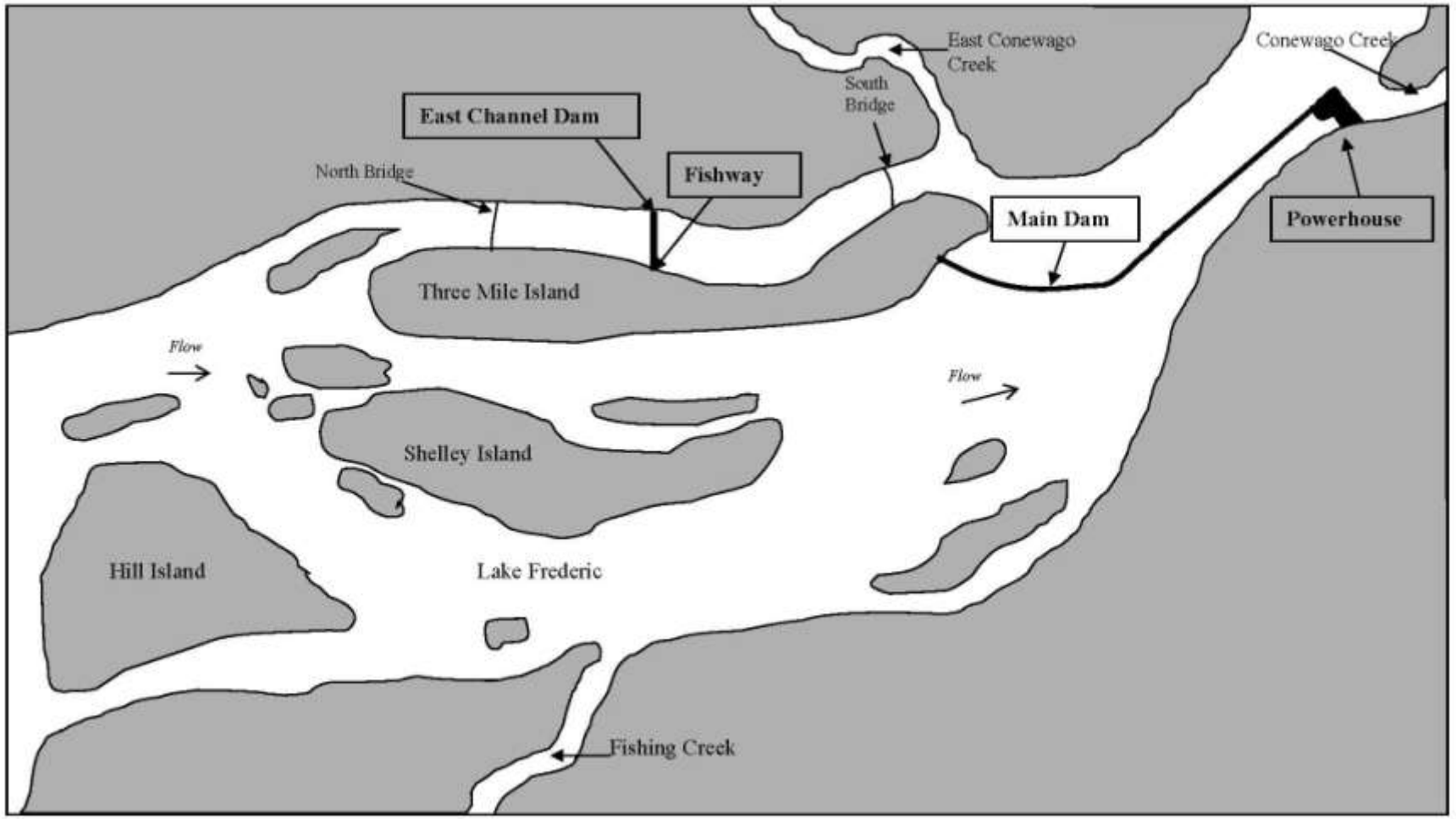


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway

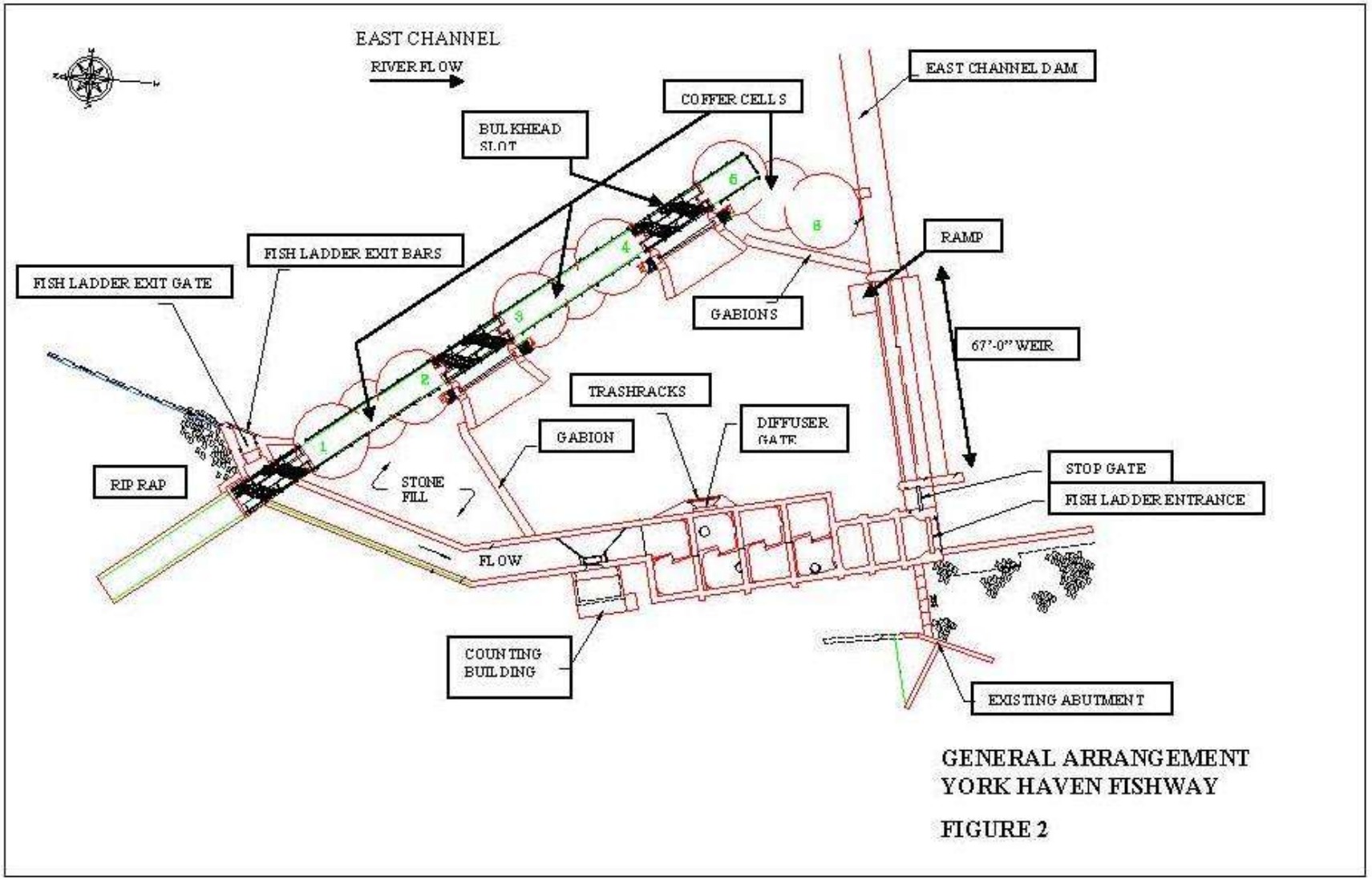


Figure 2. General Arrangement York Haven Fishway

Figure 3. Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2007

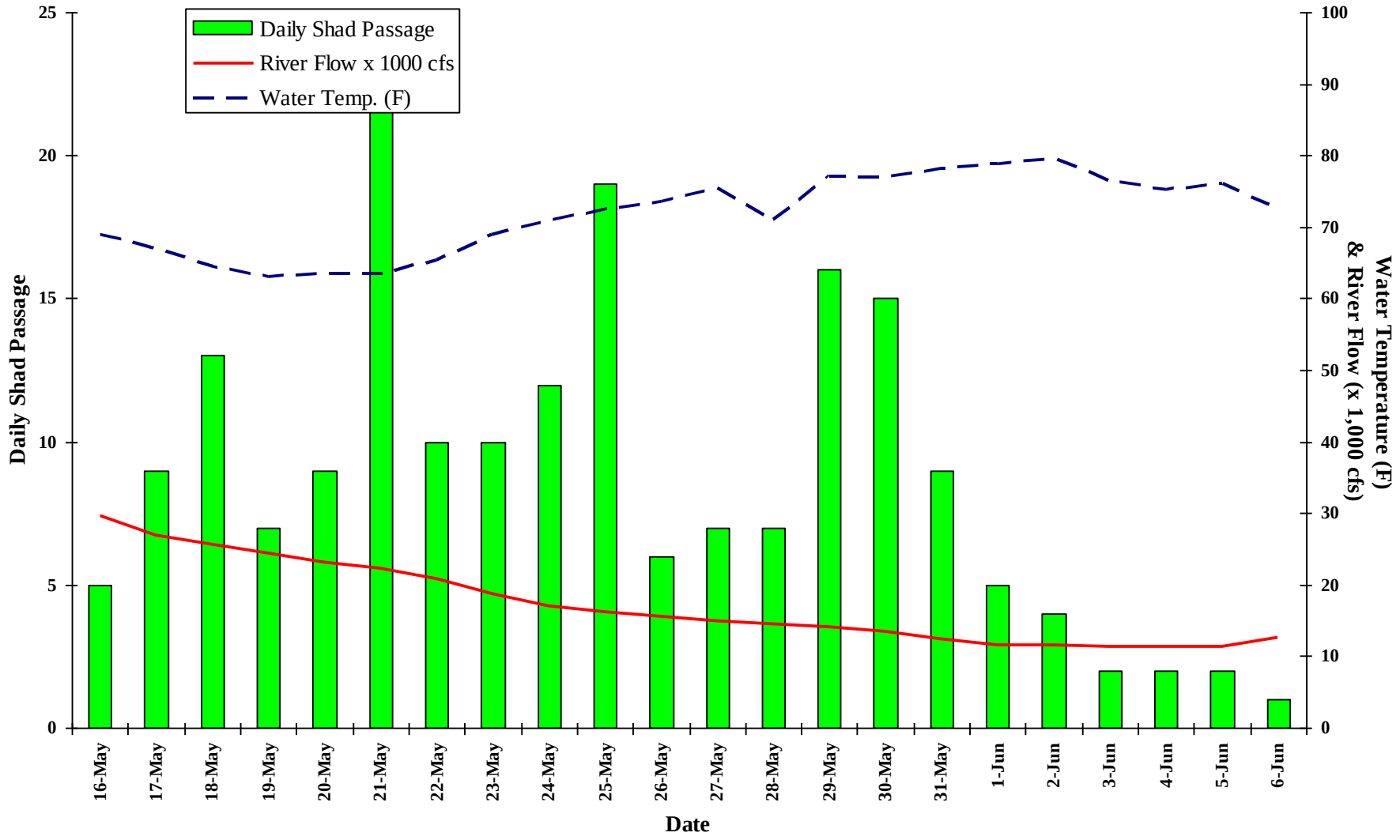


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2007

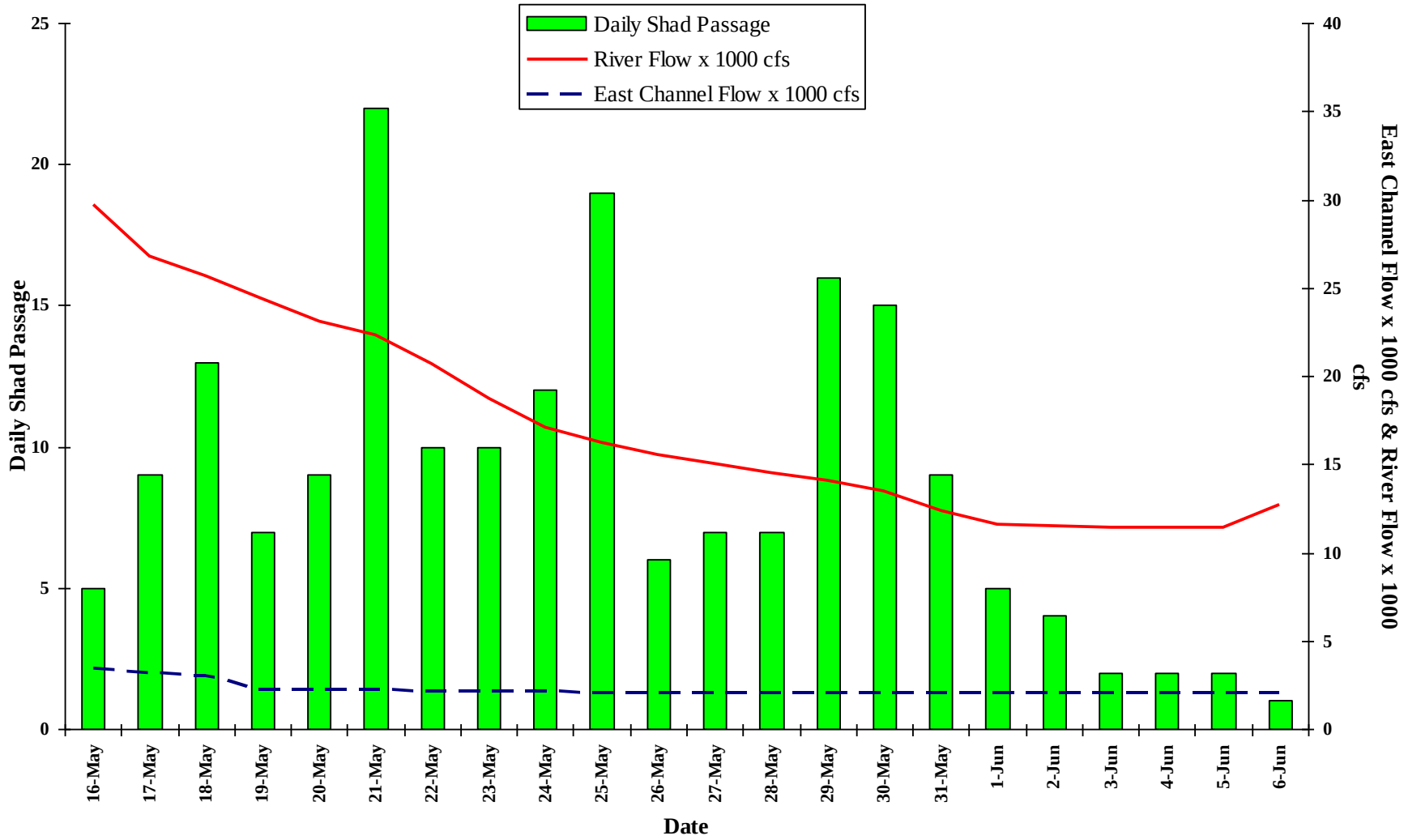
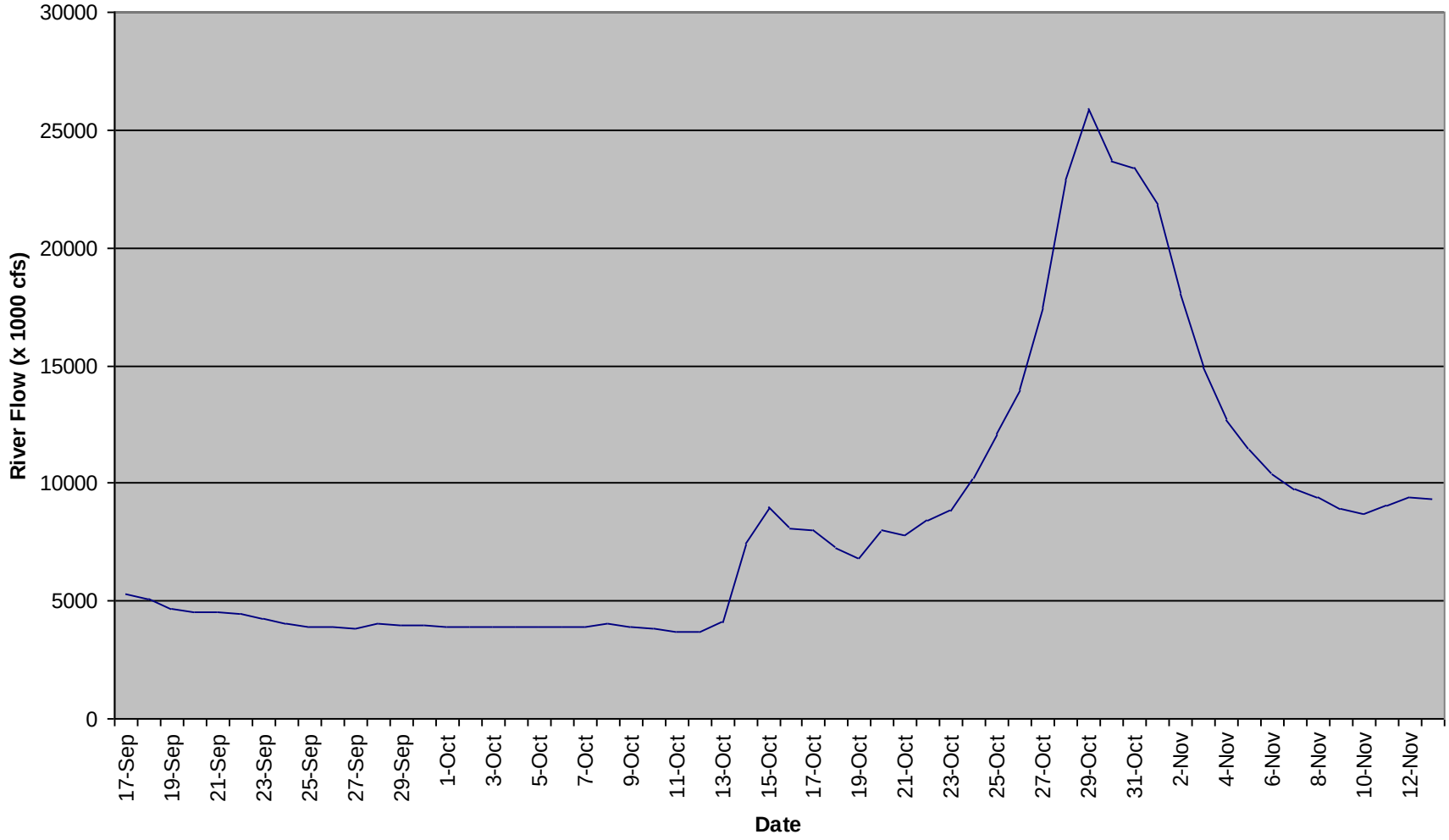


Figure 5. Plot of River Flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River, 17 September to 13 November, 2007



6.0 JOB 2, PART 1: U.S. FISH & WILDLIFE SERVICE SUSQUEHANNA RIVER AMERICAN SHAD (*ALOSA SAPIDISSIMA*) RESTORATION: POTOMAC RIVER EGG COLLECTION, 2007

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

6.1 ABSTRACT

During April and May, 2007 we used monofilament gill nets to collect 787 American shad from the Potomac River (rkm 150). The purpose of sampling was to supply viable eggs to the Pennsylvania 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 183.9 L of American shad eggs (7.5 million) with 42% fertilized for 2.9 million viable eggs. As a proportion of the total catch, ripe and green female American shad were equally represented (25.6% ripe, 26.4% green) and twice that of males (13.5%). The U.S. Fish and Wildlife Service's second attempt to deliver eggs for Susquehanna River American shad restoration resulted in slightly higher numbers of viable eggs despite the reduction of fishing time and collection location. Results from the Potomac River nearly equaled the viable eggs delivered from the Delaware and Susquehanna Rivers combined (3.0 million eggs).

6.2 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 C^o (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. Shad have undergone population fluctuations as a result of anthropogenic effects. In Pennsylvania, American shad are said to have once ruled the waters of the Susquehanna River and its tributaries (The Native Fish Conservancy 2005). 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.

6.2.1 Study Area

American shad gill netting occurs in the Potomac River at Marshall Hall, MD (rkm 150).. The collection site is bounded by Dogue Creek (North) and Gunston Cove (South) and has long been linked to shad harvest and culture. The river is approximately 1.5 km wide and 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.

6.3 MATERIALS AND METHODS

We used 6.1 m deep by 91.4 m long floating monofilament gill nets with 14.0 cm stretch mesh panels. Multiple nets were joined in series and drifted parallel to shore in depths ranging from approximately 7.6 to 16.8 m. Two small (6.7 m) boats consisting of three to four crew members set as many as three interconnected nets each. 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 (C^o), dissolved oxygen (mg/L), conductivity (micromos) 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, Figures 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= ($n/hr/ft^2$)). All CPUE values were multiplied by 1000 as a scalar for data display (Figure 1). American shad otolith samples were taken along with total length (nearest mm) and weight (nearest 0.1 gram) from 5% (n=40) of American shad captured. The samples taken were a permit requirement of the Potomac River Fisheries Commission.

6.4 RESULTS

During spring 2007 we sampled the Potomac River a total of 19 days over a 40 day period. During the 19 days of fishing we collected ≥ 5.0 L of eggs 11 times (57%). We shipped a total of 183.9 L (Range = 3.8 – 40.8 L, $\bar{x}$ = 16.7 L/shipment) of eggs from the Potomac River (M. Hendricks, pers. comm.). The egg viability averaged 42% with a range of 2 – 66% (M.

Hendricks, pers. comm.).

Gill net sampling produced 2,009 fish from the Potomac River, nine fish species from six families were represented (Table 1). Ripe and green female American shad were equally represented (25.6% ripe, 26.4% green) and proportionally twice that of males (13.5%) (Figure 2). Bycatch of striped bass and blue catfish was reduced in comparison to 2006 because nets were set further from shore in deeper waters. Reducing bycatch increased efficiency of spawning operations.

From early April to mid-May, surface water temperature gradually increased while dissolved oxygen displayed a generally descending trend. However, during the second week of sampling, the surface water temperature dropped drastically before gradually ascending to the minimum spawning temperature (Figure 1). Furthermore, the final week of sampling, the dissolved oxygen steadily increased. Potomac River surface temperatures ranged from 10.2 to 22.4 C^o ($\bar{x}$ = 17.7 C^o) while dissolved oxygen ranged from 6.3 to 8.9 ($\bar{x}$ = 7.5 mg/L) (Figure 1). CPUE for shad was variable and there was no apparent relation to which tide was fished or lunar cycle. The CPUE was the highest on the first day (4/4/07) of sampling (0.006 shad/hr/ft^2) and the lowest on the fourteenth day (5/3/07) of sampling (0.000 shad/hr/ft^2). Generally speaking, the highest CPUE was between the fifth (4/23/07) and eleventh (4/30/07) day of sampling. At this point, the CPUE ranged from 0.0015 shad/hr/ft^2 to 0.0055 shad/hr/ft^2 with an average of 0.0034shad/hr/ft^2.

6.5 DISCUSSION

American shad harvest in numbers sufficient to yield egg shipments was variable on the Potomac River. The greatest numbers of ripe/running male and female American shad were caught between surface temperatures of 16.2-18.8. Overall the ratio of ripe male to running female was 2:1; however most of the ripe males were caught early in the sampling period when few running females were present. As the spawning season continued and more running females arrived at the spawning ground, the number of ripe males decreased significantly (Table 2). Had the sex ratio been consistent with one male to two females through the entire season, the overall egg viability may have been substantially higher resulting in more fry production. On some evenings when male American shad catches were very low, male American shad were often shared between Service boats, DC Fisheries, and Maryland Department of Natural Resources (MDDNR) and occasionally re-used. Using sperm extenders to preserve milt for use later in the spawning season, or collecting ripe male American shad from the Conowingo Dam fish lift, in the future should be considered as a way to sustain the high male to female ratio.

The 2007 Potomac River American shad collection provided Pennsylvania with 183.9 L of eggs, with an overall production of 2,875,455 viable eggs (42%) (Table 3, M. Hendricks, pers. comm.). In 2006, the Service provided 99.3 L of eggs from the Potomac River, with an overall production of 2,003,222 viable eggs (44%) ((M. Hendricks, pers. comm.). The 2007 sampling season consisted of 19 days of sampling with an average CPUE of 0.0020 shad/hr/ft^2, whereas the 2006 sampling season consisted of 16 days of sampling with an average CPUE of 0.0010 shad/hr/ft^2.

6.6 CONCLUSION

The Service's second attempt to harvest eggs from the Potomac River for delivery to the Van Dyke American shad hatchery, in support of Susquehanna River restoration, was successful. Program-wide egg production was hindered by the New York Department of Environmental Conservation decision to not allow American shad collection from the Hudson River in 2007. However, 2007 sampling on the Potomac River nearly equaled results from the Potomac and Hudson Rivers during 2006 and Delaware and Susquehanna Rivers during 2007.

6.7 ACKNOWLEDGEMENTS

The Maryland Fishery Resources Office thanks those who participated in this years sampling: Jose Barrios, Sarah Bitter, Gioia Blix, Matthew Breece, Shiela Eyler, Eric Ferree, Emily Loose, Tina McCrobie, and Gretchen Murphy. We would also like to thank Matthew Baldwin from MDDNR.

6.8 LITERATURE CITED

Stier, D.J., and J.H. Crance. 1985. Habitat suitability index models and instream flow suitability curves: American shad. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.88). 34 pp.

The Native Fish Conservancy Home Page. 2005. Migratory fish restoration and passage on the Susquehanna River. http://www.nativefish.org/articles/Migratory_Fish_Restoration.php. January 9, 2006.

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.

6.9 TABLES AND FIGURES

Table 1. List of species and number collected in gill nets from the Potomac River during spring 2007

Family	Scientific Name	Common Name	Number Captured
Centrarchidae	*Micropterus salmoide*	largemouth bass	1
Clupeidae	*Alosa sapidissima*	American shad	798
	Dorosoma cepedianum	gizzard shad	467
Cyprinidae	*Cyprinus carpio*	common carp	52
	Lepisosteus osseus	longnose gar	14
Ictaluridae	*Ictalurus punctatus*	channel catfish	8
Lepisosteidae	*Morone saxatilis*	striped bass	53
Moronidae	*Ameiurus nebulosus*	brown bullhead	2
	Ictalurus furcatus	blue catfish	30

Table 2. American shad catch totals with respect to male and female ratio and the associated viability and liters of eggs produced during spring 2007

	Ripe Male	Running Female	Ratio Male:Female	Viability	Liters
4/4/07	15	39	3:1	55%	12.4
4/5/07	7	18	3:1	16%	6.2
4/9/07	19	3	6:1	0	0
4/11/07	1	0	1:0	0	0
4/23/07	119	29	4:1	34%	11.4
4/24/07	44	13	3:1	0	0
4/25/07	14	60	1:4	47%	25.5
4/26/07	3	39	1:13	47%	13.8
4/27/07	16	97	1:6	43%	40.8
4/29/07	3	74	1:24	2%	21.5
4/30/07	12	80	1:7	49%	33.8
5/1/07	2	2	1:1	0	0
5/2/07	2	6	1:3	0	0
5/3/07	0	0	0	0	0
5/7/07	9	10	1:1	66%	3
5/8/07	0	16	1:16	33%	7
5/9/07	5	19	1:4	13%	7.8
5/10/07	0	0	0	0	0
5/14/07	1	10	1:10	0	0

Table 3. 2007 American shad egg shipment and viability summary from collection sites delivered to the Van Dyke American Shad Hatchery near Thompsontown, PA (Hendricks 2007, unpublished)

Site	Shipments (N)	Volume (L)	Eggs (N)	Viable Eggs (N)	Viability (%)
Potomac R.	11	183.9	7,488,716	2,875,455	42%
Delaware R.	15	135.8	6,457,563	2,337,598	39%
Susquehanna R.	12	84	6,773,594	603,345	9%
Total	38	403.7	20,719,874	5,816,398	28%

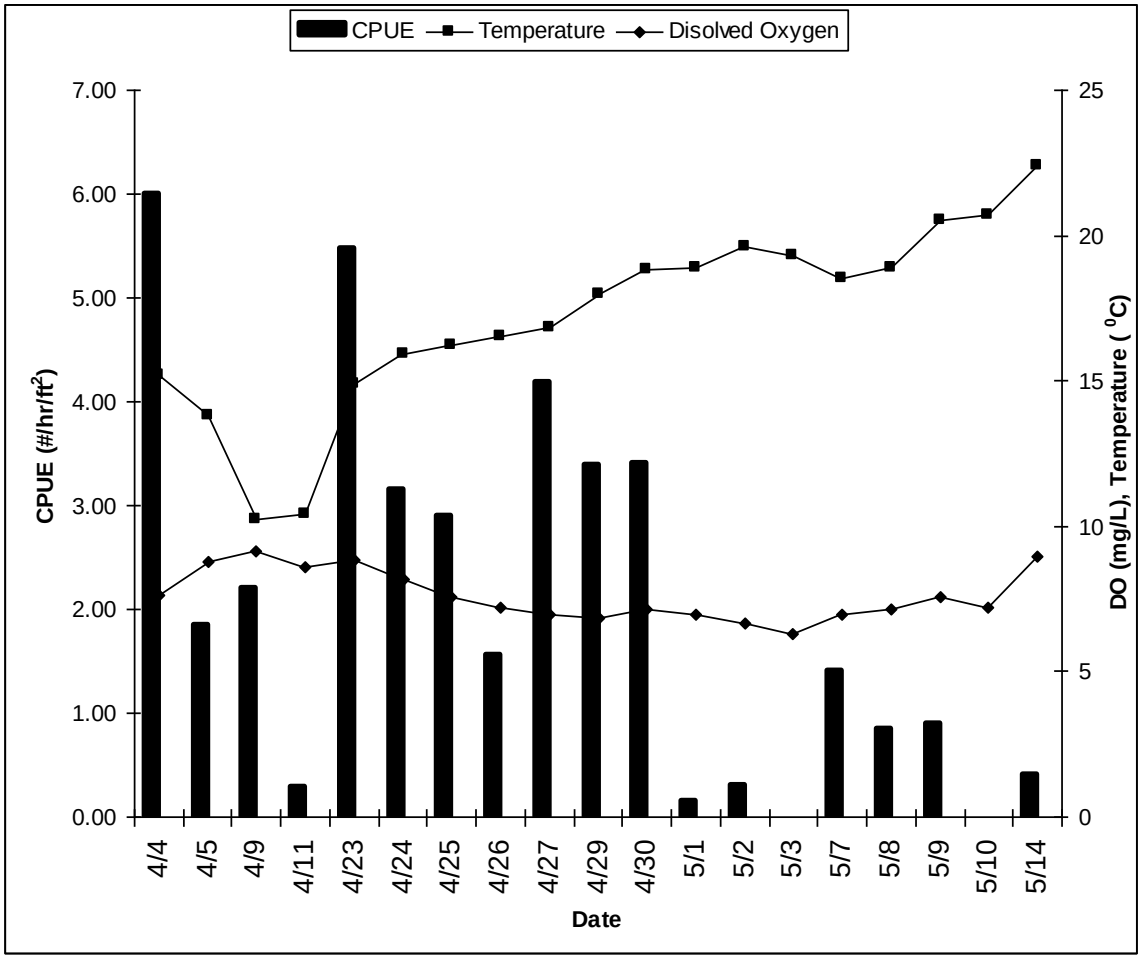


Figure 1. Spring 2007 American shad catch per unit effort, surface dissolved oxygen, and surface temperature, by sample date, for the Potomac River at Marshall Hall, MD. Surface salinity (not depicted) was always ≤ 0.10 ppt

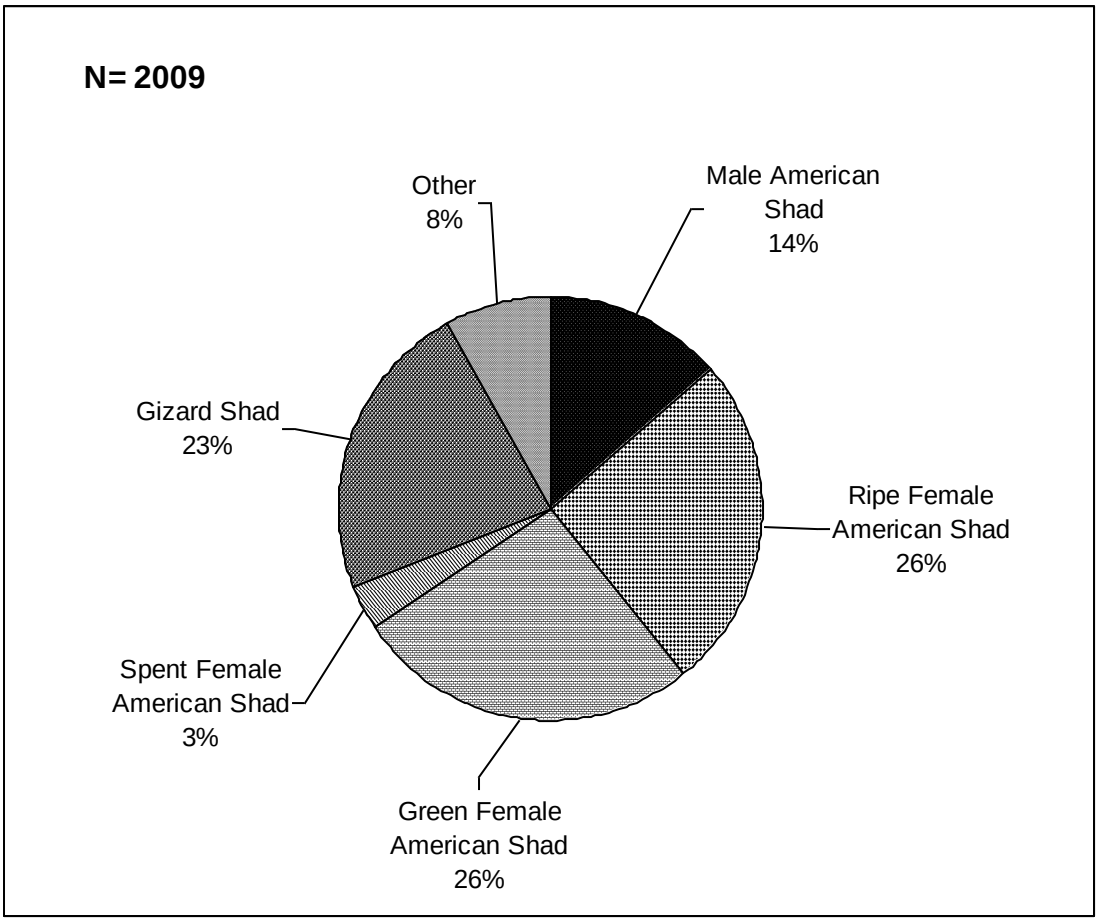


Figure 2. Spring 2007 species composition from Potomac River gill net sampling at Marshall Hall, MD. Other species and number caught listed in Table 1

7.0 JOB 2, PART 2: COLLECTION OF AMERICAN SHADS EGGS FROM THE DELAWARE RIVER, 2007

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7.1 INTRODUCTION

A key element in the restoration of American shad 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, some 1.6 million eggs were collected from the Delaware River and stocked (as eggs) into the Schuylkill River. In 1976, the Lehigh and Schuylkill Rivers each received 80,000 eggs from the Delaware source. 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 goal of this activity in 2007, as in past years, was to collect and ship up to 15 million American shad eggs.

7.2 MATERIALS AND METHODS

Brood fish were captured in gill nets set in the Delaware River at Smithfield Beach (RM 218). In past years, Ecology III of Berwick, PA provided a boat, equipment and labor support to assist the PFBC Area Fisheries Manager and his staff stationed at Bushkill, PA. In 2000 through 2007, however, the Ecology III contract was not renewed (due to termination of funding) and the PFBC Area Fisheries Manager and his staff completed egg collection without additional outside assistance. In 2007, fifteen 200-foot gill nets were set per night with the exception of the first and second nights, when fourteen and thirteen nets were set, respectively. 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 a concentrated array. Netting began at dusk and, on a typical evening; shad were picked from the nets two or three times before retrieving them at midnight. Both male and female shad were placed into water-filled tubs and returned to shore. Eggs were stripped from ripe female shad and fertilized in dry pans with sperm from ripe males. Once gametes were mixed, a small amount of fresh water was added to activate the sperm and they were allowed to stand for five minutes, followed by several washings. Cleaned, fertilized eggs were then placed into floating boxes with fine mesh sides and bottom. 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 hour.

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 rubber castrating rings. Bags were then placed into coolers and transported by truck 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

After spawning the shad, catch data was recorded for all shad including gillnet mesh size, sex, length (total and fork) and weight. Representative samples of each night's catch of both sexes were collected for scale and otolith analysis. Ovaries from mature/gravid females were also removed and weighed**.** Most adult shad did not survive the rigors of netting and artificial spawning and it was necessary to properly dispose of the carcasses. The National Park Service provided a disposal pit on park property and shad carcasses were delivered there each night and covered with hydrated lime.

7.3 RESULTS

Table 1 summarizes daily Delaware River shad egg collections during May 2007. American shad spawning operations commenced on May 9, when river flow was 3,280 cfs (USGS gauge at Montague, NJ), and river temperature was 17.1˚ C (62.8˚ F). Egg take ended on May 31, when river flow was 1,820 cfs and temperature was 23.9˚ C (77.5˚ F). Flow conditions during the 2007 egg-take operation were near perfect. River flow was well below the mean and, except for two brief, minor freshets, flow decreased during the entire season (Figure 1, Table 1). Egg-take operations were never interrupted, except by weekends and holidays. Based on angler reports and egg collection CPUE (Figure 3) the 2007 Delaware River shad run was better than in 2006.

Nets were set on 16 nights with 13-15 nets set on each night. The usual number of nets set per mesh size (stretch, inch) each night was: 4.50- 3 each; 4.75- 1 each; 5.00- 4 each; 5.25- 1 each; 5.50- 2 each; 5.75- 2 each; and 6.00- 2 each.

A total of 764 adult American shad were caught (Table 1), which was slightly below the average of 818. Nightly catches ranged from 16 to 74 shad. Sex ratio (male to female) was 0.60:1. Some 135.8 L (6.5 million) fertilized eggs were collected and shipped to the Van Dyke Hatchery in 2007, compared to 65L (2.3 million eggs) in 2006. A total of 282 thousand American shad larvae were stocked in the Lehigh River, 541 thousand were stocked in the Schuylkill River, and 48 thousand were stocked in the Delaware River at Smithfield Beach to replenish the Delaware for the adults used for egg-take. From 1983 to 2007, 160 million American shad eggs were collected from the Delaware River. From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 15.8 million in the Lehigh River, 5.8 million in the Schuylkill River, and 0.3 million in the Delaware River. Overall, the viability for Delaware River American shad eggs was 36.4%.

7.4 LITERATURE CITED

Ecology III and PA Fish and Boat Comm. 1999. Collection of American shad eggs from the Delaware River, 1998. Pp. 2-14 to 2-18 *IN* Restoration of American shad to the Susquehanna River, 1998 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 1999).

Ecology III and PA Fish and Boat Comm. 2000. Collection of American shad eggs from the Delaware River, 1999. Pp. 2-12 to 2-16 *IN* Restoration of American shad to the Susquehanna River, 1999 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2000).

Hendricks, M. L. 2001. Collection of American shad eggs from the Delaware River, 2000. Pp. 2-9 to 2-15 *IN* Restoration of American shad to the Susquehanna River, 2000 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2001).

Hendricks, M. L. 2002. Collection of American shad eggs from the Delaware River, 2001. Pp. 2-9 to 2-15 *IN* Restoration of American shad to the Susquehanna River, 2001 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2002).

Hendricks, M. L. and D. A Arnold. 2003. Collection of American shad eggs from the Delaware River, 2002. Pp. 2-8 to 2-13 *IN* Restoration of American shad to the Susquehanna River, 2002 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2003).

Hendricks, M. L. and D. A Arnold. 2004. Collection of American shad eggs from the Delaware River, 2003. Pp. 2-8 to 2-14 *IN* Restoration of American shad to the Susquehanna River, 2003 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2003).

7.5 TABLES AND FIGURES

Table 1. Delaware River American shad egg collection, 2007.

Month	Day	Year	Location	Water Temp C	No. of nets	No. of shad captured	Volume (L)	Eggs	Viable Eggs	Precent Viable
5	9	2007	Smithfield Beach	17.1	14	51	4.1	260,405	29,917	11.5%
5	10	2007	Smithfield Beach	18.8	13	68	14.0	645,722	96,811	15.0%
5	13	2007	Smithfield Beach	19.7	15	74	17.4	630,713	355,448	56.4%
5	14	2007	Smithfield Beach	18.5	15	57	11.0	557,885	315,651	56.6%
5	15	2007	Smithfield Beach	18.9	15	44	8.0	394,464	150,715	38.2%
5	16	2007	Smithfield Beach	19.2	15	46	14.0	556,724	337,787	60.7%
5	17	2007	Smithfield Beach	19.2	15	30	6.3	224,189	31,859	14.2%
5	20	2007	Smithfield Beach	16.3	15	16	No eggs			
5	21	2007	Smithfield Beach	17.4	15	51	10.0	465,694	287,578	61.8%
5	22	2007	Smithfield Beach	18	15	62	15.6	645,840	401,727	62.2%
5	23	2007	Smithfield Beach	19.3	15	32	7.0	248,467	175,755	70.7%
5	24	2007	Smithfield Beach	20.6	15	47	7.2	345,065	77,100	22.3%
5	28	2007	Smithfield Beach	23.1	15	50	5.8	299,874	41,908	14.0%
5	29	2007	Smithfield Beach	23.2	15	41	4.7	233,941	29,247	12.5%
5	30	2007	Smithfield Beach	23.9	15	52	4.7	530,123	6,094	1.1%
5	31	2007	Smithfield Beach	25.3	15	43	6.1	418,458	10,594	2.5%
					Total	**764**	**135.8**	**6,457,563**	**2,348,192**	**36.4%**

Figure 1. American shad egg collections and flow, Delaware River, 2007.

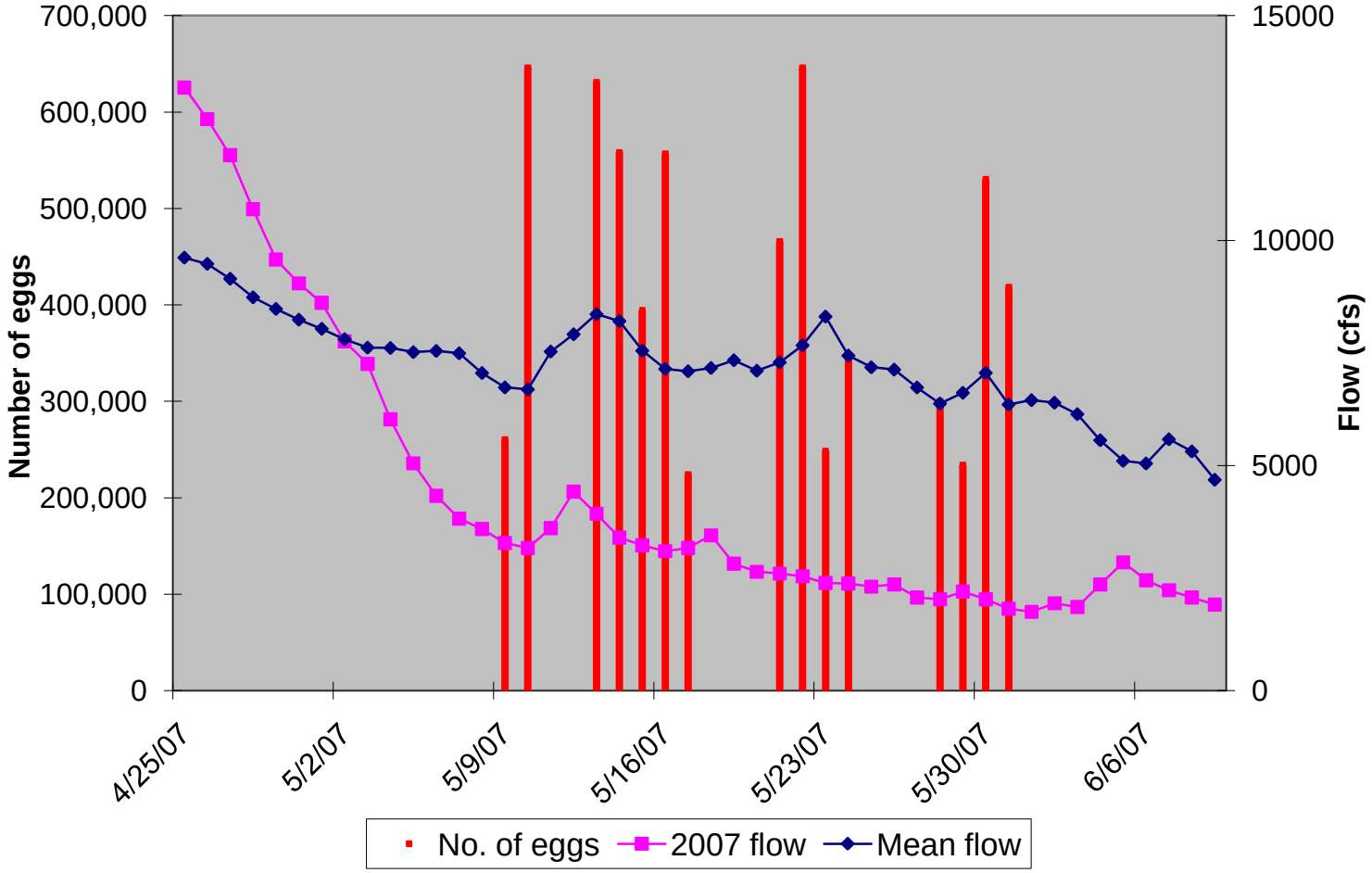


Figure 2. American shad eggs collected from the Delaware River.

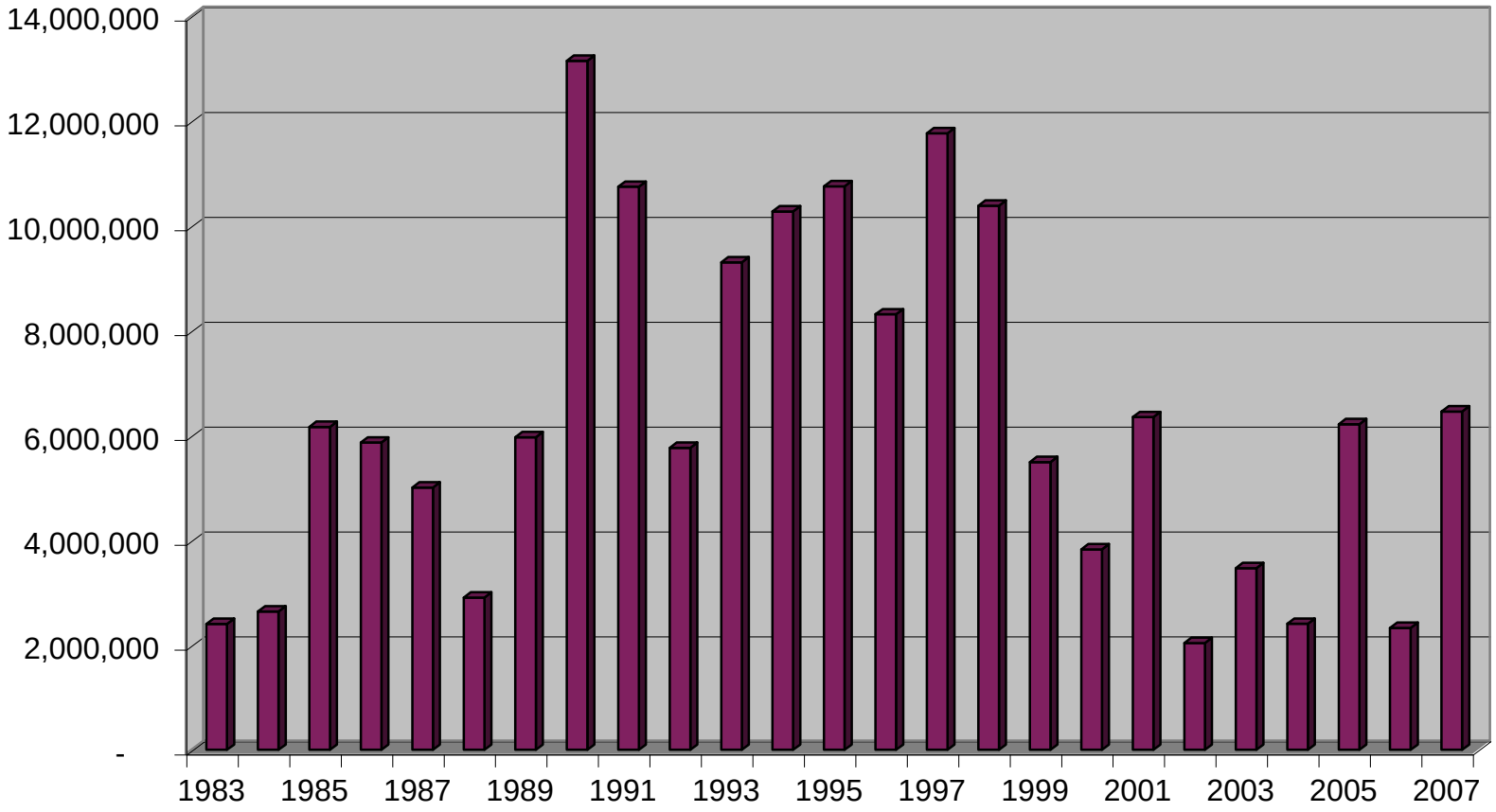
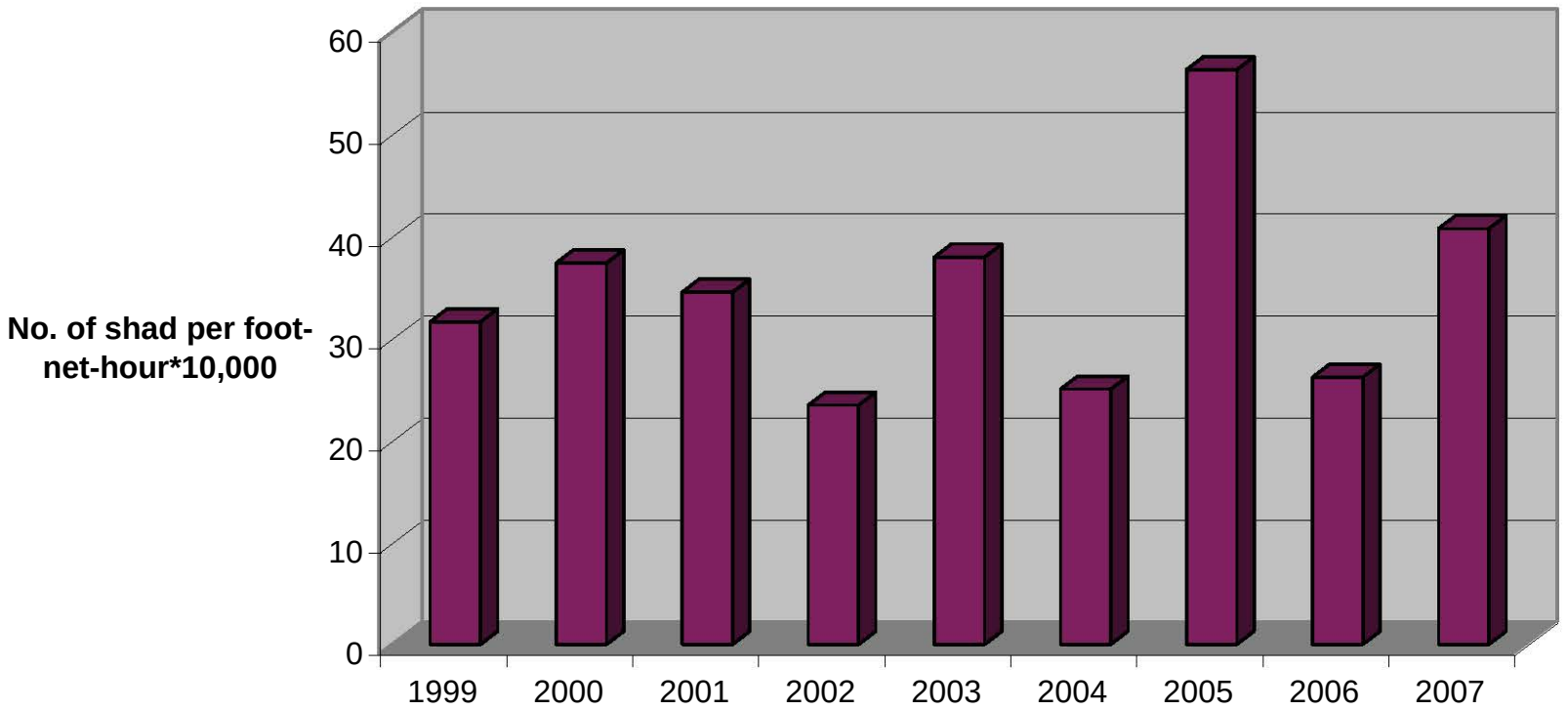


Figure 3. CPUE for adult American shad collected by gill net at Smithfield Beach, Delaware River.



8.0 JOB 2, PART 3: REPORT ON HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN AND HICKORY SHAD AT CONOWINGO DAM, 2007

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8.1 BACKGROUND

For over two decades, the Pennsylvania Fish and Boat Commission Van Dyke Hatchery has utilized strip spawned American shad eggs from Hudson and Delaware River broodstock to produce and stock over 130 million shad larvae in the Susquehanna River. The importance of these hatchery releases is evidenced by the high percentage (75-90%) of hatchery origin shad in the Susquehanna River spawning runs in the early to mid 1990's. Since the mid 1990's the contribution of hatchery fish has ranged from 30 to 72%.

The Delaware and Hudson Rivers are two east coast rivers that have been an important source of strip spawned American shad eggs during recent years. The removal of up to 15 million shad eggs from the Delaware River and up to 20 million eggs from the Hudson River became controversial and as a result strip spawning operations on the Hudson River were not permitted in 2007, and some restrictions have been placed on Delaware River operations. Strip spawning of adult broodfish from known spawning areas in the Lower Susquehanna River was attempted in 2003, 2004 and 2005 with minimal results. The Potomac River became an additional source of shad eggs for the Van Dyke Hatchery in 2006 and 2007.

Hormone induced spawning trials of American shad have been conducted on site at the Conowingo West Fish Lift each spring since 2001. Fertilized shad eggs that result from these trials are shipped to the Pennsylvania Fish and Boat Commission Van Dyke Hatchery to augment shipments of strip spawned American shad eggs from other sources. Hormone induced spawning trials of hickory shad began at the Conowingo West Fish Lift in 2003 and have continued annually.

8.2 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 Conowingo West Fish Lift is now operated under contract as (1) a source of fishes for special on-site spawning studies and studies conducted by the Maryland Department of Natural Resources at the Manning Hatchery and (2) collection of biological information from American shad. In past years, the West Fish lift has also provided pre spawn American shad for spawning studies at the USFWS

Northeast Fishery Center at Lamar, PA and adult herring for the Pennsylvania Fish and Boat Commission's tributary stocking program.

The West Fish Lift when operated 6-8 hours per day and six days per week from late April through early June typically captures 3,400 to10,000 adult American shad. The majority of these fish are in a pre-spawn condition and based on results at Lamar and Manning, many of these fish could be induced to spawn within two 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 the stress associated with lengthy transport times. The West Fish lift captures few, if any, hickory shad in a typical year. Anglers however are quite successful in catching hickories at Shures Landing in Conowingo Fisherman's Park and at the mouth of Deer Creek in early April. Maryland Department of Natural Resources and USWS biologists have also been successful in collecting hickory shad with boat mounted electrofishing gear in the Rock Run area, upstream from the Lapidum boat launch.

8.3 METHODS AND MATERIALS

Cooperating anglers at the mouth of Deer Creek provided the source for the pre spawn hickory shad for the 2007 spawning trials at the Conowingo Dam West Fish Lift. Hickory shad had appeared during the second week of April but high river flows and cooler water temperatures temporarily pushed them out of the river. Hickory shad reappeared in the angler catch after river temperature reached 11.5°C in late April.. These fish were transported to the Conowingo West Lift holding tanks by Pennsylvania Fish and Boat Commission (PFBC) personnel in an oxygenated circular tank mounted on a pick-up truck. The tank capacity was 30-40 fish per trip. A total of 134 Hickory shad was transported on 23 April, and injected with hormone pellets to begin the first spawning trial of the season. Two other spawning trials with angler caught hickory shad were conducted between 23 April and 1 May when the river temperature reached 16.2° C and American shad numbers in the Conowingo tailrace were sufficient to warrant operation of the West Fish Lift and begin spawning trials with American shad. The Conowingo West Fish Lift was the source of all pre-spawned American shad broodstock for the 14 spawning trials conducted at Conowingo Dam in 2007.

The 2007 American shad trials were patterned after similar trials conducted by USFWS at Lamar in previous years and on trials conducted at Conowingo Dam from 2001 to 2006. The 10 ft and 12 ft diameter fiberglass tanks used for spawning trials in 2007 were the same tanks that were used from 2002 to 2006. These tanks were assembled on-site at the West Fish Lift in early April and plumbed in a configuration identical to that used since 2001 (Figure 1). Both tanks were supplied with approximately 40 gpm of river water through a wall mounted 2-inch fitting. A screened 4-inch PVC drainpipe in the bottom of each tank provided the only exit for the demersal shad eggs and water from the tank. The water level in both spawning tanks was maintained by an external standpipe that also provided a source of water for the rectangular 72 by 36 by 16 inch raised egg collection tank. The calculated volumes for the small and large and tanks were 6,400 and 9,200 liters respectively. An egg sock fastened to the discharge from the spawning tank prevented the shad eggs from exiting the egg tank via the standpipe drain that maintained the water level in the egg tank.

Each of the three hickory shad trials were single tank trials. The stocking rate for the three hickory shad trials held in the 12 ft diameter tank ranged from 112 (1 fish per 82 liters) to 138 (1 fish per 67 liters). No hickory shad trials were held in the 10 ft tank in 2007. A 3:2 (M/F) sex ratio was the goal for hickory shad trials but that ratio was never attained. In two of the three hickory trials the females outnumbered the males. The stocking rates for the larger American shad were 50 (1 fish per 128 liters) and 75 (1 fish per123 liters) for the small and large tank respectively. The 3:2 sex ratio in favor of males was attained for all 14 American shad trials. All but one of the 14 American shad trials were double tank (10 and 12 ft tank) trials. All on-site spawning trials in 2007 were conducted with Lutenizing Hormone Releasing Hormone analog ($LHRH_a$) which was purchased in powder form (25 mg vials) from Syndel Labs, Vancouver BC. A portion of the powdered $LHRH_a$ was converted to 25 and 75 ug cholesterol based pellets by PFBC personnel. The remaining powder was used to make an injectable saline solution that contained 95 ug/ml for American shad trials. The injectable solution was prepared just before use due to its short shelf life. All hickory shad (males and females) received a 25ug dose of pelletized $LHRH_a$. This dose was one half of the 50ug used in previous hickory shad trials. This year's American shad dosages were also reduced. In past years, male and female American shad received 150ug of $LHRH_a$. This year, male American shad in trials 1 through 11 received a 25ug pellet and males in trials 12 through 14 received a 45ug liquid injection. Females this year in trials 1 through 8 received a 75ug pellet, females in trial 9 received two 75ug pellets and females in trials 10 through 14 received an 80 to 95ug liquid injection. Each fish was injected in the thick muscles of the shoulder area. Fish were not anesthetized prior to injection. Oxygen and temperature were monitored in the spawning tanks during each trial. Supplemental oxygen was provided in the spawning tanks during the last four trials (22 May through 30 May) when ambient dissolved oxygen levels in the river approached 7.0 ppm and tank levels approached 5.0 ppm. The egg sock was examined daily during each spawning trial. Following the initial pulse of egg production (24 to 48 hours after hormone injection) the eggs were washed out of the sock into a 10 gal plastic bucket. The eggs were then sieved with a colander with 0.25 in holes to remove scales and other debris. After sieving, the eggs settle to the bottom of 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. Except for the 5.6 liters of eggs released into the river below Conowingo Dam from trial 8, eggs were always driven to the hatchery on the same day they were collected. Following the initial egg pulse, (usually within 48 hours following injection with $LHRH_a$) the tanks were drained, mortalities, if any, recorded and the fish buried at an off-site location. No attempts were made to hand strip shad following the egg pulse.

8.4 RESULTS

Hormone induced spawning trials with hickory shad at Conowingo Dam began on 23 April and concluded on 1 May, 2007. During this interval, 3 spawning trials were conducted with 384

adult hickory shad (Appendix Table A-1). Each trial lasted two days with the largest pulse of eggs produced on the second day. A total of 27.9.1 liters of eggs was collected from the hickory shad trials (Table 1). Over 25 liters were shipped to the Van Dyke Hatchery and the remaining 2.8 liters were released into the river below Conowingo Dam. The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 69.3% (Mike Hendricks, personal communication). Water temperature in the spawning tanks ranged from 11.5 to 16.2°C and dissolved oxygen levels ranged from 9.3 to 12.2 ppm. Adult mortality rate for hickory shad during the spawning trials was 3.1%.

A total of 14 on-site spawning trials with 1504 American shad from 1 to 30 May produced 89.6 liters of eggs (Table 2 and Appendix Table A-2). Eighty four liters of eggs were shipped to the Van Dyke Hatchery and the remaining 5.6 liters released into the river below Conowingo Dam. Nine of the trials were conducted with pelletized implants, three with liquid injections and in two trials a combination of pellets and liquid injections was used. The 3:2 sex ratio in favor of males was achieved in most trials as well as a stocking density of 1 fish per 125 liters of water. The total volume of eggs produced per female in individual 2007 trials (0.148 liters) was below the average of 0.363 liter observed for the previous six years, (Table 4 and Figure 2). When adjusted for viability, the volume of viable eggs produced per female in the 2007 trials ranged from 0.05 to less than 0.01 liter (Figure 3). Water temperatures and oxygen levels in the spawning tanks were monitored daily and ranged from 17.4 to 24.5°C and 4.7 to 13 ppm. The overall estimated viability of the eggs shipped to VanDyke was 8.9% (Mike Hendricks, personal communication). Mortality rate for adult American shad during the 2007 trials was 8.3%. Mortality ranged from 2 to 11.5% in previous years.

8.5 SUMMARY

The results of the hickory shad hormone-induced spawning trials at Conowingo Dam in 2007 showed a continuation of the high quality levels achieved in 2005 and 2006 (Table 3). The estimated overall egg viability of 69.3% is the highest viability observed during the past five years of hickory shad trials.

This was the seventh year of hormone induced American shad spawning trials at the Conowingo West Fish Lift. The results of the 2007 spawning trials were disappointing in both volume of eggs produced and lower than average viability. The cause for this year's poor egg quality and quantity for the American shad spawning trials is still unexplained. If the lower dosage of hormone (75ug instead of 150ug)) used on female American shad this year was a factor, then the results of trial No. 9 when each female was given a 150ug dose should have been noticeably improved from previous trials, but they were not. The 2007 American shad spawning runs in the Lower Susquehanna River were late in getting started due to cold April water temperatures and elevated flows. By the third week of May, rapidly rising water temperatures and low flows may have led to the premature end to this year's American shad spawning runs. During the last week of May many of the American shad caught at the West Lift were spent, partially spent or in poor physical condition.

Table 1. Summary of egg production data for hormone-induced spawning trials conducted with Hickory shad in a 12 ft diameter (S-1) tank at Conowingo Dam, Spring 2007

Trial #	Liquid/ Pellet	Start/Stop Date	S-1 M/F	S-1 Liters	No. Liters Shipped	Date Shipped	Eggs	No. Viable Eggs	Percent Viable
1	Pellet	4-23/4-25	65/69	10.8	9.3	4/24	4,118,356	3,138,680	76.0%
2	Pellet	4-25/4-27	71/67	10.0	8.7	4/26	3,609,970	2,050,000	57.0%
3	Pellet	4-29/5-1	42/70	3.3	3.3	4/30	1,780,593	1,414,179	79.0%
3 cont.	Pellet	4-29-5-1	42/70	3.8	3.8	5/1	2,023,401	1,391,938	69.0%
Totals			**178/206**	**27.9**	**25.1**		**11,532,320**	**7,994,797**	**69.3%**

Total Males =178
Total Females =206
Total Fish =384
Mean liters/trial. = 9.3 liters

Mean No. of Eggs/ Liter = 459,455
Mean No. of Eggs/Female (All Trials) = 62,227
Mean No. of Viable Eggs/ Female (All Trials) = 43,123

Table 2. Summary of egg production data for hormone-induced ($LHRH_a$) spawning trials conducted with American shad in a 10 ft diameter (S-2) and 12 ft diameter (S-1) tank at Conowingo Dam, Spring 2007

Trial #	Liquid/ Pellet	Start/Stop Date	S-1 M/F	S-2 M/F	S-1 Liters	S-2 Liters	Total Liters Shipped	Date Shipped	No. eggs	No. Viable	Viabil.
1	Pellet	5-4/5-7	45/30		7.2		7.2	6-May	493,917	48,177	10%
2	Pellet	5-5/5-7	45/30	30/20	1.9	6.0	7.9	7-May	378,613	46,355	12%
3&4	Pellet	5-7/5-9	45/30	30/20	4.6	8.7	13.3	9-May	732,875	127,947	17%
5	Pellet	5-9/5-11	45/30	30/20	11.7	3.8	15.5	11-May	1,001,627	172,586	17%
6	Pellet	5-11/5-13	45/30	30/20	3.5	2.2	5.7	13-May	418,053	10,775	3%
7	Pellet	5-13/5-15	45/30	30/20	3.1	2.9	6	15-May	504,822	24,427	5%
8	Pellet	5-15/5-17	45/30	30/20	4	1.6	0	River release			
9	Pellet	5-17/5-20	45/30	30/20	1.0	3.9	4.9	19-May	521,625	84,851	16%
10	P&L	5-20/5-22	45/30	31/21	3.7	1.5	5.2	22-May	545,519	11,545	2%
11	P&L	5-22/5-24	45/30	30/20	3.8	1.2	5	24-May	596,884	15,812	3%
12	Liquid	5-24/5-26	45/30	30/21	2.9	3.4	6.3	26-May	622,888	46,930	8%
13	Liquid	5-26/5-28	45/30	30/21	1.8	0.9	2.7	28-May	302,363	6,017	2%
14	Liquid	5-28/5-30	45/30	30/20	1.7	2.6	4.3	30-May	654,407	7,923	1%
Totals			**540/360**	**361/243**	**50.9**	**38.7**	**84**		**6,773,594**	**603,345**	**8.9%**

Mean vol. / trial = 6.9 liters

Total Males = 901

Mean No. of Eggs / Liter (12 Trials) = 80,638

Total Females = 603

Mean No. of Eggs/Female (12 Trials) = 11,233

Total Fish = 1504

Mean No. of Viable Eggs/ Female (12 Trials) = 1,000

Table 3. Summary of hormone induced spawning trials with hickory shad at Conowingo Dam, 2003-07

Year	**2003**	**2004**	**2005**	**2006**	**2007**
Start/Finish date	4-15/4-27	4-19/4-26	4-15/4-27	4-11/4-19	4-23/5-1
Tank diameter (ft)	10, 12	10, 12	10, 12	10, 12	12
Tank volume (liters)	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200	9,200
No. of trials	5	4	8	4	3
Total fish	381	349	721	398	384
Males/Females per trial	40/36	48/39	55/34	62/38	59/69
Stocking density (fish/liters)	1/99	1/89	1/78	1/71	1/72
Male:Female ratio	1:0.9	1:0.8	1:0.6	1:0.6	1:1.2
Hormone injected	$LHRH_a$	$LHRH_a$	$LHRH_a$	$LHRH_a$	$LHRH_a$
Liquid, Pellet	L+P	L+P	L+P	L+P	P
Dose(ug) Male/Female	50/50	50/50	50/50	50/50	25/25
Eggs collected (liters)	30.2	33.4	73.8	26.8	27.9
Liters of eggs /Female	0.167	0.215	0.271	0.177	0.135
No. eggs/liter	477,607	405,853	388,208	565,893	459,455
Total number of eggs shipped	14,423,730	13,555,505	28,727,411	15,165,928	11,532,320
Viability (%)	44.1	46.1	61.4	60.6	69.3
Total number of viable eggs	6,360,865	6,245,259	17,645,251	9,194,583	7,994,797
Total liters of viable eggs	13.32	15.39	45.45	16.25	17.4
Adult mortality rate (%)	14.0	3.7	2.2	22.1	3.1

Table 4. Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-2007

Year:	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
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
Tank diameter (ft)	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
Number of trials	10	10	12	10	11	20	14
Total fish	599	1,000	1,504	1,055	1,135	1,557	1,504
Males/Females per trial	36/24	66/34	75/50	75/50	75/50	47/31	75/50
Stocking density (fish/liters)	1/153	1/156	1/125	1/125	1/125	1/124	1/125
Male:Female ratio	3:2	2:1	3:2	3:2	3:2	3:2	3:2
Hormone injected	LHRHa	SGnRHa	LHRHa	LHRHa	LHRHa	LHRHa	LHRHa
Liquid, Pellet	P	P	L+P	L+P	L+P	L+P	L+P
Dose (ug) Male/Female	75/150	150/150	150/150	150/150	150/150	150/150	25-45/75-95
Eggs collected (liters)	103	146.8	234	90.4	160.5	169.25	89.6
Liters of eggs /Female	0.429	0.432	0.387	0.244	0.418	0.270	0.148
No. eggs/liter	63,140	51,235	51,187	59,775	53,828	60,747	80,638
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
Viability (%)	33.2	10.1	17.7	20	23.9	21.7	8.9
Total number of viable eggs	2,159,135	760,935	2,118,852	1,080,732	1,913,801	2,232,459	603,345
Total liters of viable eggs	34.20	14.85	41.42	18.1	35.6	36.75	7.97
Adult mortality rate (%)	6.0	3.6	2.0	11.5*	3.3	3.5	8.3

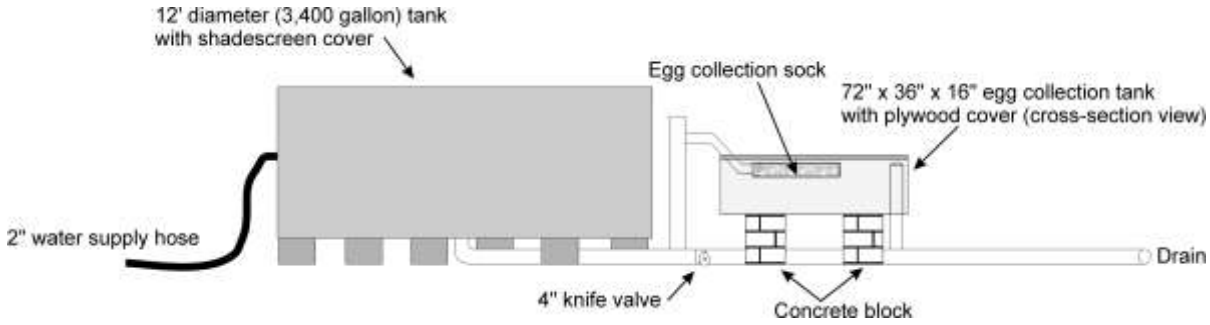

Figure 1. Schematic of tank spawning system used at Conowingo Dam West Fish Lift

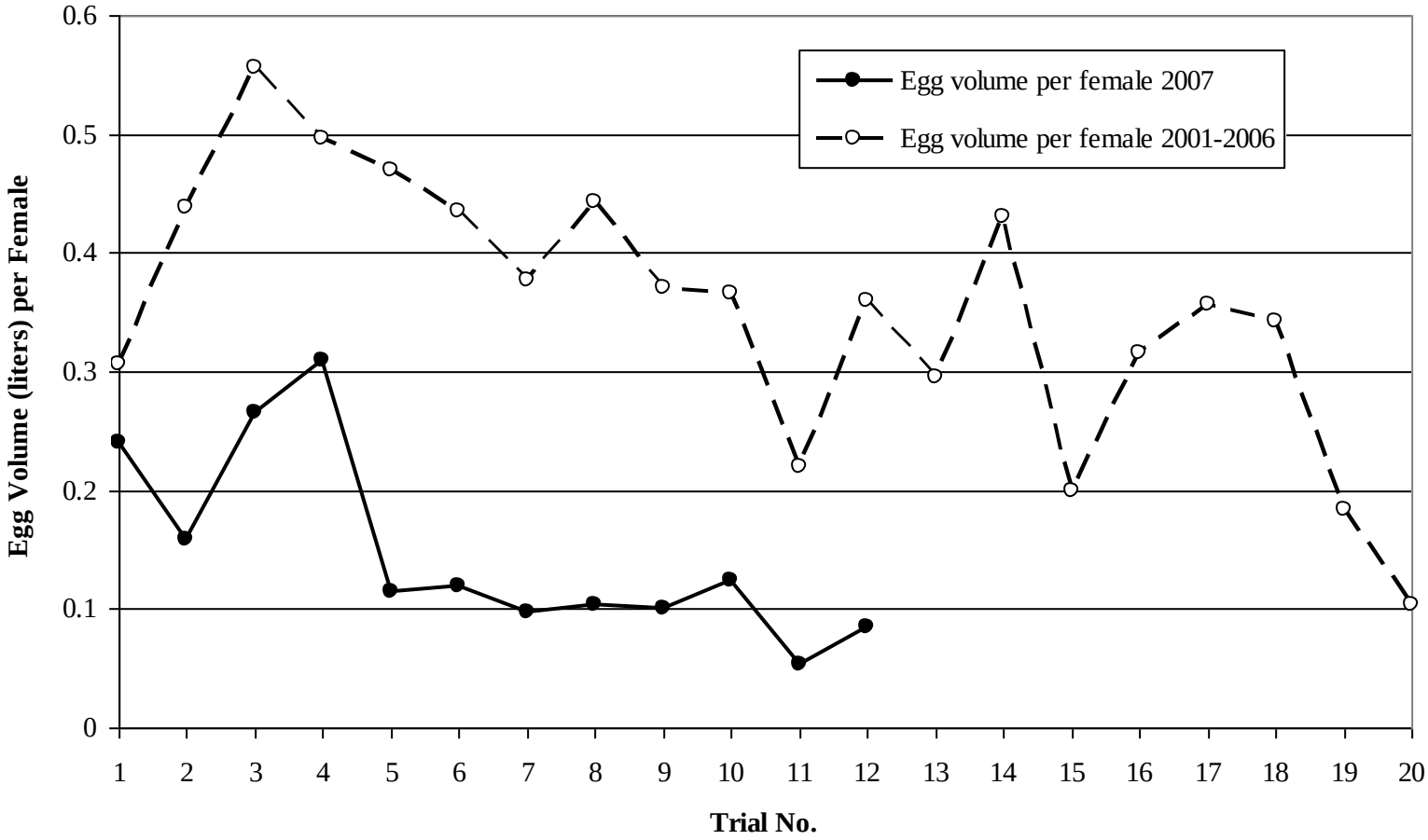

Figure 2. Comparison of American shad egg production per female by trial number at Conowingo Dam, 2007 v.s. 2001-2006

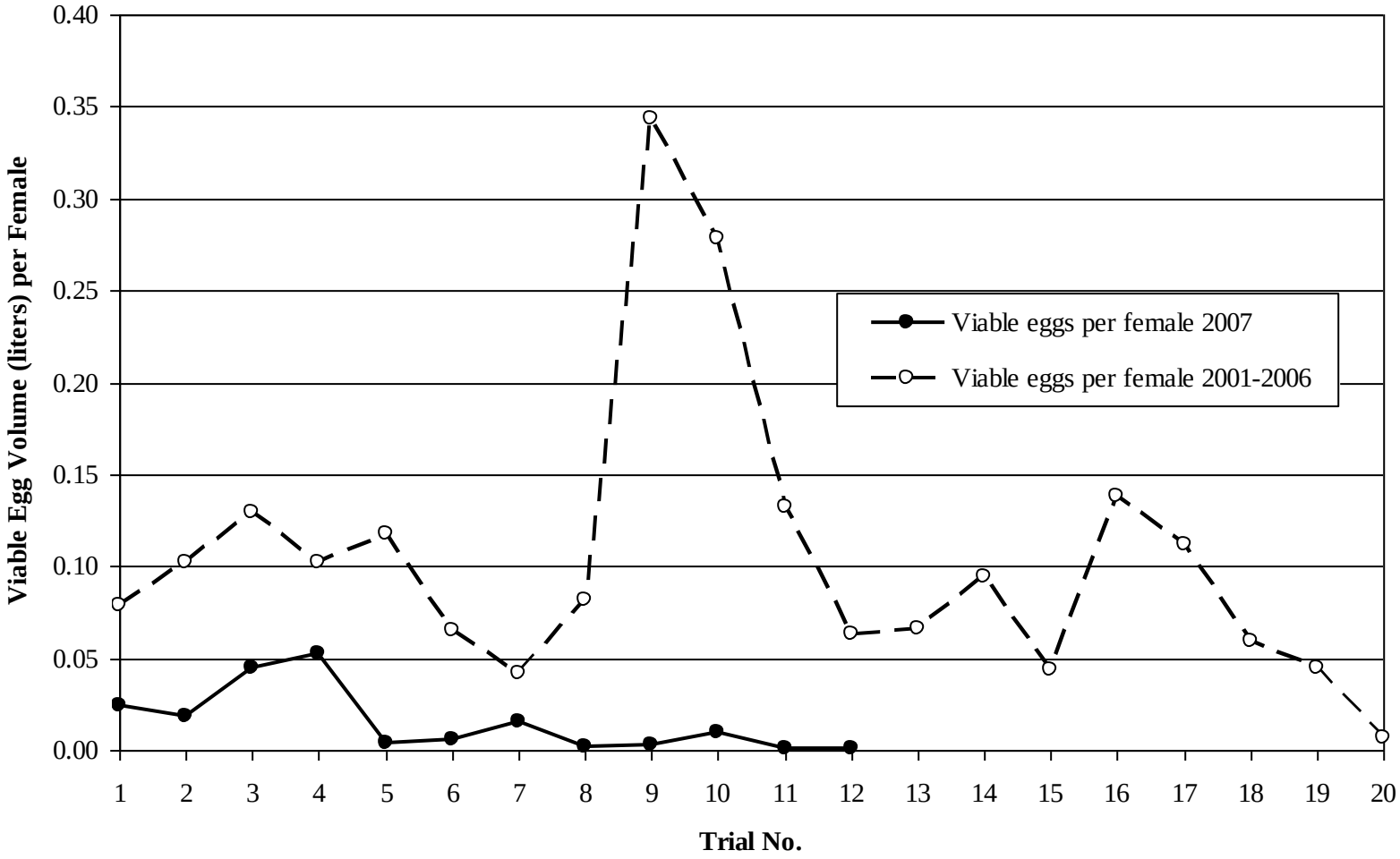

Figure 3. Comparison of viable American shad eggs produced per female by trial number at Conowingo Dam, 2007 v.s.2001-2006

Appendix Table A-1. Individual trial data for hormone induced hickory shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007

Trial No. 1

M/F Ratio	65/69				12 ft tank		
Start Date	4/23/2007	1630			Dose/fish 25 ug LHRH pellet		
End Date	4/25/2007	0830					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/23/2007	1630	11.5	12.2				
4/24/2007	0735	12.3	11.1				
4/24/2007	1130	12.6	11.2	9.3	9.3		
4/25/2007	0830	13.6	10.4	1.5		1.5	4f

Trial No. 2

M/F Ratio	71/67				12 ft tank		
Start Date	4/25/2007	1600			Dose/fish 25 ug LHRH pellet		
End Date	4/27/2007	630					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/2007	1615	13.5	9.6				
4/26/2007	725	14.1	9.6				
4/26/2007	1200	14.5	9.3	8.7	8.7		
4/27/2007	830	14.5	9.4	1.3		1.3	0

Trial No. 3

M/F Ratio	42/70				12 ft tank		
Start Date	4/29/2007	1400			Dose/fish 25 ug LHRH pellet		
End Date	5/1/2007	1530					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/29/2007	1430	15	9.7				
4/30/2007	0815	14.5	10.4				
4/30/2007	1200			3.3	3.3		
4/30/2007	1640	15.5	10.9				
5/1/2007	0755	14.8	10.3				
5/1/2007	1200	16.2	10.3	3.8	3.8		
5/1/2007	1530						3m,5f

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007.**

Trial No. 1

M/F	45/30	12 ft			Dose/female 75 ug LHRH pellet		
Start Date	5/4/2007	1000			Dose/male 25 ug LHRH pellet		
End Date	5/7/2007	900					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/2007	1130	17.6	8.8				
5/5/2007	1015	18	9.2				
5/6/2007	0920	17.8	8.8				
5/6/2007	1130			7.2	7.2		
5/7/2007	0900	17.4	8.9	1.9	1.9		2m, 6f

Trial No. 2

M/F	30/20	10 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/5/2007	1000			Dose/male 25 ug LHRH pellet		
End Date	5/7/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/5/2007	1015	18	9.2				
5/6/2007	0920	17.8	9.2				
5/7/2007	0840	17.4	9.1				
5/7/2007	1000			6	6		1m, 5f

Trial No. 3

M/F	30/20	10ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/7/2007	1145			Dose/male 25 ug LHRH pellet		
End Date	5/9/2007	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/7/2007	1500	18	8.6				
5/8/2007	0917	17.8	9.4				
5/9/2007	0830	18.1	8.9				
5/9/2007	1030			8.7	8.7		1m, 1f

Trial No. 4

M/F	45/30	12ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/7/2007	1100			Dose/male 25 ug LHRH pellet		
End Date	5/9/2007	1045					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/7/2007	1500	18	8.2				
5/8/2007	0919	17.8	9.7				
5/9/2007	0830	18.2	9.2				
5/9/2007	1045			4.6	4.6		2m, 2f

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007 (continued).**

Trial No. 5

M/F	30/20	10 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/9/2007	1200			Dose/male 25 ug LHRH pellet		
End Date	5/11/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/9/2007	1513	18.5	7.2				
5/10/2007	0900	18.6	8.4				
5/11/2007	0830	18.6	8.6				
5/11/2007	1000			3.8	3.8		3f

M/F	45/30	12 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/9/2007	1200			Dose/male 25 ug LHRH pellet		
End Date	5/11/2007	0930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/9/2007	1513	18.5	8				
5/10/2007	900	18.6	8.5				
5/11/2007	830	18.6	7.6				
5/11/2007	930			11.7	11.7		1m

Trial No. 6

M/F	45/30	12 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/11/2007	1100			Dose/male 25 ug LHRH pellet		
End Date	5/13/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/11/2007	1720	20.1	7.7				
5/12/2007	0800	19.5					
5/13/2007	0910	20.2	8.2	2.2	2.2		6f

M/F	30/20	10 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/11/2007	1130			Dose/male 25 ug LHRH pellet		
End Date	5/13/2007	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/11/2007	1720	20.1	6.8				
5/12/2007	0800	19.5	7.5				
5/13/2007	0930	20.2	7.9	3.5	3.5		1f

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007 (continued).**

Trial No. 7

M/F	45/30	12 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/13/2007	1100			Dose/male 25 ug LHRH pellet		
End Date	5/15/2007	1000					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/13/2007	1630	20.5	7.0				
5/14/2007	0730	20.9	6.9				
5/14/2007	1630	20.5	7.0				
5/15/2007	0905	21.5	7.1				
5/15/2007	1000			2.9	2.9		

M/F	30/20	10 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/13/2007	1145			Dose/male 25 ug LHRH pellet		
End Date	5/15/2007	1030					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/13/2007	1630	20.5	7.4				
5/14/2007	0730	20.9	7.2				
5/14/2007	1630	20.5	7.4				
5/15/2007	0905	21.5	7.2				
5/15/2007	1000			3.1	3.1		1f

Trial No. 8

M/F	45/30	12 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/15/2007	1115			Dose/male 25 ug LHRH pellet		
End Date	5/17/2007	1000					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/15/2007	1725	22.2	5.9				
5/16/2007	0855	21.8	5.8				
5/17/2007	0830	22.2	6.2	4		4	4f

M/F	30/20	10 ft tank			Dose/female 75 ug LHRH pellet		
Start Date	5/15/2007	1145			Dose/male 25 ug LHRH pellet		
End Date	5/17/2007	1000					
		Temp.	Oxygen	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/15/2007	1725	22.1	6.4				
5/16/2007	0855	21.8	6.2				
5/17/2007	0830	22.2	6.4	1.6		1.6	0

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007 (continued).**

Trial No. 9

M/F	45/30	12 ft tank		Dose/female 150 ug LHRH (2x75 ug pellets)			
Start Date	5/17/2007	1330		Dose/male 25 ug LHRH pellet			
End Date	2/20/2007	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/17/2007	1645	22.3	5.8				
5/18/2007	1150	21.5	5.8				
5/18/2007	1740	21.2	5.9				
5/19/2007	0835	20.2	6.2	1	1		
5/20/2007	0930						2m, 10f

M/F	30/20	10 ft tank		Dose/female 150 ug LHRH (2x75 ug pellets)			
Start Date	5/17/2007	1400		Dose/male 25 ug LHRH pellet			
End Date	5/20/2007	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/17/2007	1645	22.2	6.4				
5/18/2007	1150	21.5	6.2				
5/18/2007	1740	21.2	6.4				
5/19/2007	0835	20.2	6.9	3.9	3.9		
5/20/2007	0930						1m,1f

Trial No. 10

M/F	45/30	12 ft tank			Dose/female 80 ug LHRH liquid		
Start Date	5/20/2007	1400			Dose/male 25 ug LHRH pellet		
End Date	5/22/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
2/20/2007	1825	21.1	5.9				
2/21/2007	0900	21	6.2				
2/21/2007	1600	21.7	5.6				
2/22/2007	0900	21.6	6	3.7	3.7		1f

M/F	31/21	10 ft tank			Dose/female 80 ug LHRH liquid		
Start Date	5/20/2007	1430			Dose/male 25 ug LHRH pellet		
End Date	5/22/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/20/2007	1825	21.1	6.2				
5/21/2007	0900	21	7.0				
5/21/2007	1600	21.7	6.4				
5/22/2007	0900	21.6	6.2	1.5	1.5		1f

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007 (continued).**

Trial No. 11

M/F	45/30	12 ft tank			Dose/female 80 ug LHRH liquid		
Start Date	5/22/2007	1300			Dose/male 25 ug LHRH pellet		
End Date	5/24/2007	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/22/2007	1750	21.8	8.4				
5/23/2007	0920	20.9	5.4				
5/24/2007	0840	20.7	8	3.8	3.8		3m, 5f

M/F	30/20	10 ft tank			Dose/female 80 ug LHRH liquid		
Start Date	5/22/2007	1330			Dose/male 25 ug LHRH pellet		
End Date	5/24/2007	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/22/2007	1750	21.6	5.8				
5/23/2007	0922	20.9	7				
5/24/2007	0845	20.7	7	1.2	1.2		1m, 1f

Trial No. 12

M/F	45/30	12 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/24/2007	1300			Dose/male 48 ug LHRH liquid		
End Date	5/26/2007	1000					
Date	Time	Temp. (°C)	Oxygen* (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/24/2007	1745	21.4	6				
5/25/2007	0845	21.2	5.6				
5/26/2007	0830	21.5	7.5	2.9	2.9		1m, 10f

M/F	30/21	10 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/24/2007	1330			Dose/male 48 ug LHRH liquid		
End Date	5/26/2007	1030					
Date	Time	Temp. (°C)	Oxygen* (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/24/2007	1745	21.3	5.8				
5/25/2007	0845	21.2	5.9				
5/25/2007	1010	21.5	6.4				
5/26/2007	0830	21.5	10	3.4	3.4		5m, 3f

*supplemental oxygen provided for Trials 12 through 14

Appendix Table A-2. **Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2007 (continued).**

Trial No. 13

M/F	45/30	12 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/26/2007	1300			Dose/male 48 ug LHRH liquid		
End Date	5/28/2007	1000					
		Temp.	Oxygen*	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/26/2007	1515	22.6	5.5				
5/27/2007	0825	22	6.2				
5/27/2007	1100	22.5	7.2				
5/27/2007	1650	23.2	6.4				
5/28/2007	0730	22.4	8.8				
5/28/2007	0800			1.8	1.8		5m, 13f

M/F	30/21	10 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/26/2007	1330			Dose/male 48 ug LHRH liquid		
End Date	5/28/2007	0930					
		Temp.	Oxygen*	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/26/2007	1515	22.4	10.8				
5/27/2007	0825	22	12.8				
5/27/2007	1650	23.2	9				
5/28/2007	0730	22.4	13				
5/28/2007	0830			0.9	0.9		2f

Trial No. 14

M/F	45/30	12 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/28/2007	1330			Dose/male 48 ug LHRH liquid		
End Date	5/30/2007	930					
		Temp.	Oxygen*	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/28/2007	1524	23.3	4.7				
5/28/2007	1643	23.2	6.5				
5/29/2007	0815	23..2	8.2				
5/30/2007	0700	24.5	8	1.7	1.7		6m, 10f

M/F	30/20	10 ft tank			Dose/female 95 ug LHRH liquid		
Start Date	5/28/2007				Dose/male 48 ug LHRH liquid		
End Date	5/30/2007	1000					
		Temp.	Oxygen*	Eggs	Eggs	River	Morts
Date	Time	(°C)	(ppm)	Collected	Shipped	Releases	Removed
5/28/2007	1524	23.2	8				
5/28/2007	1643	23.2	8.4				
5/29/2007	0840	23.2	11				
5/30/2007	0730	24.5	10.5	2.6	2.6		2m, 11f

*supplemental oxygen provided for Trials 12 through 14

9.0 JOB 3: AMERICAN SHAD HATCHERY OPERATIONS, 2007

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9.1 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.

As is previous years, production goals for American shad for 2007 were to stock 10-20 million American shad larvae. All Van Dyke hatchery-reared American and hickory 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.

9.2 EGG SHIPMENTS

9.2.1 Hickory Shad

A total of 11.5 million hickory shad eggs (25.0 L) were received in four shipments from tank-spawning operations at Conowingo Dam (Table 1). Some 8.0 million (69%) of the hickory shad eggs were viable.

9.2.2 American Shad

A total of 20.7 million American shad eggs (404 L) were received in 38 shipments in 2007 (Table 1). This was the highest quantity of eggs received since 2003 due to improved egg collection on the Delaware and Potomac Rivers (Tables 2 and 3, Figure 1). Overall American shad egg viability (which we define as the percentage which ultimately hatches) was 28%. No eggs were collected from the Hudson River 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.

Eleven Potomac River egg shipments (7.5 million eggs) were received from April 5 to May 10, 2006. Overall viability was 42%. This is a significant increase in egg production over 2006 (4.5 million eggs).

Delaware River egg shipments were received from May 10 to June 1. A total of 15 shipments were received (6.5 million eggs) with a viability of 36%. By comparison, in 2005, the Delaware River produced 2.3 million eggs. Delaware River egg shipments declined from approximately 10 million annually, during 1990 to 1998, to 6 million or less during 1999 to 2006 (Table 3, Figure 1).

American shad eggs were also obtained from a tank-spawning effort at Conowingo Dam, operated by Normandeau Associates. Pre-spawn adult American shad were obtained from the West Fish Lift at Conowingo Dam, injected with hormones and allowed to spawn naturally. Some 6.8 million eggs, in 12 shipments, were delivered to the Van Dyke Hatchery, with a viability of 9%. By comparison, 10.3 million eggs, in 17 shipments, were received from this source in 2006. This has become a consistent source of eggs for the restoration program, but viability has been low, ranging from 9% to 33%.

9.3 SURVIVAL

Overall survival of American shad larvae was 43% compared to a range of 19% to 94% for the period 1984 through 2006. Tanks were divided into seven groups, based on 14-d survival and egg source (Figure 2). Nine tanks from the Potomac source experienced 14-d survival of over 70%, one tank experienced 14-d survival between 40 and 70% and three Potomac River tanks experienced 14-d survival of less than 40%. For the Susquehanna source, four tanks experienced 14-d survival between 40 and 70% and three tanks experienced 14-d survival of less than 40%. For the Delaware source, 11 tanks experienced 14-d survival of 40 to 70% and four tanks experienced 14-d survival of less than 40%.

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. Dead and dying fish had no feed in their gut, but clearly had fed (and grown) because they were significantly larger than newly hatched larvae. Several causes for the observed mortalities were explored during the season including (1) tetracycline marking, (2) problems with the dry feed, (3) oxygen super-saturation, and (4) low pH.

Inspection of the mortality patterns in the affected tanks ruled out the tetracycline marking as the cause of the problems. Delaware River larvae, tagged at 3, 6, 9, and 12 days of age did not experience high mortality until 10 days of age (Figure 3), well after the day 3 and 6 immersions.

The dry feed used in 2007 was purchased in 2006 and stored in a freezer over winter. In addition, it was green in color, not the usual red color. The manufacturer (Zeigler Brothers, Inc.) assured us that the green color was only a dye and that it would not have any impact on survival or palatability. Nevertheless, dry feed was discontinued on May 25 and additional brine shrimp

fed to make up the difference. These actions did not appear to reduce the mortalities.

Specimens from a high mortality tank were supplied to the PFBC pathologist who noted gas bubbles in the digestive tract and suggested that oxygen super-saturation was causing gas bubble disease. Van Dyke staff also noted gas bubbles in the guts of some fish, including some dead specimens that appeared to have been split open by the gas bubble. An oxygen injection system had been installed at Van Dyke before the 2005 season to assist in de-gassing the nitrogen super-saturated water as it overflowed the silo. The system was tested each year before the season and appeared to be very effective in reducing nitrogen saturation from 105% to less than 101%. Oxygen saturation increased to a range of 108 to 130%, but it was assumed that oxygen saturation would not cause problems since the fish could metabolize it. On June 1, 2007, the oxygen injector was turned down from 1.5L/min to 0.5L/min and on June 5, it was turned off. Although it was late in the season and all but two tanks had hatched out, this eliminated gas bubbles in the gut but did not appear to significantly reduce mortalities.

Van Dyke influent pH ranged from 5.7 to 6.2 with a mean of 5.9 and no trend over time. The Van Dyke pH has decreased steadily since 2001 when it ranged from 6.4 to 7.0 and averaged 6.7 (Figure 4). Low pH has always been a concern at Van Dyke. Since before 1985, 50 pounds of lime has been spread on the spring pond bottom annually, before filling, to provide some buffering for the soft, sandstone source water. Sometime prior to 1985, a load of crushed limestone was deposited in the influent end of the warming pond. A new load of limestone was added to the warming pond prior to the 2007 season to attempt to further buffer the influent water, however, this was clearly ineffective. On June 14, 2007, the spring pond source was shut off and river water was pumped into the warming pond to supply water to the hatchery. By this time, many of the fish were too sick to recover, but the river water appeared to improve the health and activity level of the remaining healthy fish.

Acid precipitation has resulted in declines or elimination of fish populations in Scandinavia, Ontario and the Northeastern United States (Baker 1982, Baker and Schofield 1982). A direct consequence of acidification of surface waters is increased solubility of metals, including aluminum (Baker and Schofield 1982). Aluminum is the most abundant metal in the earth's crust, accounting for 8% of the mass of the crust (Wang 2007). In spite of this, aluminum is usually not a problem in aquatic environments because aluminum compounds are insoluble at pH ranges found in most waters. In acidic waters, aluminum is mobilized and dissolved aluminum can cause toxicity in aquatic species.

Survival of eggs of both brook trout and white suckers was actually improved in treatments with Aluminum in water with a pH of less than 5.0 (Baker and Schofield 1982). In contrast, Aluminum concentrations of 0.1 mg/L (for white suckers) or 0.2 mg/L (for brook trout) reduced survival and growth of larvae and postlarvae at all pH levels. Mortalities appeared to be associated with necrosis of the gill epithelium causing mucous clogging of the gills and respiratory stress (Baker and Schofield 1982). Aluminum toxicity declined at pH 5.5 and above. A series of studies on laboratory survival of American shad eggs and larvae exposed to pulses of reduced pH and aluminum was conducted at Johns Hopkins University in the late 1980's using specimens supplied from the Van Dyke Hatchery. Results of these studies are directly applicable to our situation and were reported by Klauda et al. (1988), Klauda et al. (1991), and Klauda

(1994). Klauda (1994) defined lethal and critical thresholds to be 91 to 100% mortality and 50 to 90% mortality, respectively. Critical conditions for feeding American shad larvae were 4 or 8 h pulses of pH 6.2 with no aluminum and pH 6.2 with 76g/L aluminum. Feeding larvae were more sensitive than pre-feeding larvae.

Samples of Van Dyke fish culture water were analyzed for aluminum content on June 14, 2007 and the results are shown below. Spring pond samples represent influent water as it enters the Van Dyke plumbing system. This water is used to cool the egg battery to 60F from the 64F silo (heated) and used in cleaning. Supply trough water is used to supply fish culture tanks directly. We assume that the higher aluminum concentration in the supply trough is due to dissolution of aluminum from various aluminum components in our plumbing system (aluminum pipes in the heat exchanger, aluminum UV units, and aluminum supply trough). Based on the available literature, aluminum concentrations were at levels that might cause the observed mortality in our shad production system. The fact that eggs were not affected, but older, more developed larvae were, suggests that gill development may have played a role in the mortalities.

Sampling site	Dissolved Aluminum	Total Aluminum
Spring pond	0.05 mg/L	0.09 mg/L
Supply trough	0.10 mg/L	0.14 mg/L

As was the case in 2006, higher mortality tanks were reared later in the rearing season. Survival was plotted by hatch date for tanks from each of the three egg sources and exhibited a declining trend through the season (Figure 5). This declining trend in survival cannot be explained by the trend in pH, suggesting that pH is not the cause, or at least not the only cause of the mortalities. Our current hypothesis is that low pH, aluminum toxicity and oxygen super-saturation worked together to weaken the fish and cause the mortalities experienced over the last two years.

To prevent mortality problems in the future, we recommend the following actions:

1. Install and utilize additional packed column de-gassers to reduce the need for oxygen injection.
2. Measure and record oxygen and nitrogen saturation on a daily basis.
3. Use the oxygen injection system only when needed and monitor oxygen saturation and larval condition when the system is in use.
4. Install and utilize a fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and de-toxify dissolved aluminum.
5. Record pH, hardness and alkalinity on a regular basis to monitor fish culture water quality. It is hoped that increasing the pH in the warming pond will prevent dissolution of aluminum from our plumbing system and may precipitate aluminum already present in the influent water, thus reducing aluminum concentration to below 0.05 mg/L. Higher pH may also reduce toxicity of the remaining dissolved aluminum.

9.4 LARVAL PRODUCTION

Hickory shad larvae (3.3 million) were stocked in the lower Susquehanna River at Muddy Creek Access in the Conowingo Reservoir. Some 4.5 million hickory shad were also stocked in the Delaware River basin in Pennypack Creek (4.0 million) and Ridley Creek (500 thousand).

Production and stocking of American shad larvae, summarized in Tables 2, 4 and 5, totaled 2.5 million. A total of 1.1 million was released in the Juniata River, 80 thousand in the Susquehanna River near Clemson Island, 68 thousand in the West Branch Susquehanna River, 29 thousand in the North Branch Susquehanna River in Pennsylvania, 69 thousand in Conodoguinet Creek, and 50 thousand in West Conewago Creek. No shad larvae were provided to New York for stocking in the North Branch Susquehanna River or the Chemung River, due to poor hatchery production and the lack of certification that the larvae were VHS free. Although Delaware River egg collections increased over recent years, they were not sufficient to meet the goals for the Delaware River Basin, given the poor hatchery survival. Larvae were stocked in the Lehigh River (282 thousand), the Schuylkill River (541thousand), and the Delaware River (48 thousand). Larvae stocked in the Delaware River were allocated to replenish the Delaware for the brood stock taken there.

9.5 TETRACYCLINE MARKING

All American and hickory shad larvae stocked received marks produced by immersion in tetracycline (Table 6). Immersion marks for American shad were administered by bath treatments in 256-ppm oxytetracycline hydrochloride for 4h duration. All American shad larvae were marked according to stocking site and/or egg source. All hickory shad larvae were marked with 512-ppm and given a single mark on day 3. Most American shad larvae from the Potomac River egg source were stocked in the Juniata River or Susquehanna River near Clemson Island and were given a double mark at 15 and 18 days of age. Some 260 thousand Potomac River source larvae were marked at 3,6 and 9 days of age and returned to the Potomac River to replace the eggs taken at that location. Some 5,000 Potomac River source larvae were also stocked in the West Branch Susquehanna River as part of a media event held there. Larvae from the Susquehanna River egg source were stocked in the West Branch Susquehanna River (marked on days 3,6,9,12,15), Conodoguinet Creek (marked on days 3,6,12,15), West Conewago Creek (marked on days 3,9,12,15,19), or North Branch Susquehanna River (marked on days 3,6,9,15). Larvae from the Delaware River egg source were stocked in the Lehigh River (marked on days 9, 12, 15), the Schuylkill River (marked on days 3, 6, 9 ,12), or the Delaware River (marked on days 3,6,12,15,18).

Verification of mark retention was accomplished by stocking groups of marked fry in raceways 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.

All fish examined exhibited marks, however observed marks did not necessarily conform to the marking protocol, presumably due to the problems experienced in fish culture (Table 6). This is consistent with past experience: fish that do not survive and grow well do not mark well. In general, groups of mark retention fish that were cultured earlier tended to mark better and those which were cultured later, when the fish culture problems were more severe, tended to have more problematic marks. 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 2007 cohort.

Hickory shad larvae did not survive raceway culture and could not be evaluated for marks. Potomac River source fish, marked at days 3, 6 and 9 and released in the Potomac River exhibited 100% mark retention and all marks were clearly 3,6,9 marks. Potomac River source fish, marked at days 15 and 18 and released in the Juniata, Susquehanna, or West Branch Susquehanna Rivers exhibited 100% mark retention, but seven of 20 (35%) had marks that were very close together. These should be identifiable in wild-caught specimens. Susquehanna River source fish, marked on days 3, 6, 9, 12, and 15, and released in the West Branch Susquehanna River exhibited 0% retention for the intended mark. None of the 20 fish examined exhibited the day 15 mark. In addition, four of the 20 (20%) had day 9 and 12 marks which were very close together, and one (5%) exhibited marks only on days 3 and 6. There is a very real potential for these fish to be confused with fish marked on days 3,6,9 and 12, the mark used for the Schuylkill River. Susquehanna River source fish, marked on days 3, 6, 12, and 15, and released in Conodoguinet Creek exhibited 100% retention for the intended mark, but two of 20 (10%) had day 12 and 15 marks that were very close together. These could be misidentified as day 3,6,12 marks. Susquehanna River source fish, marked on days 3, 9, 12, 15 and 18, and released in West Conewago Creek exhibited 61% retention for the intended mark. Seven of the 18 specimens (39%) had the day 18 mark missing and on two of those the day 12 mark was very bright. These could be misidentified as day 3,9,12, 15 marks. Susquehanna River source fish, marked on days 3, 6, 9, and 15, and released in North Branch Susquehanna River (PA) exhibited 95% retention for the intended mark. One of the 20 specimens (5%) had the day 3 and day 6 marks run together to form a very bright mark. Such specimens could be misidentified as day 3,9, 15 marks. Delaware River source fish, marked on days 9, 12, and 15, and released in the Lehigh River exhibited 100% retention for the intended mark, but two of 20 (10%) had day 12 and 15 marks that were very close together. These should be identifiable in wild-caught specimens. Delaware River source fish, marked on days 3, 6, 9, and 12, and released in the Schuylkill River exhibited 87% retention for the intended mark, but four of 39 (10%) had day 9 and 12 marks that were very close together and appeared as one. One of 39 (3%) had the day 12 mark missing. These could be misidentified as day 3,6,9 marks. Delaware River source fish, marked on days 3, 6, 12, 15 and 18, and released in the Delaware River exhibited 33% retention for the intended mark. Three of 21 (14%) had marks on days 3,6,9,12,18,21, eight of 21 (38%) had marks on days 3,6,9,12,18, and three of 21 (14%) had marks on days 3,6,9,12,15. Marking protocols for 2006 to 2010 are given in Table 7. The primary production mark for Potomac source larvae stocked in the Juniata River or Susquehanna River near Montgomery Ferry will be changed every year to provide known age specimens for age verification.

9.6 SUMMARY

Four shipments of hickory shad eggs (12 million eggs) were received at Van Dyke in 2007. Egg viability was 69% and 8.0 million hickory shad larvae were stocked in Conowingo Reservoir and in Delaware River tributaries, Pennypack Creek and Ridley Creek.

A total of 38 shipments of American shad eggs (21 million eggs) was received at Van Dyke in 2007. Total egg viability was 28% and survival of viable eggs to stocking was 43%, resulting in production of 2.5 million larvae. Larvae were stocked in the Juniata River (1.0 million), the Susquehanna River near Clemson Island (80 thousand), the West Branch Susquehanna River (68

thousand), the North Branch Susquehanna River in Pennsylvania (29 thousand), Conodoguinet Creek (69 thousand), and West Conewago Creek (50 thousand). Delaware river source larvae were stocked in the Lehigh River (282 thousand), the Schuylkill River (541 thousand) and the Delaware River (48 thousand).

Overall survival of larvae was 43%. No episodes of major mortality occurred as a result of larvae lying on the bottom of the tank but high mortalities occurred in many tanks, particularly late in the season. These mortalities are thought to be due to oxygen super-saturation, low pH and/or aluminum toxicity.

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 mark retention specimens examined exhibited tetracycline marks, however the marks did not always appear as intended, presumably due to poor health and growth of the fish. Many mark retention specimens had missing marks or marks that were close together due to poor growth. These marks may be difficult to identify from wild-caught fish. Digital photographs of representative specimens have been archived to aid in future mark evaluation. Hickory shad were marked at 512 ppm on day three. Mark retention for hickory shad was not evaluated because no specimens survived raceway culture.

9.7 RECOMMENDATIONS FOR 2007

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. Continue to hold Delaware River eggs until 8:00AM before processing.
8. Buy new foam bottom screens each year and specify “no-fire retardants” when ordering foam.
9. Modify the egg battery to accept 23 additional MSXXX jars (total 57).
10. Continue to collect American shad eggs from the Potomac River as an additional source of out-of-basin eggs.
11. Continue to develop a reference collection of scales and otoliths from known age American shad by marking according to year stocked (Table 7). Utilize uniquely marked larvae from the Potomac River egg source, stocked in the Juniata or Susquehanna Rivers.
12. Mark hickory shad at 512ppm OTC.
13. Continue using Pfizer Terramycin 343 (now FDA approved) for marking alosines.
14. Install and utilize a fluidized bed system, using limestone sand to buffer the Van Dyke source water, neutralize the pH and reduce dissolved aluminum.
15. Record pH, hardness and alkalinity on a regular basis to monitor fish culture water quality.

16. Install and utilize additional packed column de-gassers to reduce the need for oxygen injection.
17. 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.
18. Mark all tanks of larvae beginning at 11:00AM, to ensure consistency in daily mark application.

9.8 LITERATURE CITED

Baker, J. P. 1982. Effects on fish of metals associated with acidification. Pages 165 – 176 *in* R. E. Johnson, editor. Acid rain/fisheries. American Fisheries Society, Bethesda, Md.

Baker, J. P. and C. L. Schofield. 1982. Aluminum toxicity to fish in acidic waters. Water, Air, and Soil Pollution 18:289-309.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1990. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1992. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1991. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender, Jr. 1993. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1992. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender, Jr. 1994. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1993. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender, Jr. 1995. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1996. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1997. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1996. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1998. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1997. Susquehanna

River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1999. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1998. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2001. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2000. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2002. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2001. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2003. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2002. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2004. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2003. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2005. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2004. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2006. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2005. Susquehanna River Anadromous Fish Restoration Committee.

Klauda, R. J., R. E. Palmer, and D. M. Baudler. 1988. Effects of acidic episodes in Lyons Creek on survival of the eggs and larvae of blueback herring and American shad: 1987 field and laboratory studies. Chesapeake Bay Research and Monitoring Division, Tidewater Administration, Department of Natural Resources, Annapolis, Maryland.

Klauda, R. J., S. A. Fischer, L. W. Hall, Jr., and J. A. Sullivan. 1991. American shad and hickory shad *Alosa sapidissima* and *Alosa mediocris*. Pages 9-1 to 9-27 *in* S. L. Funderburk, S. J. Jordan, J. A. Mihursky, and D. Riley, editors. Habitat requirements for Chesapeake Bay living resources, second edition. Chesapeake Bay Program, Annapolis Maryland.

Klauda, R. J. 1994. Lethal and critical effects thresholds for American shad eggs and larvae exposed to acid and aluminum in the Laboratory, with speculation on the potential role of habitat acidification on stock status in Maryland. Anadromous Alosa Symposium, Tidewater Chapter, American Fisheries Society, pp7-39.

Wang, X. 2007. Aluminum mobilization from thfe forest land. http://www.esf.edu/ResOrg/RooseveltWildlife/Research/Al/Al.htm.

9.9 TABLES AND FIGURES

Table 1. Egg shipments received at Van Dyke, 2007.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American shad	Potomac	4/4/07	4/5/07	12.4	426,389	234,423	55%
2	American shad	Potomac	4/5/07	4/6/07	6.2	224,737	35,434	16%
3	American shad	Potomac	4/23/07	4/24/07	11.4	453,332	155,369	34%
4	Hickory shad	Susq. Conowingo	4/24/07	4/24/07	9.3	4,118,356	3,138,680	76%
5	American shad	Potomac	4/25/07	4/26/07	25.5	991,668	470,714	47%
6	Hickory shad	Susq. Conowingo	4/25/07	4/26/07	8.7	3,609,970	2,050,000	57%
7	American shad	Potomac	4/26/07	4/27/07	13.8	495,010	230,321	47%
8	American shad	Potomac	4/27/07	4/28/07	40.8	1,689,120	720,982	43%
9	American shad	Potomac	4/29/07	4/30/07	21.5	855,016	14,310	2%
10	Hickory shad	Susq. Conowingo	4/29/07	4/30/07	3.3	1,780,593	1,414,179	79%
11	American shad	Potomac	4/30/07	5/1/07	33.8	1,529,075	750,274	49%
12	Hickory shad	Susq. Conowingo	4/30/07	5/1/07	3.8	2,023,401	1,391,938	69%
13	American shad	Susq. Conowingo	5/5/07	5/6/07	7.2	493,917	48,177	10%
14	American shad	Susq. Conowingo	5/6/07	5/7/07	7.9	378,613	46,355	12%
15	American shad	Potomac	5/7/07	5/8/07	3.8	171,908	113,230	66%
16	American shad	Potomac	5/8/07	5/9/07	7.0	319,757	106,301	33%
17	American shad	Susq. Conowingo	5/8/07	5/9/07	13.3	732,875	127,947	17%
18	American shad	Delaware	5/9/07	5/10/07	4.1	260,405	29,917	11%
19	American shad	Potomac	5/9/07	5/10/07	7.8	332,705	44,098	13%
20	American shad	Delaware	5/10/07	5/11/07	14.0	645,722	96,811	15%
21	American shad	Susq. Conowingo	5/10/07	5/11/07	15.5	1,001,627	172,586	17%
22	American shad	Susq. Conowingo	5/12/07	5/13/07	5.7	418,053	10,775	3%
23	American shad	Delaware	5/13/07	5/14/07	17.4	630,713	355,448	56%
24	American shad	Delaware	5/14/07	5/15/07	11.0	557,885	315,651	57%
25	American shad	Susq. Conowingo	5/14/07	5/15/07	6.0	504,822	24,427	5%
26	American shad	Delaware	5/15/07	5/16/07	8.0	394,464	150,715	38%
27	American shad	Delaware	5/16/07	5/17/07	14.0	556,724	337,787	61%
28	American shad	Delaware	5/17/07	5/18/07	6.3	224,189	31,859	14%
29	American shad	Susq. Conowingo	5/18/07	5/19/07	4.9	521,625	84,851	16%
30	American shad	Delaware	5/21/07	5/22/07	10.0	465,694	287,578	62%
31	American shad	Susq. Conowingo	5/21/07	5/22/07	5.2	545,519	11,545	2%
32	American shad	Delaware	5/22/07	5/23/07	15.6	645,840	401,727	62%
33	American shad	Delaware	5/23/07	5/24/07	7.0	248,467	175,755	71%
34	American shad	Susq.-Conowingo	5/23/07	5/24/07	5.0	596,884	15,812	3%
35	American shad	Delaware	5/24/07	5/25/07	7.2	345,065	77,100	22%
36	American shad	Susq.-Conowingo	5/25/07	5/26/07	6.3	622,888	46,930	8%
37	American shad	Susq.-Conowingo	5/27/07	5/28/07	2.7	302,363	6,017	2%
38	American shad	Delaware	5/28/07	5/29/07	5.8	299,874	41,908	14%
39	American shad	Delaware	5/29/07	5/30/07	4.7	233,941	29,247	13%
40	American shad	Susq. Conowingo	5/29/07	5/30/07	4.3	654,407	7,923	1%
41	American shad	Delaware	5/30/07	5/31/07	4.7	530,123	6,094	1%
42	American Shad	Delaware	5/31/07	6/1/07	6.1	418,458	10,594	3%
	Totals		**No. of shipments**					
	American shad	**Potomac**	**11**		**183.9**	**7,488,716**	**2,875,455**	**42%**
		Delaware	**15**		**135.8**	**6,457,563**	**2,348,192**	**36%**
		Susq.- Conowingo	**12**		**84.0**	**6,773,594**	**603,345**	**9%**
		Grand total	**38**		**403.7**	**20,719,874**	**5,826,992**	**28%**
	Hickory shad	**Susq.- Conowingo**	**4**		**25.0**	**11,532,320**	**7,994,797**	**69%**

Table 2. Annual summary of American shad production, 1976-2007.

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 Fingerling stocked (exp.3)	Total stocked (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518		266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969		35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124		6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629		34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526		5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030		24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019		41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048		98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996		30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960		115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876		61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274		81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441		74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267		60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034		253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963		233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645		34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870		79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720	*	140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930	*	-	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466	*	-	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019		25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757		2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412		-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535		-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524		7	6,531	0.31	0.88
2002	943	35.6	38.8	13.8	2,589		-	2,589	0.07	0.19
2003	1005	33.0	49.4	16.3	12,742		-	12,742	0.39	0.78
2004	462	17.3	54.0	9.3	5,637		-	5,637	0.33	0.60
2005	372	17.1	36.6	6.0	5,208		1	5,209	0.30	0.87
2006	394	19.0	35.2	6.7	4,945		-	4,945	0.26	0.74
2007	404	20.7	27.7	5.8	2,509		-	2,509	0.12	0.43
							Total	**247,875**		
							Total since 1985 (OTC marked)	**216,478**		

*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
1971				8,420,000									
1972				7,100,000									
1973				4,740,000			4,300,000	8,450,000	6,480,000				34,640,000
1974							530,000	9,750,000	6,800,000	19,200,000		8,180,000	5,560,000
1975								1,880,000		7,150,000		18,420,000	5,700,000
1976		4,100,000										54,800,000	
1977							350,000	4,400,000	570,000	3,420,000		8,900,000	
1978								6,900,000		10,110,000			
1979								3,170,000		4,990,000			
1980								6,730,000		6,830,000			
1981								4,580,000		1,260,000		5,780,000	
1982								2,030,000		1,250,000		22,570,000	
1983	1,170,000	2,400,000						5,490,000		5,910,000		19,510,000	
1984		2,640,000						9,830,000		740,000		27,880,000	
1985		6,160,000						5,280,000		2,050,000		12,060,000	
1986		5,860,000						5,620,000		1,070,000		39,970,000	
1987		5,010,000						4,350,000		110,000		23,530,000	
1988		2,906,800						1,921,000		47,700		26,917,800	
1989	11,179,200	5,963,600						1,909,800		526,400		23,098,200	
1990	14,531,200	13,146,900				327,200		477,700			123,000		
1991	17,658,100	10,745,000				296,400	1,103,900						
1992	3,003,600	9,601,000					5,712,700			171,900			
1993	2,971,763	9,303,194					7,445,260	1,781,857					
1994	6,286,914	10,273,763					4,091,410	534,134	29,186				
1995	11,852,454	10,752,738											
1996	5,694,043	8,308,940				407,647							
1997	11,080,420	11,764,260											
1998	15,679,097	10,384,059				1,660,829							
1999	21,102,147	5,489,339											
2000	14,881,847	3,827,250											
2001	3,919,113	6,348,308	5,808,909			5,052,614							
2002	18,507,572	2,039,613	7,079,774			7,993,882							
2003	17,120,964	3,614,283	11,721,891	555,265	23,379								
2004	9,390,423	2,406,785	4,740,195	752,667									
2005	2,923,555	6,213,988	7,998,778										
2006	1,859,518	2,328,165	10,281,444										4,511,426
2007		6,457,563	6,773,594										7,488,716
Total	186,028,856	153,045,832	29,350,770	21,567,932	23,379	15,738,572	23,533,270	85,084,491	13,879,186	64,836,000	123,000	291,616,000	45,900,000

Table 4. American and hickory shad stocking, 2007.

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age	Size
5/3/07	A1 1	Hickory shad	1,554,988	Pennypack Cr., Ridley Cr.	3	Susquehanna	4	Fry
5/3/07	A2 1	Hickory shad	1,529,534	Pennypack Cr., Ridley Cr.	3	Susquehanna	4	Fry
5/4/07	A3 1	Hickory shad	1,294,761	Muddy Cr. Access	3	Susquehanna	4	Fry
5/4/07	A4 1	Hickory shad	713,237	Muddy Cr. Access	3	Susquehanna	4	Fry
5/9/07	B1 1	Hickory shad	1,407,377	Pennypack Cr., Ridley Cr.	3	Susquehanna	4	Fry
5/10/07	B2 1	Hickory shad	1,315,743	Muddy Cr. Access	3	Susquehanna	4	Fry
4/26/07	C1 1	American shad	259,119	Potomac River	3,6,9	Potomac	14	Fry
5/22/07	C2 1	American shad	79,546	Millerstown (Rt. 17 Bridge)	15,18	Potomac	20	Fry
5/24/07	C3 1	American shad	45,787	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
5/24/07	C4 1	American shad	129,563	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
5/25/07	D1 1	American shad	123,624	Millerstown (Rt. 17 Bridge)	15,18	Potomac	20	Fry
5/26/07	D2 1	American shad	57,720	Millerstown (Rt. 17 Bridge)	15,18	Potomac	20	Fry
5/27/07	D3 1	American shad	71,003	Millerstown (Rt. 17 Bridge)	15,18	Potomac	21	Fry
5/25/07	D4 1	American shad	219,111	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
5/29/07	E1 1	American shad	167,497	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
5/28/07	E2 1	American shad	115,507	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
6/1/07	E3 1	American shad	80,383	Clemson Island	15,18	Potomac	22	Fry
6/4/07	E4 1	American shad	50,000	W.Conewago Cr.	3,9,12,15,18	Susquehanna	21	Fry
6/3/07	F1 1	American shad	75,317	Millerstown (Rt. 17 Bridge)	15,18	Potomac	19	Fry
6/4/07	F2 1	American shad	68,783	Conodoguinet Cr.	3,6,12,15	Susquehanna	19	Fry
6/8/07	F3 1	American shad	57,800	Schuylkill	3,6,9,12	Delaware	20	Fry
6/5/07	F4 1	American shad	5,000	W. Br. Susquehanna R.	15,18	Potomac	20	Fry
6/5/07	G1 1	American shad	52,673	W. Br. Susquehanna R.	3,6,9,12,15	Susquehanna	17	Fry
6/8/07	G2 1	American shad	100,000	Schuylkill	3,6,9,12	Delaware	18	Fry
6/8/07	G3 1	American shad	100,000	Schuylkill	3,6,9,12	Delaware	17	Fry
6/7/07	G4 1	American shad	10,000	Bald Eagle Creek	3,6,9,12,15	Susquehanna	16	Fry
6/8/07	H1 1	American shad	63,575	Schuylkill	3,6,9,12	Delaware	16	Fry
6/8/07	H2 1	American shad	89,276	Schuylkill	3,6,9,12	Delaware	15	Fry
6/8/07	H3 1	American shad	105,004	Schuylkill	3,6,9,12	Delaware	15	Fry
6/8/07	H4 1	American shad	25,000	Schuylkill	3,6,9,12	Delaware	14	Fry
6/19/07	I1 1	American shad	26,268	N. Br. Susquehanna R. (PA)	3,6,9,15	Susquehanna	24	Fry
6/18/07	I2 1	American shad	41,781	Lehigh	9,12,15	Delaware	20	Fry
6/18/07	I3 1	American shad	64,002	Lehigh	9,12,15	Delaware	19	Fry
6/19/07	I4 1	American shad	1,681	N. Br. Susquehanna R. (PA)	3,6,9,15	Susquehanna	19	Fry
6/18/07	A1 2	American shad	5,000	Lehigh	9,12,15	Delaware	18	Fry
6/18/07	A2 2	American shad	93,517	Lehigh	9,12,15	Delaware	18	Fry
6/18/07	A3 2	American shad	77,584	Lehigh	9,12,15	Delaware	18	Fry
6/27/07	A4 2	American shad	1,000	Delaware River	3,6,12,15,18	Delaware	26	Fry
6/19/07	B1 2	American shad	1,000	N. Br. Susquehanna R. (PA)	3,6,9,15	Susquehanna	17	Fry
6/27/07	B2 2	American shad	45,587	Delaware River	3,6,12,15,18	Delaware	21	Fry
6/27/07	B4 2	American shad	1,000	Delaware River	3,6,12,15,18	Delaware	19	Fry

Table 5. Summary of stocking of juvenile Alosines from the Van Dyke Hatchery, 2007.

	Site	Fry
American shad Releases	Millerstown (Rt. 17 Bridge)	1,084,676
	Juniata River Subtotal	**1,084,676**
	Clemson Island	80,383
	Conodoguinet Creek	68,783
	West Conewago Creek	50,000
	North Branch Susquehanna River (PA)	28,949
	West Banch Susquehanna River	67,673
	Susquehanna River Basin Subtotal	**1,380,463**
	Delaware River	47,587
	Schuylkill River	540,655
	Lehigh River	281,884
	Potomac River	259,119
	Total American shad	**2,509,708**
Hickory shad releases	Muddy Creek Access Area	3,323,741
	Susquehanna River Basin Subtotal	**3,323,741**
	Pennypack Creek	3,991,899
	Ridley Creek	500,000
	Delaware River Basin Subtotal	**4,491,899**
	Total Hickory shad	**7,815,640**

Table 6. Summary of marked Alosines stocked in Pennsylvania, 2007.

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										
1,165,059	Fry	15,18	Juniata/Susq. R.	Potomac	256ppm OTC	100%[a]	-	-	Van Dyke	-
5,000	Fry	15,18	W. Br. Susq. R.	Potomac	256ppm OTC	100%[a]	-	-	Van Dyke	-
-	Fry	3,6,9	Juniata/Susq. R.		256ppm OTC	N/A				
62,673	Fry	3,6,9,12,15	W. Br. Susq. R.	Susquehanna	256ppm OTC	0%[b]	-	-	Van Dyke	-
68,783	Fry	3,6,12,15	Conodoguinet Cr.	Susquehanna	256ppm OTC	100%[c]	-	-	Van Dyke	-
-	Fry	3,9,12,15	Conestoga R.		256ppm OTC	N/A				
50,000	Fry	3,9,12,15,18	W. Conewago Cr.	Susquehanna	256ppm OTC	61%[d]	-	-	Van Dyke	-
-	Fry	3,6,9,15,18	Swatara Cr.		256ppm OTC	N/A				
28,949	Fry	3,6,9,15	N. Br. Susq. R.(PA)	Susquehanna	256ppm OTC	95%[e]	-	-	Van Dyke	-
-	Fry	3,6,9,12,18	N. Br. Susq. R.(NY)		256ppm OTC	N/A				
-	Fry	3,15,18	Chemung R. (NY)		256ppm OTC	N/A				
276,000	Fry	9,12,15	Lehigh R.	Delaware	256ppm OTC	100%[f]	-	-	Van Dyke	-
540,655	Fry	3,6,9,12	Schuylkill R.	Delaware	256ppm OTC	87%[g]	-	-	Van Dyke	-
47,587	Fry	3,6,12,15,18	Del. R. (Smithfield)	Delaware	256ppm OTC	33%[h]	-	-	Van Dyke	-
259,119	Fry	3,6,9	Potomac R.	Potomac	256ppm OTC	100%	-	-	Van Dyke	-
Hickory shad										
3,323,741	Fry	3	Conowingo Res.	Susquehanna	512ppm OTC	Dead[i]	-	-	Van Dyke	-
500,000	Fry	3	Ridley Cr.	Susquehanna	512ppm OTC	Dead[i]	-	-	Van Dyke	-
3,991,899	Fry	3	Pennypack Cr.	Susquehanna	512ppm OTC	Dead[i]	-	-	Van Dyke	-

[a] seven of 20 (35%) had marks very close together

[b] All specimens were marked, however, d15 mark absent on all, four of 19 (21%) had d9 and d12 close together, one exhibited only day 3 and 6 marks

[c] two of 17 (12%) had last two marks very close together

[d] Seven of 18 (39%) had d18 mark missing, on two of those d12 mark was very bright

[e] One of 20 had d3 and d6 marks run together to form bright mark

[f] two of 20 (10%) had last two marks very close together

[g] four of 39 (10%) had d9 and d12 marks close together to appear as one mark, one of 39 (3%) had d 12 mark missing

[h] three of 21 (14%) had marks on days 3,6,9,12,18,21, eight of 21 (38%) had marks on days 3,6,9,12,18, three of 21 (14%) had marks on days 3,6,9,12,15

[i] No hickory shad survived in the raceways for mark retention analysis

Table 7. Proposed marking plan for Alosines stocked in Pennsylvania, 2006-2010.

Size	Immersion mark (days)	Immersion mark	Stocking Location	Egg Source	Years
American shad					
Fry	18	256ppm OTC	Juniata/Susq. R.	Potomac	2006
Fry	15,18	256ppm OTC	Juniata/Susq. R.	Potomac	2007
Fry	15,18,21	256ppm OTC	Juniata/Susq. R.	Potomac	2008
Fry	3,9,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Potomac	2009
Fry	3,6,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Potomac	2010
Fry	3,6,9	256ppm OTC	Juniata/Susq. R.	Susquehanna	2006-2010
Fry	3,6,9,12,15	256ppm OTC	W. Br. Susq. R.	Potomac	2006-2010
Fry	3,6,12,15	256ppm OTC	Conodoguinet Cr.	Potomac	2006-2010
Fry	3,9,12,15	256ppm OTC	Conestoga R.	Potomac	2006-2010
Fry	3,9,12,15,18	256ppm OTC	W. Conewago Cr.	Potomac	2006-2010
Fry	3,6,9,15,18	256ppm OTC	Swatara Cr.	Potomac	2006-2010
Fry	3,6,9,15	256ppm OTC	N. Br. Susq. R.(PA)	Potomac	2006-2010
Fry	3,6,9,12,18	256ppm OTC	N. Br. Susq. R.(NY)	Potomac	2006-2010
Fry	3,15,18	256ppm OTC	Chemung R. (NY)	Potomac	2006-2010
Fry	9,12,15	256ppm OTC	Lehigh R.	Delaware	2006-2010
Fry	3,6,9,12	256ppm OTC	Schuylkill R.	Delaware	2006-2010
Fry	3,6,12,15,18	256ppm OTC	Del. R. (Smithfield)	Delaware	2006-2010
Fry	3,6	256ppm OTC	Potomac R.	Potomac	2006-2010
Hickory shad					
Fry	3	512ppm OTC	Conowingo Res.	Susquehanna	2006-2010
Fry	3	512ppm OTC	Delaware River	Susquehanna	2006-2010
Fry	3	512ppm OTC	Ridley Cr.	Susquehanna	2006-2010
Fry	3	512ppm OTC	Pennypack Cr.	Susquehanna	2006-2010

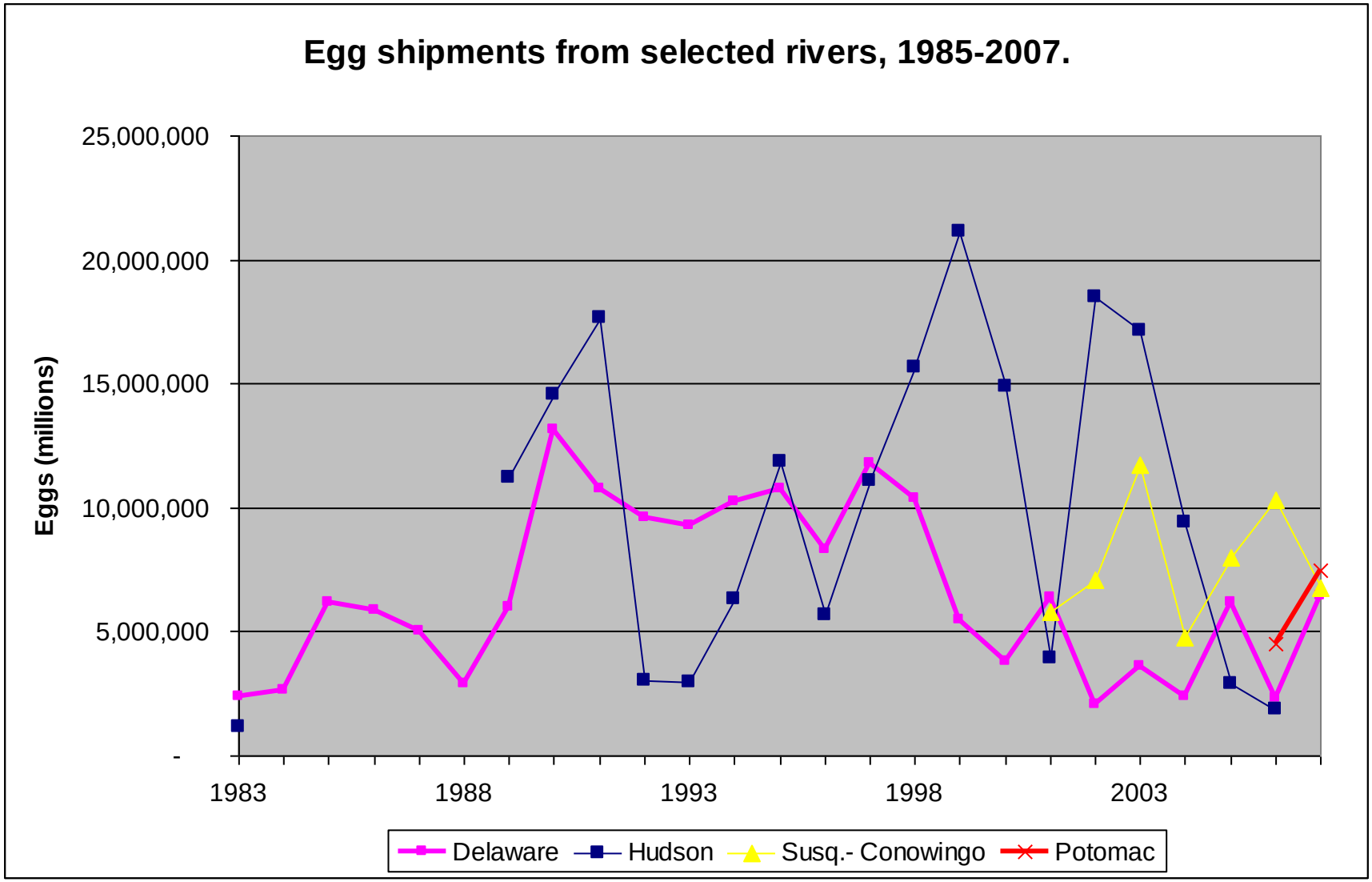

Figure 1. Egg Shipments from Selected Rivers, 1985-2007

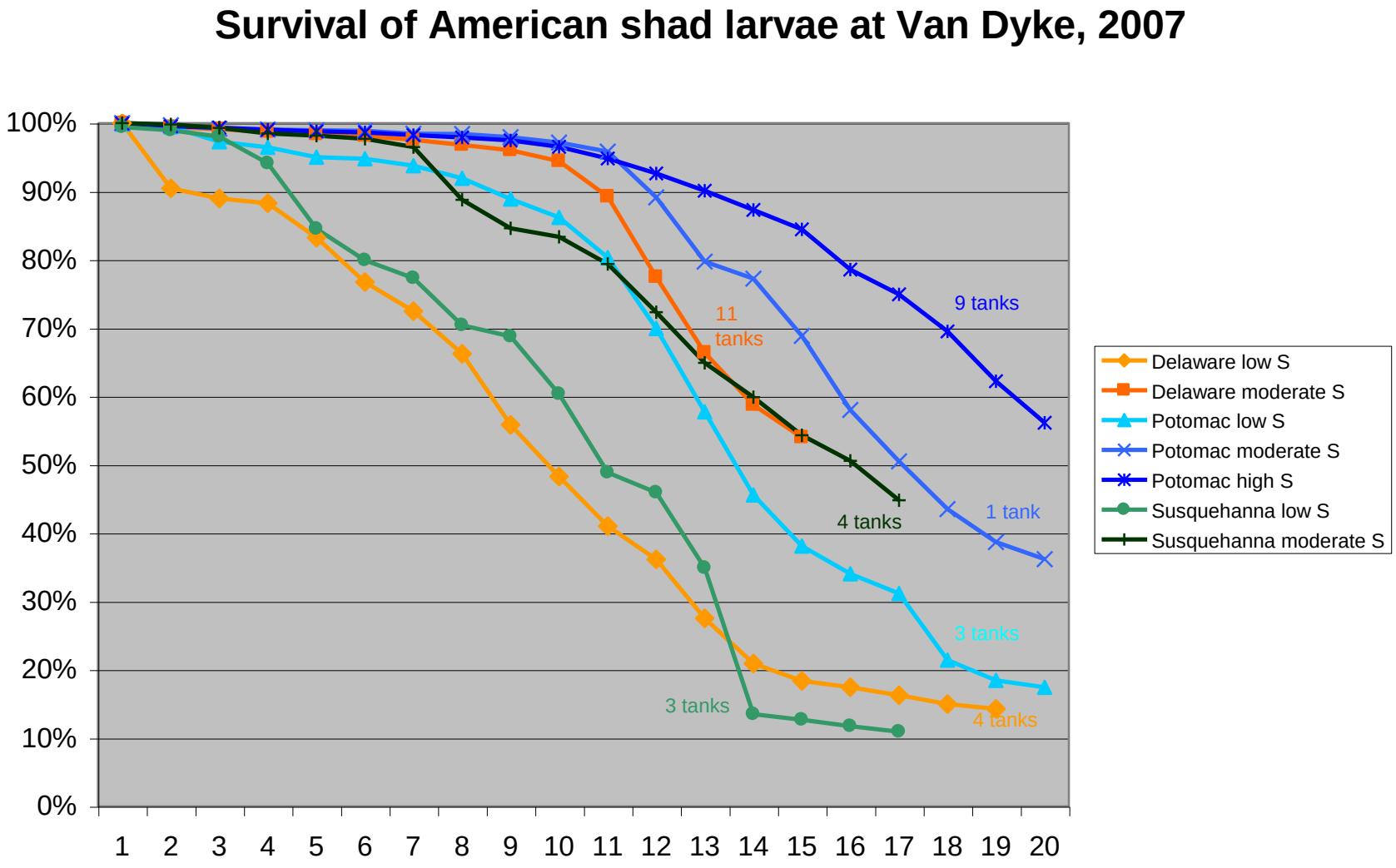

Figure 2. Survival of American Shad Larvae at Van Dyke, 2007

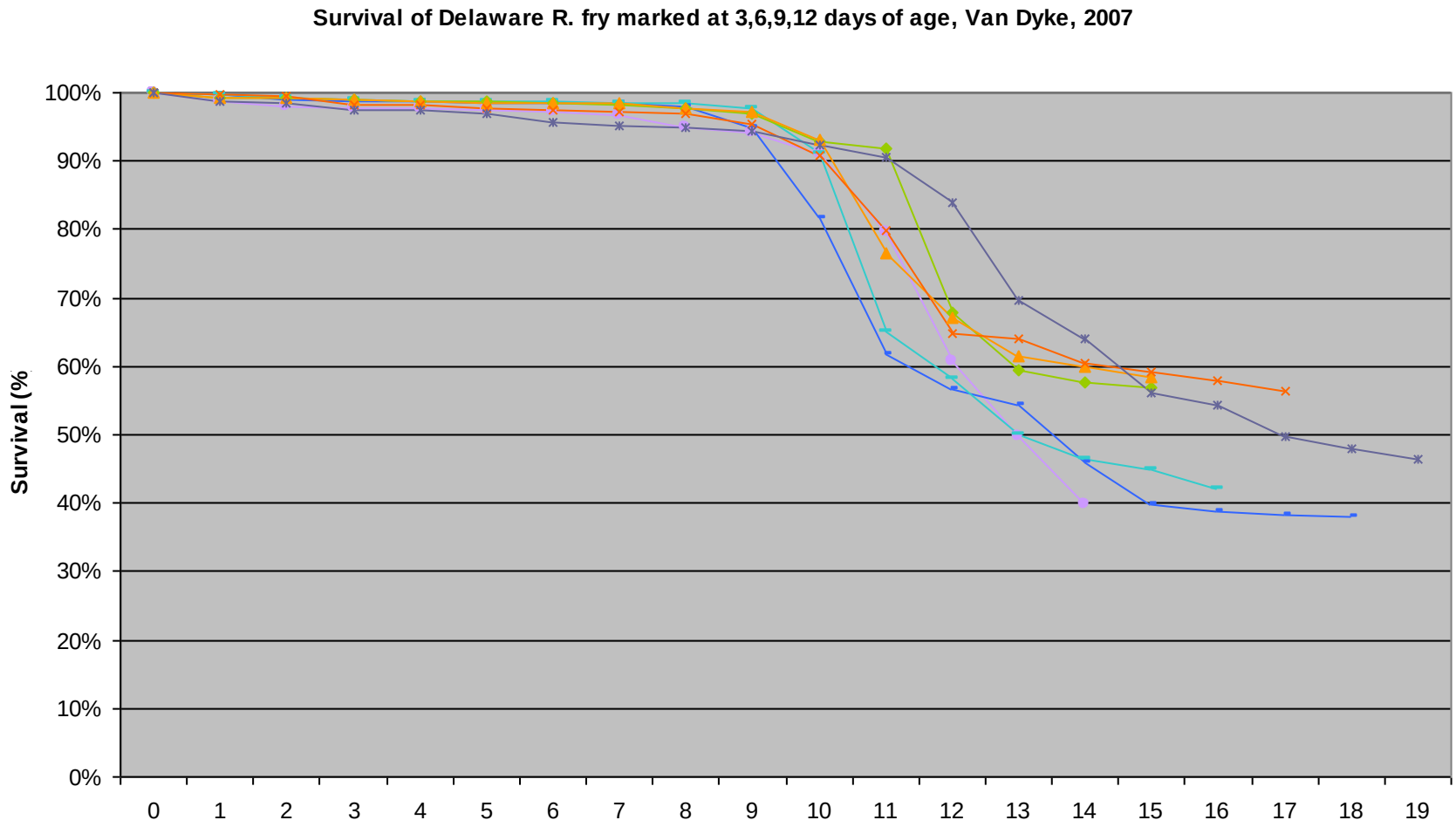

Figure 3. Survival of Delaware River Fry Marked at 3, 6, 9, 12 days of age, Van Dyke, 2007

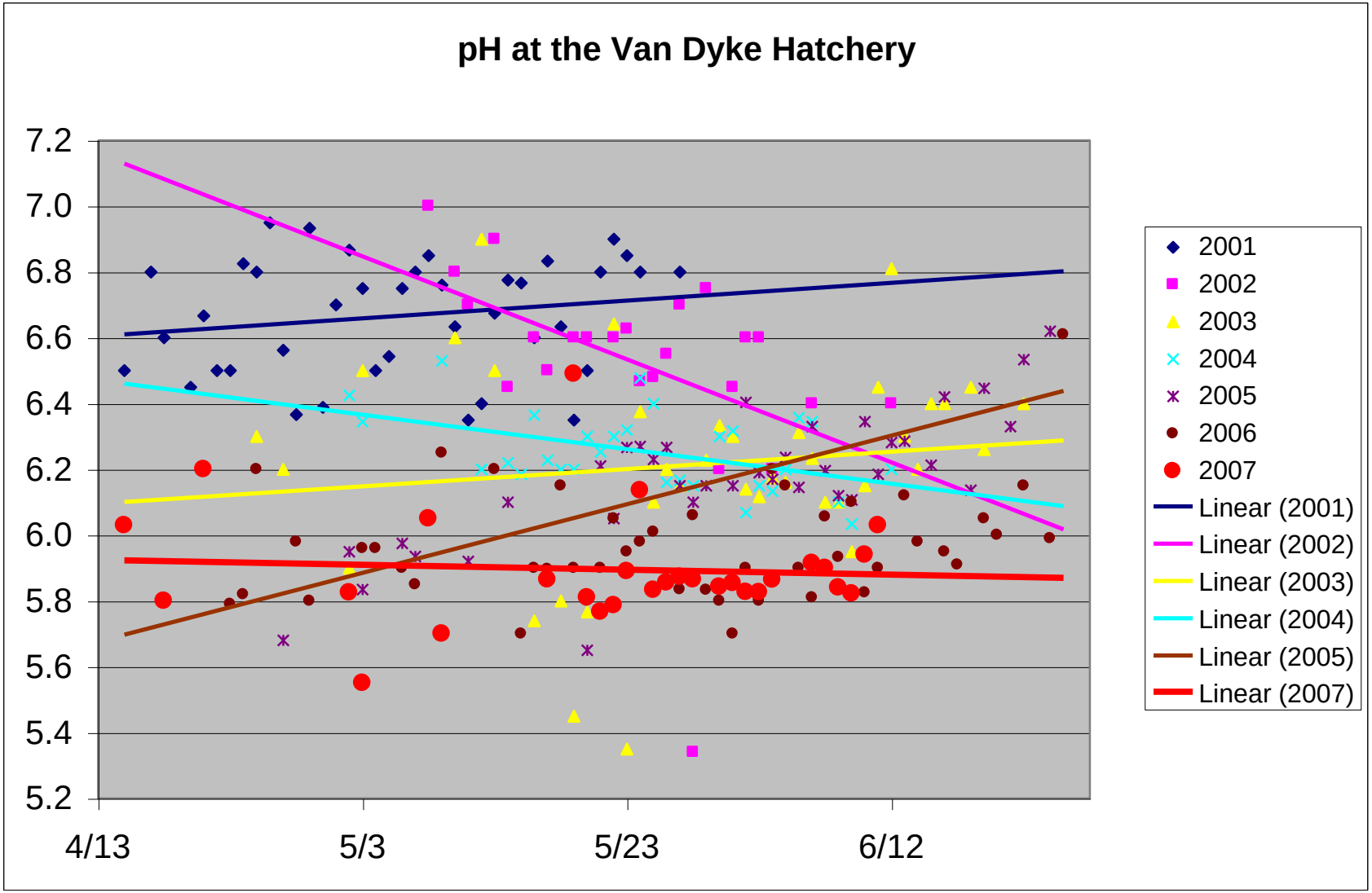

Figure 4. pH at the Van Dyke Hatchery

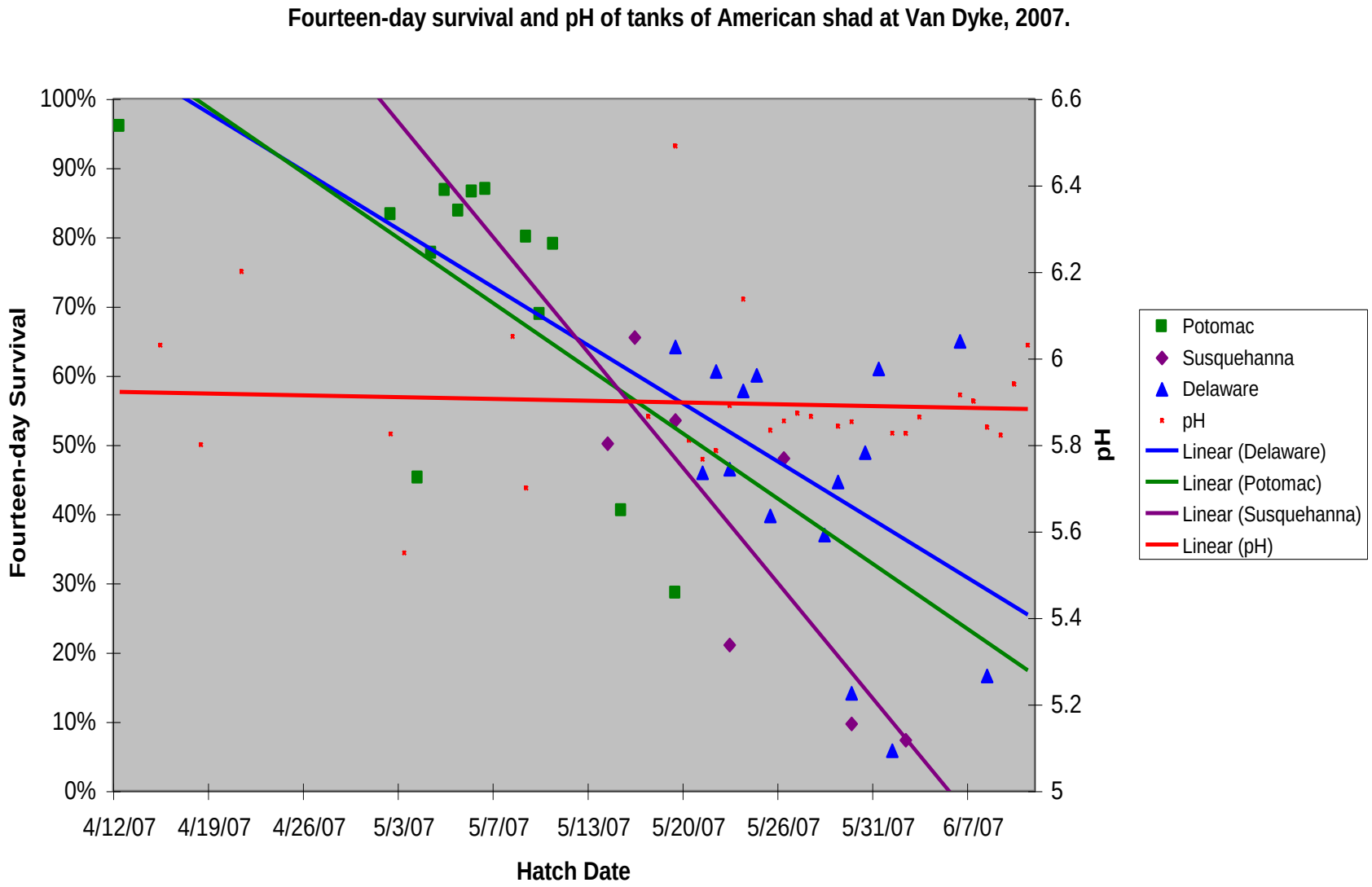

Figure 5. Fourteen-day Survival and pH of Tanks of American Shad at Van Dyke, 2007

10.0 JOB 4: ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER, 2007

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10.1 INTRODUCTION

This report summarizes the results of bio-monitoring activities for juvenile alosines conducted in the Susquehanna River and its tributaries in 2007.

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 2,301 adult shad were collected at the Conowingo West Lift. The majority were released back into the Conowingo tailrace, with 875 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 Fabri-Dam 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 2007 spring migration, Conowingo East Lift passed 25,464 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 10,338, 7,215 and 192 American shad, respectively. Some 460 blueback herring and 429 alewife were passed at Conowingo Dam. No river herring were passed at Holtwood, Safe Harbor or York Haven Dams. No hickory shad were passed at any of the four 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 2007 production season, the PFBC Van Dyke Research Station for Anadromous Fish produced 1.4 million shad larvae which were released in the Susquehanna Basin in Pennsylvania. Larval releases occurred from May 22 to June 19 during a period of steadily decreasing flows. Larvae were released in the following locations and numbers:

Juniata River (Millerstown)	1,084,676
Susquehanna River (Clemson Island)	80,383
North Branch Susquehanna River (PA)	28,949
West Branch Susquehanna River	67,673

Conodoguinet Creek	68,783
West Conewago Creek	50,000

The production goal of 10 million larvae was not met, primarily due to fewer eggs shipped from the Hudson River.

10.2 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.

Geometric mean catch-per-unit effort (CPUE) was calculated as an index of juvenile abundance for haul seine and lift net 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 collects juvenile shad during the directed outmigration, (AUC) measures of juvenile abundance were also calculated for lift net collections.

10.2.1 Haul Seining – Main Stem

Haul seining in the lower Susquehanna River was scheduled once each week beginning mid-July and continuing through October. Fifteen weekly sampling events were conducted in 2007. Sampling was concentrated near the Columbia Borough boat launch since this location proved very productive in past years. 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.

10.2.2 Holtwood Dam, Peach Bottom Atomic Power Station, and Conowingo Dam

Sampling at the Holtwood Dam inner fore-bay began on September 11 and continued every third day through December 7, 2007. A total of 30 sampling events was planned for 2006, but by early December it was apparent from the low collection numbers that further sampling efforts were not warranted. Therefore, the program was terminated after completion of 27 of the 30 scheduled events.

Sampling at the Holtwood Dam inner fore-bay was conducted using a fixed 8-ft square lift-net. Sampling began at sunset and consisted of 10 lifts with a 10-minute interval between lift cycles. The lift-net was placed on the north side of the coffer cell in the inner fore-bay. A lighting system was used to illuminate the water directly over the lift-net similar to that employed in previous years.

Intake screens were monitored for impinged alosines at Peach Bottom APS in 2007. Intake screen sampling was conducted daily, (Monday through Friday), from 22 October to 30 November, 2007. Twenty-seven 24-hour sampling events were conducted during the outmigration period. Conowingo Hydroelectric Station's cooling water intake strainer sampling was conducted twice weekly (Monday and Friday) from 15 October through 30 November 2007. Sampling generally occurred twice weekly during this period for a total of 13 sampling events.

10.2.3 Susquehanna River Mouth and Flats

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

10.2.4 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 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.

10.3 RESULTS

10.3.1 Haul Seining – Main Stem

Two juvenile American shad were captured by haul seine; both were of wild (untagged) origin. One was collected on July 24, the other on July 31 (Figure 1). The Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) was 0.02 (Tables 1 and 2). Table 3 lists weekly catches of American shad by haul seine from 1989 to 2007. Catches generally peaked in August and September, except in 1989 and 1992 when catches peaked in July, and in 2005 -2007 when there was no peak.

10.3.2 Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner fore-bay resulted in no juvenile American shad captured in 270 lifts (Table 4). Geometric Mean CPUE (individual lift) and GM CPUE (combined daily) were 0.00 (Table 5). Area under the curve (AUC) was also 0. Historical weekly catches peaked in October, except in 1985, 1997, 2000, and 2001 when catches peaked in November (Table 5, Figure 2).

Peach Bottom intake screens produced 19 juvenile American shad, one alewife and 6 blueback herring between October 23 and November 28 (Table 7).

Cooling water intake strainers at Conowingo produced 3 American shad, collected between 9 and 26 November (Tables 8 and 9). Three alewives and four blueback herring were collected in strainer samples in 2007.

10.3.3 Susquehanna River Mouth and Flats

In 2007, 1,122 juvenile American shad were captured at seven permanent sites and 322 juvenile American shad were captured at the auxiliary sites (Table 11).

10.3.4 Otolith Mark Analysis

Results of otolith analysis are presented in Table 12. A total of 24 juvenile American shad were collected in haul seines, lift nets, Peach Bottom intakes and Conowingo strainers. Of the 24 specimens evaluated for hatchery tags, 25% were wild and 75% were hatchery. Represented in the catch were YOY shad from releases in the Juniata River, Conodoguinet Creek, West Conewago Creek, and the West Branch Susquehanna River. No shad were recaptured from releases in the North Branch Susquehanna River (see Job III, Appendix 1 for a discussion of relative survival).

10.4 DISCUSSION

River conditions for the Susquehanna River Basin during 2007 could be characterized by stable and steadily decreasing flows culminating in drought conditions in August and September. Water temperatures at Conowingo Dam increased gradually from 54F on April 23 to 80F on May 31, with the exception of a three degree drop from May 17 to May 18. No stockings were postponed due to high water.

Fish passage at Conowingo Dam continued its six –year downward trend with only 25,464 shad passed. Fish passage efficiency at Holtwood (10,338) was better than average with 41% passage, based on counts at Conowingo and Holtwood (long-term mean = 34%). Fish passage at Safe Harbor (7,215) was 70%, close to the long-term mean of 73%, based on counts at Holtwood and Safe Harbor. Fish passage at York Haven (192) was 3%, lower than the long-term mean of 12%, based on counts at Safe Harbor and York Haven. Production of wild juvenile shad was, no doubt, negatively impacted by the low numbers of shad passed into spawning habitat above York Haven Dam.

10.4.1 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 2007, haul seine and lift net CPUE were among lowest ever recorded.

GM CPUE for haul seine (both individual lifts, and combined daily lifts, Table 2) was the second lowest value ever recorded for that gear type since 1990. GM CPUE for lift net collections (Table 5) in the Holtwood Dam forebay was 0.00, an all-time low, matching 2004. Juvenile shad abundance has been below normal for six consecutive years, a disturbing trend that may impact upstream fish passage counts during 2008 to 2012. 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. The poor catch rates in 2007 can be attributed to decreased egg deliveries, poor survival in the hatchery (see Job III), and poor fish passage.

10.4.2 Stock Composition and Mark Analysis

Hatchery contribution was 75% for all sites combined and exceeded wild contribution at nearly every collection site in 2007. Contribution of hatchery fish from Columbia, Peach Bottom and Conowingo was 0%, 89% and 50%, respectively.

10.5 SUMMARY

- Juvenile American shad were collected by haul seine at Columbia in cooling water intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam.
- Haul seine GM CPUE (combined daily lifts) of 0.02 was the second lowest recorded for that gear type since 1990.
- Lift-net GM CPUE (combined daily lifts) of 0.00 was the lowest recorded for that gear type for the period of record. Lift net AUC was the lowest recorded for the period of record.
- Otoliths from the four sites combined were 25% wild and 75% hatchery.
- Fewer eggs were delivered to the Van Dyke Hatchery, and hatchery survival was reduced, resulting in decreased production of hatchery larvae, and decreased production of juvenile American shad in the Susquehanna River basin.

10.6 ACKNOWLEDGMENTS

Normandeau Associates (Drumore, PA) was contracted by the PFBC to perform juvenile collections. Many individuals supplied information for this report. Keith Beamer and Alinson Antony processed shad otoliths.

10.7 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.

10.8 TABLES AND FIGURES

Table 1. Number of fish collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2007.

Date	18-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	5-Sep	12-Sep	18-Sep	25-Sep	3-Oct	10-Oct	16-Oct	23-Oct	Total
Daily Mean River Flow (cfs)	5,270	4,750	8,900	5,150	8,080	9,940	11,500	6,020	5,130	6,400	4,470	4,130	4,250	9,140	9,570	
Water Temperature (°C)	28.0	24.0	28.0	29.5	27.0	19.0	25.5	22.0	23.0	20.0	23.5	22.0	23.5	16.0	18.0	
Secchi Disk (in)	48	72	36	43	25	34	64	90	87	84	88	85	98	90	60	
American shad	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2
Gizzard shad	196	30	5	41	48	101	245	5	9	47	-	1	-	10	34	772
Common carp	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2
Golden shiner	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Comely shiner	3	3	-	2	6	3	-	1	-	1	-	-	-	-	2	21
Spottail shiner	-	-	2	-	1	-	6	-	-	-	-	1	-	-	-	10
Spotfin shiner	56	15	27	24	13	17	9	14	5	8	19	9	19	17	-	252
Mimic shiner	-	2	-	3	5	-	-	-	1	-	-	1	1	-	-	13
Bluntnose minnow	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	4
Fallfish	-	3	-	-	2	1	-	-	-	1	-	-	-	-	-	7
Quillback	20	4	2	-	1	1	4	-	10	-	-	-	7	-	3	52
Northern hog sucker	-	-	-	2	-	-	1	-	-	-	-	-	1	-	-	4
Channel catfish	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2
Banded killifish	-	-	-	1	1	-	3	-	-	-	-	-	-	-	-	5
Mosquitofish	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	5
Rock bass	-	1	-	-	-	1	1	1	1	1	-	-	-	1	1	8
Redbreast sunfish	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	5
Bluegill	-	-	-	-	-	-	-	2	4	2	13	-	3	3	3	30
Smallmouth bass	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
Tessellated darter	-	-	2	-	1	3	-	-	-	-	-	1	-	-	-	7
Walleye	-	-	1	1	-	-	7	-	-	-	1	-	2	-	-	12
Total	**275**	**60**	**41**	**74**	**79**	**127**	**277**	**23**	**30**	**62**	**46**	**13**	**35**	**31**	**44**	**1,217**
No. of Species	**4**	**9**	**8**	**7**	**10**	**7**	**9**	**5**	**6**	**8**	**6**	**5**	**7**	**4**	**6**	**22**

Table 2. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990 - 2007.

		Total				Wild			Hatchery		
Year	No. Hauls	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Haul CPUE*	No. Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	No. Fish	Mean Combined Daily CPUE (Hatchery)	GM Combined Daily CPUE (Hatchery)
1990	87	285	4.40	1.23	-	13	0.15	0.11	272	3.13	1.18
1991	144	170	1.01	0.54	-	80	0.48	0.35	90	0.63	0.21
1992	97	348	5.10	1.69	-	166	2.57	0.90	182	1.88	0.94
1993	111	235	1.99	1.27	-	174	1.61	1.01	61	0.55	0.28
1994	110	395	4.85	2.30	-	254	3.07	1.31	141	1.29	1.16
1995	48	409	8.92	7.89	-	58	1.29	1.06	351	7.30	6.85
1996	105	283	2.89	2.05	-	157	1.61	1.20	126	1.20	0.99
1997	90	879	9.77	6.77	3.36	136	1.51	1.24	743	8.26	5.65
1998	94	230	2.51	1.03	0.50	5	0.05	0.05	225	2.39	0.97
1999	90	322	3.58	1.16	0.67	13	0.15	0.13	309	3.43	1.06
2000	90	31	0.34	0.26	0.14	0	0.00	0.00	31	0.34	0.26
2001	90	377	4.19	3.04	1.52	119	1.32	1.25	258	2.87	2.14
2002	84	0	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00
2003	48	17	0.35	0.28	0.20	2	0.04	0.04	15	0.31	0.25
2004	66	25	0.38	0.25	0.17	0	0.00	0.00	25	0.38	0.25
2005	90	23	0.26	0.24	0.16	21	0.23	0.24	2	0.02	0.02
2006	66	1	0.02	0.01	0.01	0	0.00	0.00	1	0.02	0.01
2007	66	2	0.02	0.02	0.02	2	0.02	0.02	0	0.00	0.00

* Required by ASMFC

Table 3. Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River, 1989 through 2007

Month	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	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	250
24-31 Jul	45	31	-	-	0	60	24	15	22	144	1	0	42	0	0	*	0	*	2	386
1-7 Aug	-	0	0	20	0	24	29	32	14	30	1	2	70	0	*	*	5	0	0	227
8-15 Aug	61	0	0	2	8	13	35	56	20	0	0	6	37	0	*	0	1	0	0	239
16-23 Aug	7	69	0	16	0	46	40	43	171	9	0	1	36	0	0	*	2	0	0	440
24-31 Aug	-	-	-	-	13	-	42	39	120	10	10	0	36	0	8	16	2	0	0	296
1-7 Sep	-	25	12	-	20	-	43	34	129	3	*	0	23	0	5	5	3	*	0	302
8-15 Sep	-	97	16	-	41	75	65	4	135	3	264	0	31	0	4	4	0	0	0	739
16-23 Sep	-	28	30	-	27	14	46	12	59	4	17	0	15	0	0	*	1	0	0	253
24-30 Sep	-	0	73	-	11	5	15	15	32	0	20	1	34	0	*	*	2	0	0	208
1-7 Oct	-	0	69	2	22	5	19	10	91	3	1	0	6	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	60
16-23 Oct	-	-	5	-	-	10	-	-	14	0	5	0	0	*	*	0	3	1	0	38
24-31 Oct	-	-	0	0	-	-	0	0	-	-	-	-	0	0	*	0	*	-	-	0
1-7 Nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	0
8-15 Nov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0
TOTAL	**1,161**	**250**	**212**	**166**	**142**	**353**	**442**	**283**	**879**	**230**	**322**	**31**	**377**	**0**	**17**	**25**	**23**	**1**	**2**	**4,916**

* No sampling due to high river flow.

Table 4. Fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 2007

Date:	11 Sep	14 Sep	17 Sep	20 Sep	23 Sep	26 Sep	29 Sep	02 Oct	05 Oct	08 Oct	11 Oct	14 Oct	17 Oct	20 Oct	23 Oct	26 Oct
Water Temp (°C):	26.0	25.0	23.5	22.5	22.0	22.5	22.5	22.0	22.5	22.5	22.0	21.0	19.3	17.0	18.8	17.5
Secchi (in):	48	33	75	52	54	50	53	38	42	40	35	50	48	46	43	40
River Flow (cfs):	6,260	4,520	6,740	5,450	5,130	4,480	4,660	4,100	2,980	4,380	3,870	6,170	9,250	8,620	9,580	15,400
Start Time (hr):	1848	1829	1845	1851	1845	1815	1823	1820	1800	1800	1804	1800	1800	1751	1750	1732
End Time (hr):	2013	2002	2000	2002	2000	1940	1930	1940	1940	1940	1855	1935	1915	1914	1909	1913
Gizzard shad	1	252	100	1	-	-	-	-	-	5	5	2	34	21	11	7
Comely shiner	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Spottail shiner	-	8	6	-	-	-	-	1	-	-	-	-	-	-	-	-
Spotfin shiner	1	3	-	-	1	1	-	8	-	-	-	-	1	-	-	-
Mimic shiner	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Total	**2**	**266**	**109**	**2**	**1**	**1**	**0**	**9**	**0**	**5**	**5**	**2**	**35**	**21**	**11**	**7**
No. of Species	**2**	**5**	**3**	**2**	**1**	**1**	**0**	**2**	**0**	**1**	**1**	**1**	**2**	**1**	**1**	**1**

Date:	29 Oct	01 Nov	04 Nov	07 Nov	10 Nov	13 Nov	16 Nov	19 Nov	21 Nov	25 Nov	28 Nov	01 Dec	04 Dec	07 Dec		
Water Temp (°C):	15.5	13.5	12.5	10.5	9.5	9.5	8.5	6.8	6.5	6.8	6.5	5.0	3.0	1.0		
Secchi (in):	30	36	47	44	55	69	47	43	40	60	48	30	20	40		
River Flow (cfs):	27,400	24,100	14,800	11,300	10,200	11,100	21,000	41,600	33,800	34,900	41,900	57,800	35,700	36,100		
Start Time (hr):	1742	1710	1634	1620	1600	1605	1611	1607	1632	1556	1555	1603	1604	1606		
End Time (hr):	1848	1849	1818	1738	1755	1737	1740	1722	1754	1715	1726	1715	1720	1716	**TOTAL**	**%**
Gizzard shad	12	63	173	-	30	687	8	3	28	-	4	1	1	-	1,449	97.4
Comely shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	0.3
Spottail shiner	-	1	-	-	-	-	-	-	-	-	-	-	-	-	16	1.1
Spotfin shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	1.0
Mimic shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.1
Bluegill	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	0.1
Total	**12**	**64**	**173**	**0**	**31**	**687**	**8**	**3**	**28**	**0**	**4**	**1**	**1**	**0**	**1,488**	**100.0**
No. of Species	**1**	**2**	**1**	**0**	**2**	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**1**	**0**	**6**	

Table 5. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2007

		Total					Wild				Hatchery			
Year	No. Lifts	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Lift CPUE*	Area under curve AUC	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	Area under curve AUC	No. Hatchery Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	Area under curve AUC
1985	378	3,626	20.3	7.5		1423								
1986	404	2,926	10.3	5.7		917								
1987	428	832	3.2	1.9		182								
1988	230	929	3.9	1.3		255								
1989	396	556	0.5	0.3		60								
1990	300	3,988	13.3	3.4		1060	70	0.2	0.2	17	3,918	13.1	3.6	1043
1991	290	208	0.7	0.5		72	19	0.1	0.1	7	189	0.7	0.5	66
1992	300	39	0.1	0.1		14	14	0.0	0.0	5	25	0.1	0.1	9
1993	300	1,095	3.7	1.3		383	669	2.8	0.6	234	426	1.4	0.6	149
1994	300	206	0.7	0.4		71	35	0.1	0.1	12	171	0.6	0.3	59
1995	115	1,048	9.1	1.3		802	83	0.7	0.3	59	965	8.4	1.2	744
1997	300	1,372	4.6	0.9	0.6	412	100	0.3	0.2	30	1,272	4.2	0.9	382
1998	300	180	0.6	0.4	0.2	53	9	0.0	0.0	3	171	0.6	0.4	50
1999	300	490	1.6	0.8	0.5	147	19	0.1	0.1	6	471	1.6	0.8	141
2000	300	406	1.4	0.6	0.2	122	4	0.0	0.0	1	402	1.3	0.6	121
2001	299	1,245	4.2	1.4	0.4	322	538	1.8	0.4	135	707	2.4	1.0	186
2002	300	68	0.2	0.1	0.1	20	15	0.1	0.0	5	53	0.2	0.1	16
2003	300	61	0.2	0.1	0.1	18	3	0.0	0.0	1	58	0.2	0.1	17
2004	240	0	0.0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0
2005	300	200	0.7	0.1	0.1	60	47	0.2	0.1	14	153	0.5	0.1	46
2006	230	8	0.0	0.03	0.01	2	0	0.0	0.0	0	8	0.0	0.0	2
2007	270	0	0.0	0.00	0.00	0	0	0.0	0.0	0	0	0.0	0.0	0

* Required by ASMFC

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

Table 6. 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*

	Year																						
Week	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Mean**
1-7 Aug	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
8-15 Aug	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-		0.0
16-23 Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-	-		0.0
24-31 Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-	-		0.0
1-7 Sep	-	-	-	0.0	-	0.0	0.0	0.0	0.0	-	0.0	-	-	-	-	-	-	-	-	-	-		0.0
8-15 Sep	-	-	1.3	-	-	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.00	0.1
16-23 Sep	-	-	0.7	-	2.3	0.0	0.0	0.1	0.0	0.0	-	0.0	0.0	6.7	0.0	0.0	-	0.0	0.0	0.0	0.0	0.00	0.6
24-30 Sep	-	-	0.3	-	-	7.6	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.5
1-7 Oct	-	-	0.9	0.0	1.2	3.9	0.1	0.9	0.2	4.3	0.1	0.0	0.1	4.7	0.0	0.5	0.0	1.3	0.0	0.0	0.0	0.00	0.9
8-15 Oct	-	16.7	4.1	0.1	1.2	6.9	0.1	0.0	0.2	3.6	0.0	0.0	0.8	3.7	0.0	0.1	0.0	0.5	0.0	0.0	0.0	0.00	1.8
16-23 Oct	0.1	30.3	4.5	0.0	3.2	65.1	0.6	0.5	0.1	0.8	5.1	0.0	2.1	1.9	0.2	0.1	3.3	0.3	0.0	0.0	0.0	0.00	5.4
24-31 Oct	1.0	5.4	1.3	10.0	0.5	43.6	0.9	0.5	17.5	0.2	68.9	0.2	2.5	0.5	1.2	0.9	0.0	0.0	0.0	6.7	0.2	0.00	7.4
1-7 Nov	41.6	5.3	4.8	19.1	0.0	5.3	1.1	0.0	14.8	0.7	56.1	0.0	1.1	0.0	1.5	1.9	0.0	0.0	0.0	0.0	0.0	0.00	7.0
8-15 Nov	28.6	4.1	4.5	2.0	0.0	0.5	2.4	0.0	19.0	0.1	9.3	25.1	0.1	0.0	2.8	7.3	0.0	0.0	0.0	0.0	0.0	0.00	4.8
16-23 Nov	10.8	19.5	0.3	0.3	0.0	0.2	0.5	0.0	1.6	0.0	0.0	27.1	0.1	0.0	7.2	6.7	0.0	0.0	0.0	0.0	-	0.00	3.5
24-30 Nov	36.4	6.3	0.7	0.4	-	0.0	1.2	-	0.1	0.0	0.0	1.5	0.1	0.0	1.9	2.8	0.0	0.0	0.0	0.0	-	0.00	2.7
1-7 Dec	62.8	14.2	0.0	0.0	-	-	-	-	-	0.0	-	0.0	0.0	0.0	0.0	23.4	0.0	0.0	0.0	-	-	0.00	7.2
8-15 Dec	4.3	0.1	-	-	-	-	1.2	-	-	-	-	-	0.6	0.0	0.0	-	0.0	0.0	-	-	-		0.8
16-23 Dec	0.5	0.0	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0.2
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	68	61	0	200	8	0	
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	300	300	260	300	240	270	230	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	0.26	0.20	0.00	0.74	0.03	0.00	

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

Table 7. Number of fish collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall 2007

Species	Unit 2	Unit 3	Total
Alewife	1	0	**1**
Blueback herring	5	1	**6**
American shad	9	11	**20**
Gizzard shad	70,819	79,497	**150,316**
Carp	1	1	**2**
Golden shiner	1	1	**2**
Comely shiner	2	4	**6**
Spottail shiner	1	1	**2**
Spotfin shiner	1	2	**3**
Quillback	2	1	**3**
Northern hogsucker	1	1	**2**
White catfish	0	1	**1**
Channel catfish	134	143	**277**
Flathead catfish	1	1	**2**
Rock bass	8	11	**19**
Green sunfish	9	12	**21**
Pumpkinseed	0	3	**3**
Bluegill	505	671	**1,176**
Smallmouth bass	3	1	**4**
Largemouth bass	1	2	**3**
White crappie	7	15	**22**
Black crappie	0	2	**2**
Yellow perch	0	1	**1**
Walleye	66	95	**161**
Tessellated darter	6	2	**8**
Greenside darter	1	0	**1**
Logperch	0	1	**1**
Crayfish	74	152	**226**
TOTAL	***71,658***	***80,633***	***152,291***

Table 8. Number of juvenile American shad collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall 2007.

Date	Unit 2	Unit 3	Total
23 Oct	1 (Adult)	0	**0**
29 Oct	0	1	**1**
02 Nov	0	1	**1**
13 Nov	0	1	**1**
19 Nov	2	0	**2**
20 Nov	2	4	**6**
21 Nov	2	3	**5**
27 Nov	2	0	**2**
28 Nov	0	1	**1**
TOTAL	***8***	***11***	***19***

Table 9. Species and number of fish collected during cooling water intake sampling at Conowingo Dam in Fall, 2007.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	3	0	3
Gizzard shad	10,886	30,077	40,963
Alewife	3	0	3
Blueback herring	3	1	4
Comely shiner	2	3	5
Channel catfish	4	1	5
Carp	3	0	3
White perch	1	0	1
Largemouth bass	1	0	1
White crappie	1	0	1
TOTAL	**10,907**	**30,082**	**40,989**

Table 10. Number of juvenile American shad collected during cooling water intake strainer sampling at Conowingo Dam in fall 2007

Date	Francis Units (7)	Kaplan Units (4)	Total
09 Nov	1	0	**1**
26 Nov	2	0	**2**
TOTAL	***3***	***0***	***3***

Table 11. Catch of juvenile American shad by location from the upper Chesapeake Bay during the 2007 Maryland DNR juvenile finfish haul seine survey

Permanent Sites

Location	Round 1	Round 2	Round 3	Totals
HOWELL PT.	4	24	8	36
TIMS CR	1	0	0	1
SASSAFRAS NRMA	17	15	2	34
PARLOR PT.	8	9	4	21
ELK NECK PARK	0	133	32	165
WELCH PT.	126	133	14	273
HYLAND PT.	254	194	144	592
Total	410	508	204	1122
Mean Catch Per Haul	**102.50**	**127.00**	**51.00**	

Auxiliary Sites

Location	Round 1	Round 2	Round 3	Totals
CARPENTER PT	25	8	2	35
POPLAR PT	no haul	no haul	no haul	
PLUM PT	37	71	140	248
SPOIL ISLAND	10	13	14	37
TYDINGS ESTATE	2	0	0	2
TOLCHESTER	0	0	0	0
Total	74	92	156	322
Mean	**14.80**	**18.40**	**31.20**	

Table 12. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2007.

		Immersion marks										
Collection Site	Coll. Date	Day 15, 18 Jun. R./ Susq. R.	Days 3,6,9,15 N. Br. Susq. R.(PA)	Days 3,6,9, 12,15 W. Br. Susq. R.	Days 3,9,12 15,18 W. Conewago	Days 3,6,12,15 Conodoguinet Cr.	Total Hatchery		Total Wild		Total Processed	Total Collected
Columbia	7/24/07	0.0	0.0	0.0	0.0	0.0	0.0		1.0		1	1
	7/31/07	0.0	0.0	0.0	0.0	0.0	0.0		1.0		1	1
Peach Bottom	11/2/07	1.0	0.0	0.0	0.0	0.0	1.0		0.0		1	1
Impingement	11/13/07	0.0	0.0	0.0	1.0	0.0	1.0		0.0		1	1
	11/19/07	2.0	0.0	0.0	0.0	0.0	2.0		0.0		2	2
	11/20/07	6.0	0.0	1.0	0.0	0.0	7.0		0.0		7	7
	11/21/07	4.0	0.0	0.0	0.0	0.0	4.0		1.0		5	5
	11/27/07	1.0	0.0	0.0	0.0	1.0	2.0		0.0		2	2
	11/29/07	0.0	0.0	0.0	0.0	0.0	0.0		1.0		1	1
Conowingo	11/8/07	0.0	0.0	0.0	0.0	0.0	0.0		1.0		1	1
Strainers	11/25/07	1.0	0.0	0.0	0.0	0.0	1.0		1.0		2	2
Holt./P. Bot./Con.		15.0	0.0	1.0	1.0	1.0	18.0	**	4.0	**	22.0	22.0
Percent		68.2%	0.0%	4.5%	4.5%	4.5%	81.8%		18.2%			
Grand Total		15.0	0.0	1.0	1.0	1.0	18.0	**	6.0	**	24.0	24.0
Percent		62.5%	0.0%	4.2%	4.2%	4.2%	75.0%		25.0%			

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

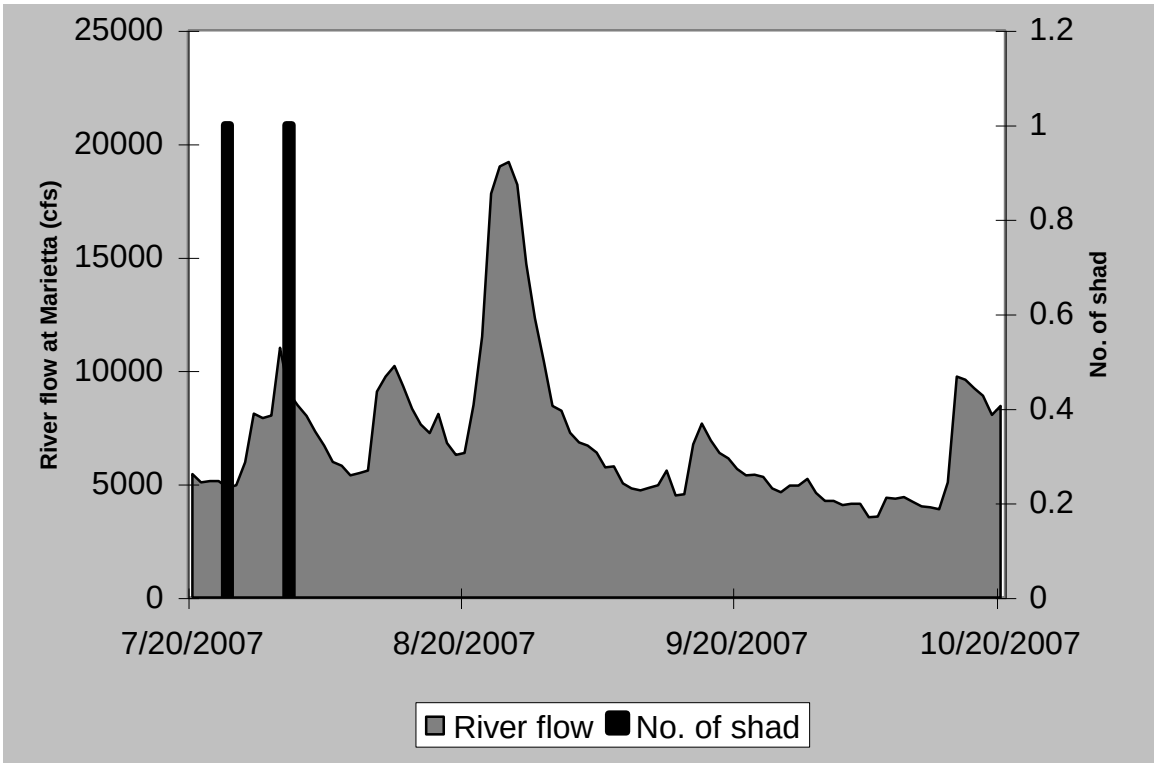

Figure 1. Number of American shad collected by haul seine and river flow, Susquehanna River, 2007

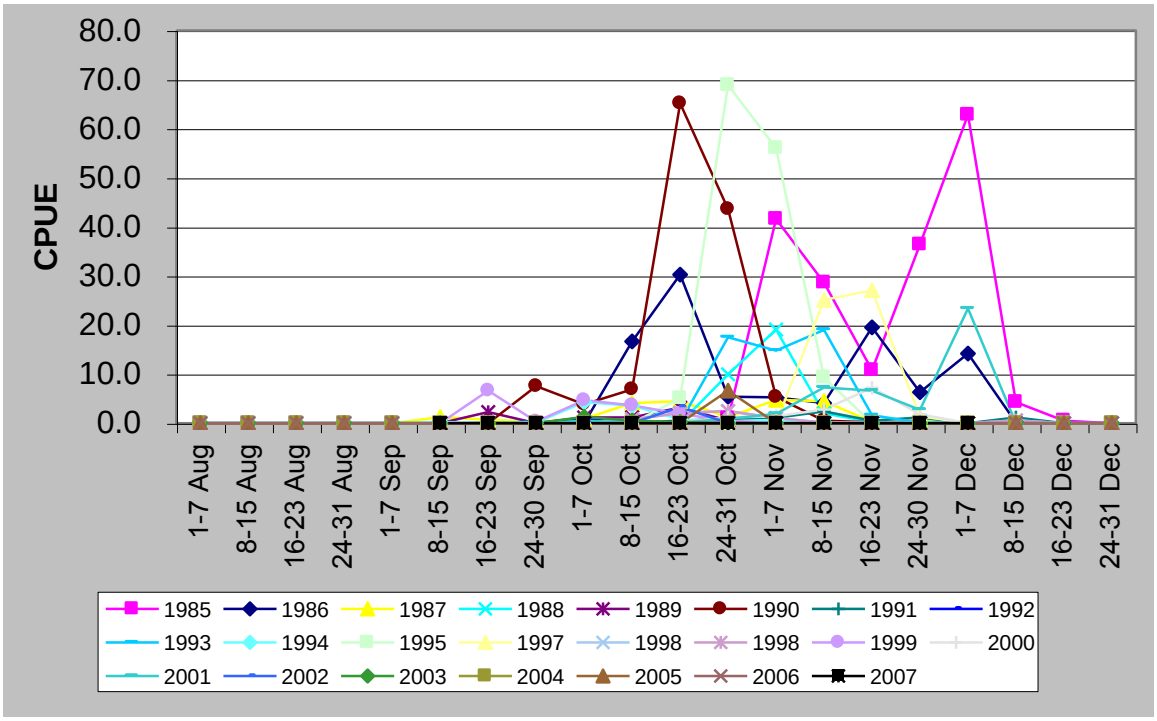

Figure 2. Annual YOY American shad CPUE for lift net collections in the Holtwood Dam forebay

11.0 JOB 5, TASK 1: ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 2007

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11.1 ABSTRACT

A total of 158 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2007. Based on tetracycline marking and otolith microstructure, 52% of the 155 readable otoliths were identified as wild and 48% 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 1986-2001 year classes, stocking of approximately 3-6 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 1.31 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.

11.2 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.

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.

11.3 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. In addition, adult American shad were collected in the upper Chesapeake Bay by Maryland DNR, processed by MDNR staff and are not reported here.

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 2007. Age composition data was gathered as follows: for 1996 to 2007, 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.

11.4 RESULTS AND DISCUSSION

A total of 158 shad was sacrificed for otolith analysis from Conowingo Dam in 2007. Of these, 85 were West Lift sacrifices and 73 were from tank-spawn trials. No samples were collected from the East Lift since it was operated in fish passage mode. There were three unreadable otoliths (Table 1). A total of 81 (52%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 70 (45%) fish exhibited tetracycline marks including single, triple, quadruple and quintuple marks. One fish exhibited a double mark on days 3 and 6 suggesting it was missing a third mark on day 9 or it was a stray from Maryland, Virginia or North Carolina. Three fish (2%) exhibited hatchery microstructure, but marks were not present or unreadable due to inexperience in grinding. 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 1989-2007 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish showed an increasing trend from 1989 to 2000 and have decreased since 2000 (Figure 2). This is consistent with the coastwide depression of American shad stocks documented in the ASMFC stock assessment (ASMFC 2007).

Length frequencies, age frequencies, mean total length, and mean weight are detailed in Tables 3 to 7. In general, age, length and weight increased from 1993 to 2003, decreased from 2004 to 2006, and increased again in 2007. Increases in size in 2007 were related to the scarcity of younger fish. Age distributions were similar for wild and hatchery fish. Sex ratios (Table 8) have ranged from 7:10 to 23:10 (males: females) with no trend over time.

Tables 9 and 10 detail age and repeat spawning for otolith and scale ages. Repeat spawning has been highly variable, ranging from 1% in 2001 to 43% in 2005, however, determination of repeat spawning is an inexact science.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 11, while percent virgin by year and age is presented in Table 12. 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 2000 are

not fully recruited and are not included in the analysis. For the period 1986-2000, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 68 to 724, with a mean of 314 (Table 13). L/A was highest (477-724) for the early cohorts (1986 – 1989). During 1990 to 2001, L/A improved to 68-446, presumably due to improvements in fish culture practices.

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 14). For the period 1986-2001, 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 15). For the period 1986 to 2001, transport of an average of 1.31 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 16. 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 2001 are not yet fully recruited.

Adult relative survival for individual stocking sites was highly variable between cohorts (Table 16). For example, relative survival for the Juniata River/Juniata or middle Susquehanna sites ranged from 0.12 to 1.00. For the North Branch Susquehanna River the range was from 0.00 to 0.46. For West Conewago Cr., relative survival ranged from 0.00 to 1.00. For Swatara Cr., relative survival ranged from 0.00 to 0.56. For Conodoguinet Creek, relative survival ranged from 0.00 to 1.00. Conodoguinet Creek exhibited the highest survival for the 1997 cohort and a very high relative survival for the 1996 and 1999 cohorts (0.83 and 0.88, respectively). Both adult and juvenile relative survival rates were consistently poor for the West Branch Susquehanna River until 2002 when they were 0.68 and 0.54, respectively. This may be reflective of recent water quality improvements associated with mine drainage abatement projects.

Stocking site/cohort specific relative survival of juvenile shad was correlated to that for adult shad (Figure 3) but the relationship was not significant ($p=0.167$). This result is counter-intuitive since it is logical to assume that groups which exhibited better survival as juveniles would also exhibit better survival as adults. Either survival to the juvenile stage has no strong relationship to survival to adulthood, one of the recapture samples are not representative of the population, or errors in aging resulted in incorrect partitioning of the lift catch which had the effect of randomizing the data. It is difficult to believe that stocking site carries with it some survival advantage (or disadvantage) which is expressed between the Fall outmigration, when juveniles are recaptured, and the Spring spawning migration, when returning adults are recaptured several years later. It is equally unlikely that the Conowingo Fish Lifts select for or against adult shad based on the site where they were stocked. It seems more likely that collections of juveniles at Holtwood, Peach Bottom and Conowingo somehow select for or against fish based on stocking site, however the mechanism by which that occurs is not known. Perhaps distance between the stocking site and juvenile recapture site, coupled with river flow and migration rate are somehow interacting to produce a recapture sample that is not representative of the population. Errors in otolith aging certainly occur and can be as much as 60 to 80% (McBride et al. 2005). Aging errors, coupled with small sample size in some of the recapture groups (Table 16) could explain the lack of correlation between juvenile and adult survival.

It is interesting that a similar phenomenon was detected when analyzing recaptures of shad marked according to egg source river. For the 1989 to 1994 cohorts, relative survival of juveniles from Hudson River source larvae was always 1.00, while relative survival of Delaware River source larvae ranged from 0.06 to 0.83 with a mean of 0.29 (Hendricks, 2001). Clearly, Hudson River source juveniles were recaptured at a much higher rate than Delaware River source juveniles. When recapture rates of adults at the Conowingo Fish Lifts were analyzed, the trend was reversed. Relative survival of Delaware source adults ranged from 0.83 to 1.00 with a mean of 0.96, compared to a range of 0.29 to 1.00 and a mean of 0.75 for Hudson River adults. This analysis was also dependent upon correct aging. It is possible that aging errors were the cause of both of these anomalous observations. For this reason, marking protocols for 2004 and beyond included an alternating marking scheme to provide known age specimens (see Job III).

11.5 LITERATURE CITED

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

Washington, D.C. August 2007.

Hendricks, M.L. 1996. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1995. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. 1997. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1996. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1996. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. 1998. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1997. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1997. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. 1999. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1998. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1998. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2001. Job V, Task 2. Analysis of adult American shad otoliths. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2000. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.W.H. Backman, and D.L. Torsello. 1991. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad in the Susquehanna River. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1990. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1986. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1987. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management. 11: 212-219.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1992. American shad hatchery operations, 1991. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1991. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. and T.R. Bender, Jr. 1993. American shad hatchery operations, 1992. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1992. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. and T.R. Bender, Jr. 1995. American shad hatchery operations, 1994. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., D. L. Torsello, and T.W.H. Backman. 1994. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad (Alosa sapidissima) in the Susquehanna River. North American Journal of Fisheries Management.

Lorson, R.D. and V.D. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. N. Am. J. Fish. Mgmt. 7:453-455.

McBride, R.S., M. L. Hendricks, and J. E. Olney. 2005. Testing the validity of Cating's (1953) method for age determination of American shad using scales. Fisheries 30(10):10-18.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxberry Press, Belmont, California 730 p.

Young, L.M. 1987. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

11.6 TABLES AND FIGURES

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2007. One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis

		Conowingo Dam	
Conowingo Dam		N	%
Wild Microstructure, No TC Mark		81	52%
Hatchery Microstructure			
No TC Mark*		3	2%
Single TC Mark	Day 3 or 5	28	18%
Double TC Mark	Days 3,6 or 3,7**	1	1%
Triple TC Mark	Days 3,6,9	34	22%
	Days 5,9,13		0%
	Days 3,13,17		0%
	Days 3,9,12	2	1%
	Days 9,12,15		0%
Quadruple TC Mark	Days 5,8,13,17		0%
	Days 3,6,9,12		0%
	Days 3,6,9,15	1	1%
	Days 3,9,12,15	2	1%
Quintuple TC Mark	Days 3,6,9,15,18	1	1%
	Days 3,6,9,12,18	2	1%
	Days 3,6,12,15,18		0%
	Total Hatchery	74	48%
	Total readable otoliths	155	
	Unreadable Otoliths***	3	
	Total	158	

*Includes poor grinds and otoliths with autofluoresence obscuring mark.

**Could be 3,6,9 with d9 tag missing or stray

***Includes missing, broken and poorly ground otoliths.

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

		Hatchery									
	Sample:	Larvae									
	One			below					Naturally		Total
	in	Susquehanna		Conowingo Dam		Fingerling		Unmarked**	reproduced		sample
Year	??	N	%	N	%*	N	%*	N	N	%	size
1989	50	36	82*	-		-		94	29	18	159
1990	100	49	73*	1	1	-		42	32	26	124
1991	100	111	67*	8	5	3	2	63	68	27	253
1992	100	154	73*	8	4	2	1	19	54	23	237
1993	100	76	64*	21	18	2	2	4	21	17	124
1994	100	217	81*	22	8	3	1	17	28	10	287
1995	100	255	77*	19	6	4	1	1	52	16	331
1996	100	180	48*	22	6	4	1	1	172	45	379
1997	50	84	34	12	5	4	2	0	150	60	250
1998	50	29	22	7	5	2	2	0	92	71	130
1999	50	90	48	9	5	1	1	0	88	47	188
2000	50	78	40	11	6	0	0	0	104	54	193
2001	50	120	58	9	4	0	0	0	79	38	208
2002	50	118	65	2	1	0	0	0	62	34	182
2003	50	146	74	0	0	0	0	0	50	26	196
2004	50	113	72	0	0	0	0	0	45	28	158
2005	50	176	64	2	1	0	0	0	96	35	274
2006	50	89	50	0	0	0	0	0	88	50	177
2007	50	71	47	1	1	0	0	3	81	52	156
Totals		2,192	60	154	4	25	1	244	1,391	35	4,006

*Unmarked hatchery fish distributed among groups based on annual percentage.
**Distinguished from naturally-reproduced fish by otolith microstructure.

Table 3. Length-frequency of American shad collected in the Susquehanna River at the Conowingo West Fish Lift, 1993-2007.

Males

TL - mm	1993	1994	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006	2007
250		no										1			
275		data													
300	2														
325	3		1												
350	17		1	2			1					2	2		
375	17		18	11	12	1	8		1	2		5	2	6	
400	18		31	45	48	6	13	7	4	11	8	2	18	9	11
425	27		80	56	47	13	40	32	5	5	12	14	26	21	20
450	6		107	44	34	26	22	55	20	9	27	15	33	21	11
475			71	32	24	19	15	27	34	14	24	19	31	12	7
500			18	13	6	2	4	12	20	24	12	12	11	4	5
525			4	9	1	1	1	3	1	8		3	4	1	
550			2	2						2		1			
575											2				
600															
625				1											
650															
675															
Total	90		333	215	172	68	104	136	85	75	85	74	127	74	54

Females

TL - mm	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
250		no													
275		data													
300															
325															
350			1												
375	3		1	2			1								1
400	9			2	2								2		
425	7		2	1	3		3					1	1	5	
450	7		6	11	4	4	12	3	3	1	5	4	6	10	6
475	14		64	28	28	11	20	14	16	4	11	10	19	28	25
500	4		91	36	20	27	26	12	36	14	14	24	44	33	36
525	1		47	49	12	24	14	21	39	32	19	26	34	21	23
550			14	17	10	6	8	5	18	42	21	12	29	9	9
575			8	7	3		4	4	2	15	23	11	11		4
600			2							4	7		2		
625			1				1				1				
650															
675											1				
Total	45		237	153	82	72	89	59	114	112	101	88	148	106	104

Table 3. Length-frequency of American shad collected in the Susquehanna River at the Conowingo West Fish Lift, 1993-2007 (continued).

Sexes Combined

TL - mm	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
250		No										1	0		
275		data													
300	2														
325	3		1												
350	17		2	2			1					2	2		
375	20		19	13	12	1	9		1	2		5	2	6	1
400	27		31	47	50	6	13	7	4	11	8	2	20	9	11
425	34		82	57	50	13	43	32	5	5	12	15	27	26	20
450	13		113	55	38	30	34	58	23	10	32	19	39	31	17
475	14		135	60	52	30	35	41	50	18	35	29	50	40	32
500	4		109	49	26	29	30	24	56	38	26	36	55	37	41
525	1		51	58	13	25	15	24	40	40	19	29	38	22	23
550			16	19	10	6	8	5	18	44	21	13	29	9	9
575			8	7	3		4	4	2	15	25	11	11		4
600			2							4	7				
625			1	1			1				1				
650															
675											1				
Total	135		570	368	254	140	193	195	199	187	187	162	273	180	158

*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, 1995-2007.

Wild Males

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
2		3										1	
3	2	54	33	1	11	12	2	6	2	8	4	1	1
4	25	41	58	27	22	48	12	3	8	5	30	20	12
5	8	15	5	17	8	8	11	7	7	6	10	17	5
6	2		3			2	2	3	5	2	4	5	5
7									1	3			
8										1			
9													
??	2	8									1		
Total	37	121	99	45	41	70	27	19	23	25	49	44	23
Mean Age	4.3	3.4	3.8	4.4	3.9	4.0	4.5	4.4	4.8	4.6	4.2	4.5	4.6

Hatchery Males

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
2		1											
3	9	25	28	3	8.0	7	2	10	2	5	3	4	
4	50	29	24	9	40	37	17	12	41	7	32	12	13
5	74	32	12	10	8	17	31	24	10	27	18	10	11
6	12	1	2		2	3	5	6	12	6	18	2	4
7	2	2						2	1	2	3		
8					1				1		1		
9								1					
??	5	2	2		1			1	2				
Total	147	92	68	22	60	64	55	56	69	47	75	28	28
Mean Age	4.6	4.1	3.7	4.3	4.1	4.3	4.7	4.4	4.4	4.9	4.9	4.4	4.7

Wild Females

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
2													
3		3	2			1					1		
4	4	20	23	8	14	11	11	5	4	1	9	5	5
5	7	14	16	28	22	13	27	14	7	9	11	33	21
6	2	6	9	9	8	6	10	18	11	3	18	3	26
7				1	1			4	4	5	3	2	1
8								1		1	3		1
9											1		
??		6			2			1			1		
Total	13	49	50	46	47	31	48	43	26	19	47	43	54
Mean Age	4.8	4.0	4.6	5.1	4.7	4.8	5.0	5.4	5.6	5.8	5.4	5.0	5.5

Hatchery Females

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
2			1										
3									1		1		
4	10	24	5	4	10	2	7	8	8	4	9	9	5
5	79	60	11	6	24	14	29	29	23	34	22	33	8
6	26	10	12	5	5	8	24	24	33	13	53	11	31
7	7	5	2		1	2	4	5	9	13	13	6	1
8								2	1	1	1	1	1
9												1	
10													
11											1		
??	5	6	1		2			1			1		
Total	122	105	32	15	42	26	64	69	75	65	101	61	46
Mean Age	5.2	4.7	5.1	5.1	4.7	5.4	5.4	5.4	5.6	5.6	5.6	5.3	5.7

Table 5. Mean total length and weight of adult American shad collected at the Conowingo Dam West Fish Lift, 1993-2007

Males	1993	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006	2007
N	90	333	215	172	68	104	136	85	75	95	74	127	74	54
Total Length (mm)	404	456	452	441	461	445	465	479	481	474	463	458	450	451
SD	36	33	41	32	26	32	26	28	44	36	48	35	33	31
N		333	208	172	68	104	136	86	75	95	75	127	74	54
Weight (g)		889	808	797	783	739	862	912	1041	1032	947	907	860	859
SD		205	227	187	149	145	169	180	303	293	255	228	197	205
Females														
N	45	237	156	82	62	89	59	114	112	102	88	148	106	106
Total Length (mm)	457	513	507	509	519	478	493	524	550	547	528	526	507	514
SD	37	32	79	38	27	40	32	25	27	44	34	35	31	31
N		237	150	82	62	89	59	114	112	101	88	148	106	106
Weight (g)		1371	1413	1441	1295	1201	1346	1372	1618	1735	1474	1508	1311	1424
SD		284	292	349	261	251	292	215	347	443	315	333	307	289
Combined														
N	135	624	371	254	130	193	195	199	187	197	163	277	180	160
Total Length (mm)	422	479	475	463	489	474	483	505	523	512	498	495	483	493
SD	44	43	66	47	39	47	39	34	49	54	52	49	42	43
N		624	358	254	130	193	195	200	187	196	164	277	180	160
Weight (g)		1090	1062	1005	1027	966	1026	1174	1387	1394	1232	1229	1125	1233
SD		342	394	392	331	318	327	304	434	516	390	416	347	376

Table 6. Mean total length (mm) at age for American shad collected at the Conowingo Dam West Fish Lift, 1995-2007.

Otolith age	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006	2007
Male													
2		392										442	
3	410	424	416	431	420	454	478	419	429	366	411	394	432
4	445	463	447	454	443	460	465	471	458	387	441	442	439.4
5	466	484	488	473	472	488	486	502	488	430	474	460	451.2
6	477	526	481		482	515	494	527	512	444	496	483	483.8
7	529	492					480	509	510	477	492		
8					509				512	410	510		
9								536					
Female													
2			426										
3			442						450		405		
4	492	504	486	491	499	500	506	528	489	445	488	494	498.4
5	511	526	515	521	508	526	521	547	540	461	521	501	509.3
6	515	473	538	539	521	541	537.5	554	560	486	531	522	521
7	566	533	560	495	540	549	537	580	579	495	549	535	527.7
8								579	570	498	571	537	443
9											620	573	
10													
11											575		

Scale age	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006	2007
Male													
2												442	
3						453	447	418	440	366	424	397	423
4						463	481	470	467	397	443	445	438.9
5	scales not read					488	488	502	495	434	472	468	470
6						516	500	522	518	448	495	475	485.3
7								509		477	493		510
8										410			
9													
Female													
2													
3						461	510		470		405		
4						512	511	528	508	450	490	491	491.3
5						518	527	545	545	461	522	503	504.9
6	scales not read					550	548	554	577	490	531	533	532.8
7						587	551	580	600	494	550	534	566
8								568	570	498	571	573	
9									620		620		
10													
11											575		

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

Table 7. Mean weight (g) at age for American shad collected at the Conowingo Dam West Fish Lift, 1995-2007.

Otolith age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Male													
2		546										630	
3	610	662	667	614	642	838	949	669	740	590	608	557	780
4	840	869	834	750	717	828	831	986	919	834	797	811	777
5	936	967	1022	861	855	983	956	1126	1090	1025	982	921	885
6	1022	1220	1018		885	1195	1009	1413	1336	1094	1160	1047	1072
7	1293	970					795	1280	1335	1402	1237		
8					1130				1180	1020	1270		
9								1380					
Female													
2			1400										
3			950						1000		673		
4	1162	1344	1233	1012	1154	1227	1247	1383	1216	1250	1242	1253	1212
5	1343	1440	1524	1311	1234	1425	1340	1619	1726	1345	1437	1248	1380
6	1418	1513	1647	1474	1382	1495	1496	1657	1817	1572	1555	1468	1494
7	1826	1321	1695	1210	1500	1885	1460	1841	1989	1739	1740	1589	1517
8								1675	2080	1715	1613	1605	1195
9											2470	2050	
10													
11											1900		

Scale age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Male													
2												630	
3						809	728	670	810	600	703	564	695
4						840	923	960	967	869	814	830	769
5			scales not read			1018	983	1155	1196	1047	976	962	1005
6						1128	1060	1333	1365	1106	1161	1024	1059
7								1280		1402	1170		1304
8										1020			
9													
Female													
2													
3						915	1355		1103		673		
4						1322	1284	1391	1406	1297	1276	1219	1150
5						1369	1399	1590	1732	1347	1442	1252	1356
6			scales not read			1562	1638	1690	1946	1610	1552	1618	1602
7						2230	1080	1726	2218	1722	1721	1486	1940
8								1703	2080	1715	1613	2050	
9									2550		2470		
10													
11											1900		

Table 8. Sex ratio of American shad collected at the Conowingo Dam West Fish Lift, 1993-2007.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Male:Female	20:10	no data	15:10	8:10	19:10	9:10	9:10	23:10	7:10	12:10	9:10	12:10	9:10	7:10	5:10

Table 9. Otolith age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2007.

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%

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%

Table 9. (continued).

Sexes Combin	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%

Table 10. Scale age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2007.

Male	Scale Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		37	70	22	2						131	
Repeats	0		37	65	14	1						117	89%
	1			5	4	1						10	8%
	2				4							4	3%
2001	N		10	45	24	1						80	
Repeats	0		10	45	23	1						79	99%
	1				1							1	1%
	2											0	0%
2002	N		15	17	25	13	2					72	
Repeats	0		15	12	10	5						42	58%
	1			5	12	4						21	29%
	2				3	4	2					9	13%
2003	N		17	44	20	10						91	
Repeats	0		17	41	20	9						87	96%
	1			3		1						4	4%
	2											0	0%
2004	N		13	20	28	7	5	1				74	
Repeats	0		13	18	23	6	3	1				64	86%
	1			2	5	1	1					9	12%
	2						1					1	1%
2005	N		9	64	31	19	0	0	0	0	0	123	
Repeats	0		9	45	20	7						81	66%
	1			19	7	7						33	27%
	2				4	5						9	7%
	3					2	1					3	2%
	4											0	0%
2006	N		7	36	25	5	0	0	0	0	0	73	
Repeats	0	1	7	35	16	4						63	86%
	1			1	7							8	11%
	2				2	1						3	4%
	3											0	0%
	4											0	0%
2007	N		3	33	14	4	1	0	0	0	0	55	
Repeats	0		3	24	10							37	67%
	1			9	2	1	1					13	24%
	2				2	2						4	7%
	3					1						1	2%
	4											0	0%

Table 10. (continued).

Female	Scale Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		2	16	24	15	1					58	
Repeats	0		2	14	17	11						44	76%
	1			2	3	1						6	10%
	2				4	2						6	10%
	3					1						1	2%
	4						1					1	2%
2001	N		1	35	54	11	1					102	
Repeats	0		1	35	54	11	1					102	100%
	1											0	0%
	2											0	0%
2002	N			15	45	39	9	2				110	
Repeats	0			12	22	18	4	1				57	52%
	1			3	19	16	5					43	39%
	2				4	5		1				10	9%
2003	N		5	18	43	28	5	1	1			101	
Repeats	0		5	17	36	23	5	1				87	86%
	1			1	4	1			1			7	7%
	2				3	4						7	7%
2004	N			40	82	142	46	12				322	
Repeats	0			39	77	139	39	10				304	94%
	1			1	4	2	4					11	3%
	2				1	1		1				3	1%
	3						3					3	1%
	4							1				1	0%
2005	N		2	19	36	68	16	4	1	0	1	147	
Repeats	0		2	12	21	36	4	1				76	52%
	1			7	8	21	3	2				41	28%
	2				7	5	3	1	1		1	18	12%
	3					6	4					10	7%
	4						2					2	1%
2006	N		0	19	68	14	4	1	0	0	0	106	
Repeats	0			17	55	8						80	75%
	1			2	10	5	3					20	19%
	2				3		1					4	4%
	3					1		1				2	2%
	4											0	0%
2007	N		0	13	51	37	2	0	0	0	0	103	
Repeats	0			13	31	19	1					64	62%
	1				11	5	1					17	17%
	2				9	9						18	17%
	3					4						4	4%
	4											0	0%

Table 10. (continued).

Sexes Combin	Scale Age	2	3	4	5	6	7	8	9	10	11	Total	%
2000	N		39	86	46	17	1					189	
Repeats	0		39	79	31	12						161	85%
	1			7	7	2						16	8%
	2				8	2						10	5%
	3					1						1	1%
	4						1					1	1%
2001	N		11	80	78	12	1					182	
Repeats	0		11	80	77	12	1					181	99%
	1				1							1	1%
	2											0	0%
2002	N		15	32	70	52	11	2				182	
Repeats	0		15	24	32	23	4	1				99	54%
	1			8	31	20	5					64	35%
	2				7	9	2	1				19	10%
2003	N		22	62	63	38	5	1	1			192	
Repeats	0		22	58	56	32	5	1				174	91%
	1			4	4	2			1			11	6%
	2				3	4						7	4%
2004	N		13	60	110	149	51	13				396	
Repeats	0		13	57	100	145	42	11				368	93%
	1			3	9	3	5					20	5%
	2				1	1	1	1				4	1%
	3						3					3	1%
	4							1				1	0%
2005	N		11	83	67	89	17	4	1		1	273	
Repeats	0		11	57	41	43	4	1				157	58%
	1			26	15	28	3	2				74	27%
	2				11	10	3	1	1		1	27	10%
	3					8	5					13	5%
	4						2					2	1%
2006	N			20	77	15	4	1				117	
Repeats	0			18	62	8						88	75%
	1			2	12	6	3					23	20%
	2				3		1					4	3%
	3					1		1				2	2%
	4											0	0%
2007	N		3	46	65	41	3					158	
Repeats	0		3	37	41	19	1					101	64%
	1			9	13	6	2					30	19%
	2				11	11						22	14%
	3					5						5	3%
	4											0	0%

Table 11. Age composition and origin of Susquehanna River American shad collected at the Conowingo Dam Fish Lifts

												% Composition by Hatchery Release Site							
	Total											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%						52%	

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

Used scale ages for 1988-1996, otolith ages for 1997-2004.

Table 12. 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%	

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

Table 13. 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**	**1997**	**1998**	**1999**	**2000**	**2001**
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	0				
2000							0	344	4,469	12,615	32,605	6,876	0			
2001								0	2,339	24,562	57,254	27,486	2,339	0		
2002								0	413	2,067	10,544	13,360	8,576	6,616	0	
2003									0	515	5,283	29,330	22,444	30,281	2,573	0
2004										0	501	7,515	10,521	32,481	9,018	6,513
2005											0	171	812	7,447	6,854	9,766
2006												0	0	869	2,782	12,173
2007													0	162	162	2,838
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	84,739	44,692	77,857	21,389	31,291
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	8.02	11.70	13.50	9.46	5.51
Number of larvae to return 1 adult:	724	487	477	641	183	305	206	271	203	174	68	95	262	173	442	176
Survival	0.0014	0.0021	0.0021	0.0016	0.0055	0.0033	0.0049	0.0037	0.0049	0.0057	0.0147	0.0106	0.0038	0.0058	0.0023	0.0057

Mean number of larvae to return 1 adult (1986-2001): 306

Table 14. 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
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
2000							0	0	0	0	0
2001								0	0	0	0
2002								0	0	0	0
2003									0	0	0
2004										0	0
2005											0
2006											
2007											
Total recruits to lifts:	238	186	242	324	490	519	501	1,091	822	220	43
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
Number of fingerlings to return 1 adult:	305	437	264	186	184	105	44	73	170	0	0

Mean number of fingerlings to return 1 adult (1986-1994): 196

Table 15. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986- 2001.

		Cohort															
	Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	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	0				
	2000						0	0	458	5,959	16,820	43,474	9,168	0			
	2001							0	0	1,580	16,585	38,658	18,559	1,580	0		
	2002								0	217	1,086	5,540	7,020	4,506	3,476	0	
	2003									0	181	1,858	10,316	7,894	10,651	905	0
	2004										0	200	2,993	4,190	12,935	3,591	2,594
	2005											0	93	443	4,062	3,738	5,327
	2006												0	0	860	2,751	12,036
0	2007													0	173	173	3,025
	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	48,149	18,612	32,156	11,159	22,982
	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	31.36	10.65	39.66	21.9	89.8
	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	0.65	0.57	1.23	1.96	3.91
	Mean number of adults transported to return 1 adult (1986-2001):	1.31															

Table 16. 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
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	50	14,292	74		0.49	1.00
2001	1,859,345	Juniata & Susq. R.	Susq.	58	14,989	81		0.54	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.	0	0	0		0.00	0.09
2001	210,831	Conestoga R.	Susq.	11	3,171	150		1.00	0.11
2001	182,490	Swatara Cr.	Susq.	1	266	15		0.10	0.56
2001	676,982	N. Br. Susq. R.	Hudson	4	1,586	23	64	0.16	0.51
2002	1,906,173	Juniata R.	Hud/Susq.	18	4,423	23		0.12	0.15
2002	216,560	Juniata R.	Susq.	16	4,218	195		1.00	0.37
2002	101,350	W. Br. Susq. R.	Hud/Susq.	5	1,351	133		0.68	0.54
2002	2,000	Conodoguinet Cr.	Susq.	0	0	0		0.00	0.00
2002	18,924	Conestoga R.	Susq.	1	341	180		0.92	0.00
2002	15,000	Swatara Cr.	Susq.	1	164	110		0.56	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.	0	0	0		0.00	0.62
2002	2,000	Chemung R. (NY)	Hudson	0	0	0		0.00	0.00
2002	198,351	Chemung R. (NY)	Hudson	0	0	0	40	0.00	1.00
2003	5,712,662	Juniata/Susq. R.	Hudson	9	2,008	4		0.41	0.40
2003	1,947,223	Juniata/Susq. R.	Susquehanna	9	1,655	9		1.00	1.00
2003	591,558	W. Br. Susq. R.	Hudson	0	0	0		0.00	0.53
2003	167,774	Conodoguinet Cr.	Hudson	0	0	0		0.00	0.46
2003	158,146	Conestoga R.	Hudson	0	0	0		0.00	0.00

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

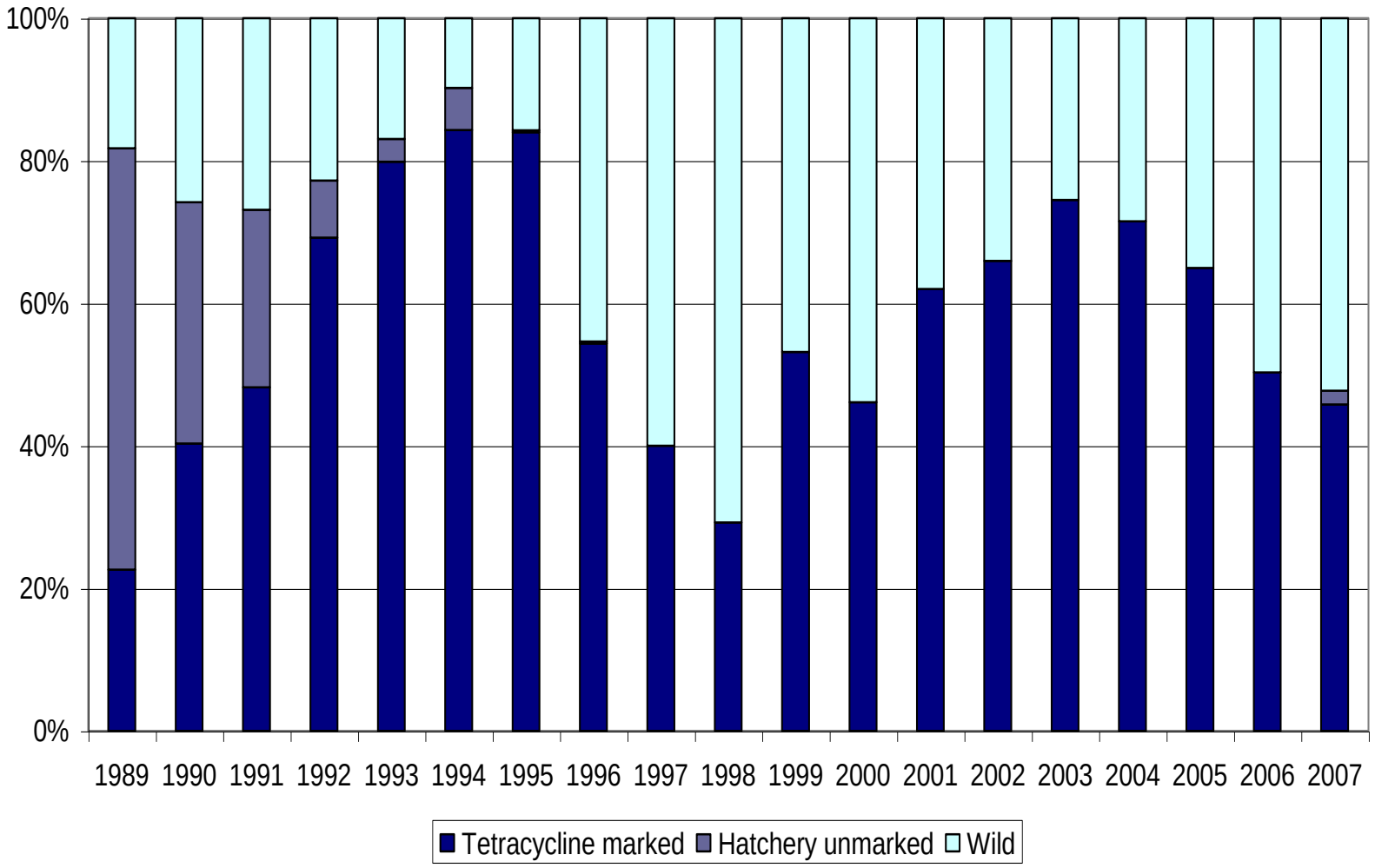


Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

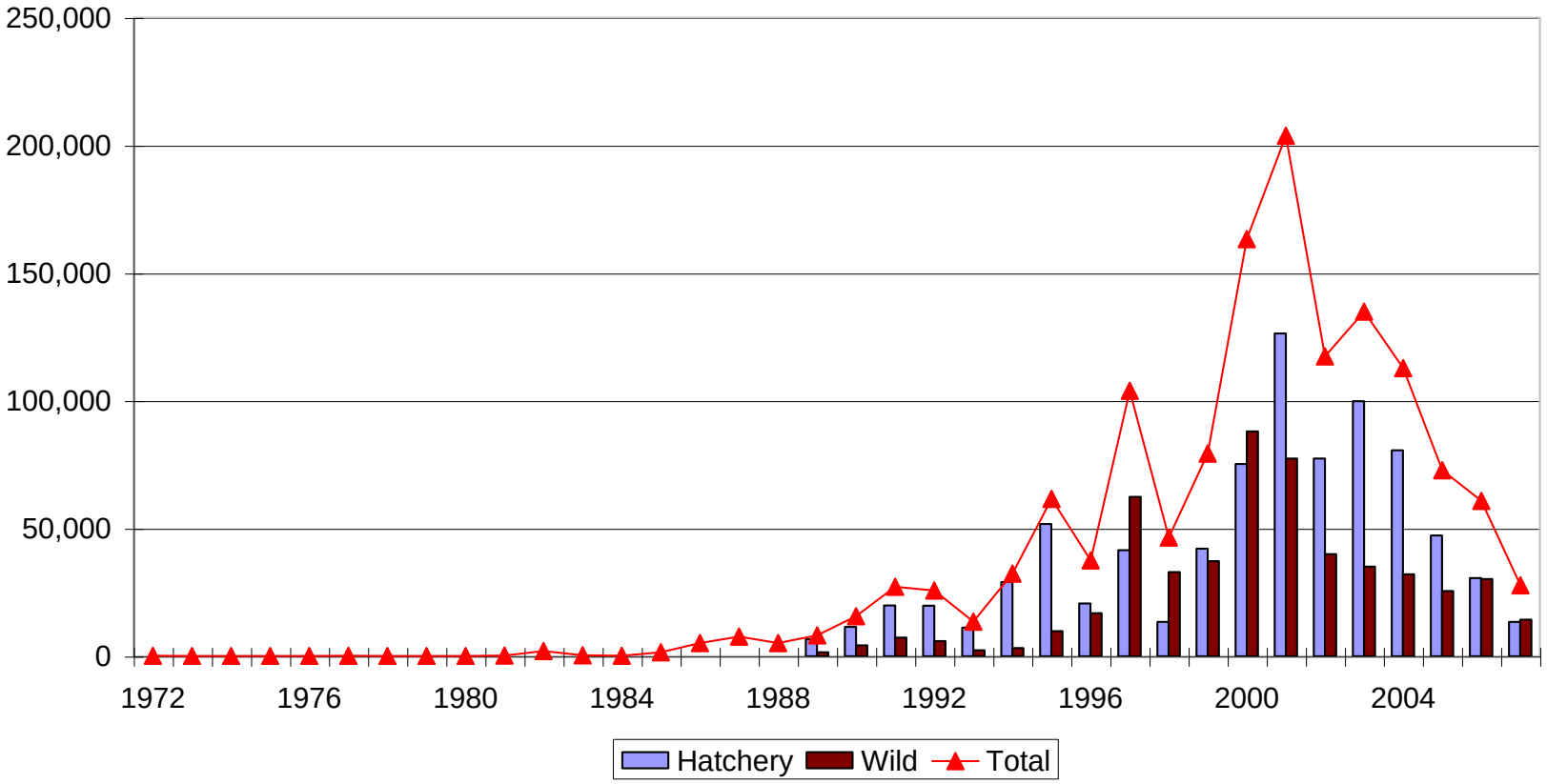
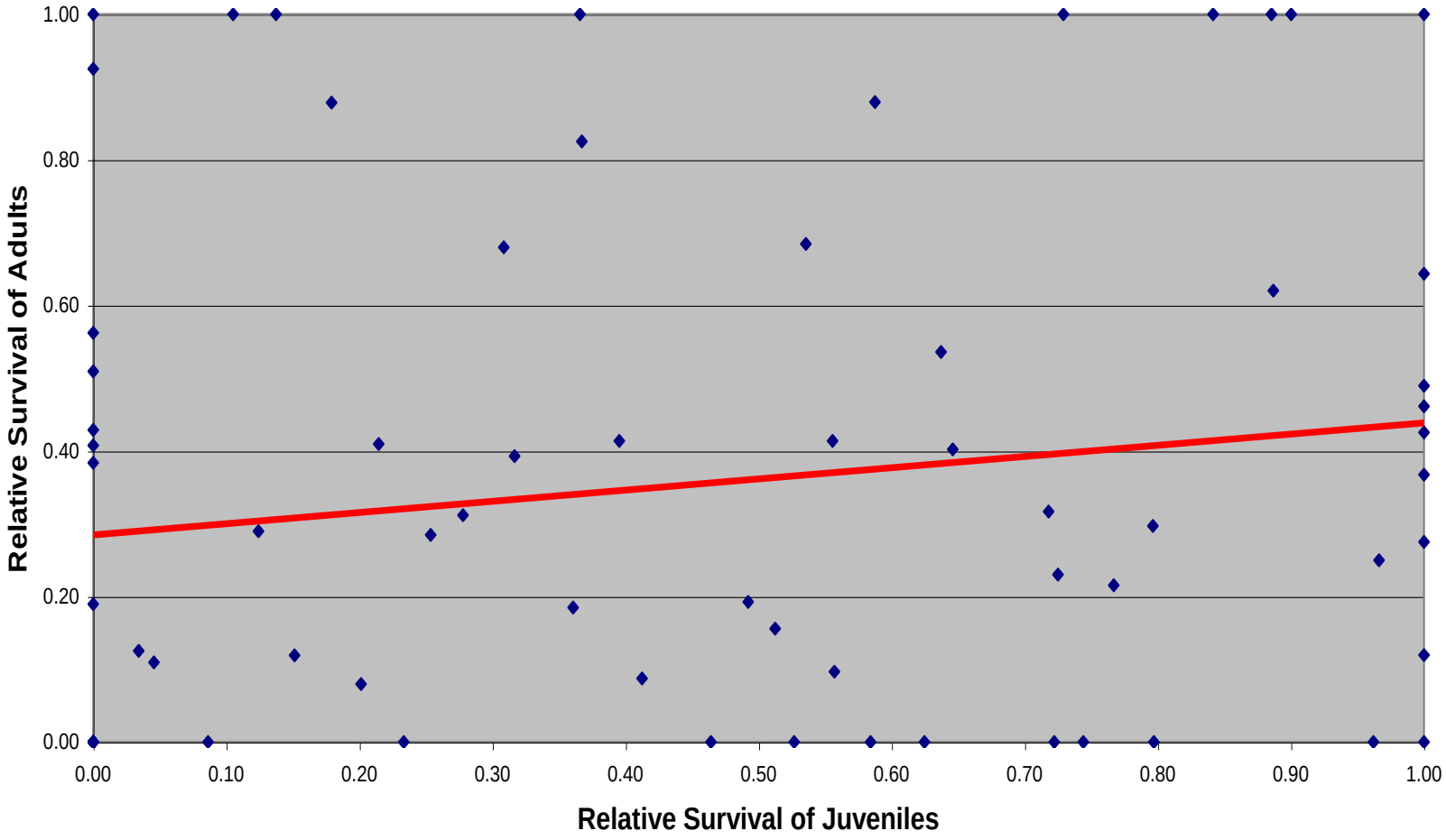


Figure 3. Stocking site/cohort specific relative survival of juvenile shad vs. adult shad, Susquehanna River, 1995-2003.



12.0 JOB 5, TASK 2: AMERICAN EEL SAMPLING AT CONOWINGO DAM, 2007

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12.1 BACKGROUND

American eel occupy a significant and unique niche in the estuarine and freshwater habitats of the Atlantic coast. Eels are a catadromous species that ascend freshwater environments as juveniles. These fish 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 very abundant in East Coast streams, comprising more than 25 percent of the total fish biomass in many locations. This abundance has declined from historic levels but remained relatively stable until the 1970s. More recently, fishermen, resource managers, and scientists have noticed a further decline in abundance from harvest and assessment data.

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 10. Before mainstem dams were constructed, the annual harvest of silver eels in the Susquehanna River was nearly one million pounds. There is currently no commercial harvest (closed fishery in Pennsylvania) and very few fish (resulting from Pennsylvania Fish & Boat Commission stockings in the early 1980s) are taken by anglers above the dam. The Maryland Biological Stream Survey (MBSS) collects data in freshwater drainages of Maryland. Eel captures in this survey were collected for the Susquehanna River and tributaries in the vicinity of Conowingo Dam (Figure 1). This data reflects the fact that the dam blocks the upstream migration of eels. By extrapolating densities of eels captured in Maryland the MBSS survey estimated that there would be over 11 million eels in the Susquehanna watershed if their migration was not blocked by dams.

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 eels are needed to allow them access to the watershed above dams.

Ongoing research conducted by the USGS, Northern Appalachian Research Laboratory indicates that American eel may be the primary fish host for the freshwater mussel, eastern elliptio (*Elliptio complanata*) (Lellis et al. 2001). The larval stage (glochidia) of freshwater mussels must parasitize a host fish to complete metamorphosis to the juvenile life stage. Some mussel species are generalists and can use multiple fish species as hosts while others are specialists that rely heavily on one or two host fish species to complete this life stage. Glochidia collected from

eastern elliptio in Pine Creek (a tributary to the Susquehanna River) appear to have much higher metamorphosis success rates on American eels than on other fish species found in the river (Lellis et al. 2001).

Eastern elliptio is abundant throughout most of its range which spans the entire east coast. However, in comparison with other rivers such as the Delaware River where the eastern elliptio population is estimated to be in the millions (Lellis 2001), biologists have noticed a distinct absence of eastern elliptio abundance and recent recruitment to the Susquehanna River (personal communication, William Lellis, USGS, Wellsboro, PA). Low recruitment of eastern elliptio could be linked to the lack of eel passage over 4 dams in the Susquehanna River.

If eels are essential to the reproduction of eastern elliptio or other freshwater mussel species, the implications of providing eel passage to freshwater mussel populations and in turn, ecosystem function could be significant. Similar to oysters in the Chesapeake Bay, freshwater mussels provide the service of natural filtration to the rivers and streams where they live. A healthy reproducing population of eastern elliptio could remove algae, sediment, and micronutrients from billions of gallons of Susquehanna River water each day. Restoring the upstream distribution of American eels and eastern elliptio could potentially improve water quality of not only the Susquehanna River but also the Chesapeake Bay. A research project to further evaluate the relationship between eastern elliptio and American eel has been funded under the USFWS, Region 5, Science Support Program during 2008.

12.2 SURVEY METHODS AND EQUIPMENT PLACEMENT

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

Sampling for eels took place from May 30 through August 8, 2007. Once again our sampling was limited to the west side of the dam; however this year we attempted to further develop our sampling efforts. As in previous years a modified Irish elver ramp was used to sample for elvers, and eel pots with a 6 mm square mesh, were set around the base of the West Fish Lift to catch larger eels. This year an experimental eel passage was created on the shore of the west bank in an attempt to further determine the population of juvenile eels at the base of Conowingo Dam (Figure 2). River flows were collected from a USGS gauging station (USGS 01578310). Lunar fraction (percent moon illumination) was collected from the U.S. Naval Observatory (http://aa.usno.navy.mil/). The elver ramp was initially operated outside of the West Fish Lift raceway, but due to large fluctuations in the water levels caused by power generation, and a lack of rain, the ramp would become inoperable during periods of low water level. The ramp was moved to the shore adjacent to the West Fish Lift when 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. (Figure 3 and 4)

12.3 RESULTS

Eels were captured throughout the period sampled, May 30th - August 8th (Table 1). Juvenile eel length frequencies ranged from 76 to 169 mm TL (Figure 5), and the length frequency of yellow and silver eels varied from 256 to 734 mm TL (Figure 6). Yellow and silver eels captured were sedated, measured, fin clipped, and had a Passive Integrated Transponder tag (PIT tag) inserted in the dorsal musculature and released. A total of 51 silver or yellow eels were captured and tagged, 28 of which were recaptured at a later date. Elvers were sedated, measured, counted, and in the occurrence of large numbers, eels were volumetrically counted. Elvers were then transported to Deer Creek and released above Wilson Mill dam. Several methods of collecting elvers were attempted and altered as the sampling season progressed. The Irish elver ramp that was operated on the rip rap by the West Fish Lift was the most prevalent method of capturing elvers (Figure 7). It captured significantly more elvers than the eel passage pipe. The overflow from water pumped to the west fish lift ran down to an eddy in the river directly below the dam. We believe this provided attractive upstream flow in an area where elvers were concentrated.

We believe that yellow eels become trap happy or set up distinctive home ranges from which they do not emigrate or immigrate since we recaptured the same individuals many times. We compared elver captures to water temperature, stream flow, lunar phase and date. It appears that elvers reach the dam first week of May through the end of June.

In 2007 elvers were taken to Manning Hatchery and marked with oxytetracycline (OTC) for an age validation study. The elvers were collected in the West Fish Lift at Conowingo Dam and immersed in an OTC bath at a concentration of 550 ppm for 7 hours. After which the elvers were placed in a small pond on hatchery grounds and collected again a year later. A total of 31 elvers were harvested and sacrificed. Otoliths were removed and viewed under an ultraviolet light to view the OTC markings. The results of this study validate that American Eels form an annual growth ring on the otolith.

12.4 LITERATURE CITED

Lellis, W. A. 2001. Freshwater mussel survey of the Delaware Water Gap National Recreation Area: qualitative survey. Report to the National Park Service. 13pp.

12.5 TABLES AND FIGURES

Table 1. Number of eels caught at the base of Conowingo Dam on the Susquehanna River by a eel passage pipe, Irish Elver Ramp on rip rap, floating elver ramp in the tailrace and Eel Pots during 2007

Collection Date	Lunar Fraction	Eels Collected in Eel Passage	Eels Collected in Elver Ramp	Eels Collected in Modified Elver Ramp	Total Eels Captured
30-May	0.97	0	0	0	0
1-Jun	1	0	0	2	2
4-Jun	0.9	0	0	8	8
6-Jun	0.74	0	0	7	7
8-Jun	0.53	0	0	21	21
11-Jun	0.21	5	0	0	5
13-Jun	0.05	8	0	1	9
15-Jun	0	5	0	0	5
18-Jun	0.12	20	0	2	22
20-Jun	0.28	15	0	0	15
22-Jun	0.47	10	0	0	10
25-Jun	0.74	17	1320	0	1337
27-Jun	0.89	11	525	0	536
29-Jun	0.98	9	391	0	400
2-Jul	0.97	5	216	0	221
5-Jul	0.77	7	62	0	69
9-Jul	0.33	8	100	0	108
11-Jul	0.14	5	53	0	58
18-Jul	0.15	47	74	0	121
20-Jul	0.31	6	96	0	102
23-Jul	0.59	111	408	0	519
26-Jul	0.85	33	125	0	158
30-Jul	1	9	46	0	55
3-Aug	0.79	11	34	0	45
6-Aug	0.46	14	8	0	22
8-Aug	0.25	14	9	0	23

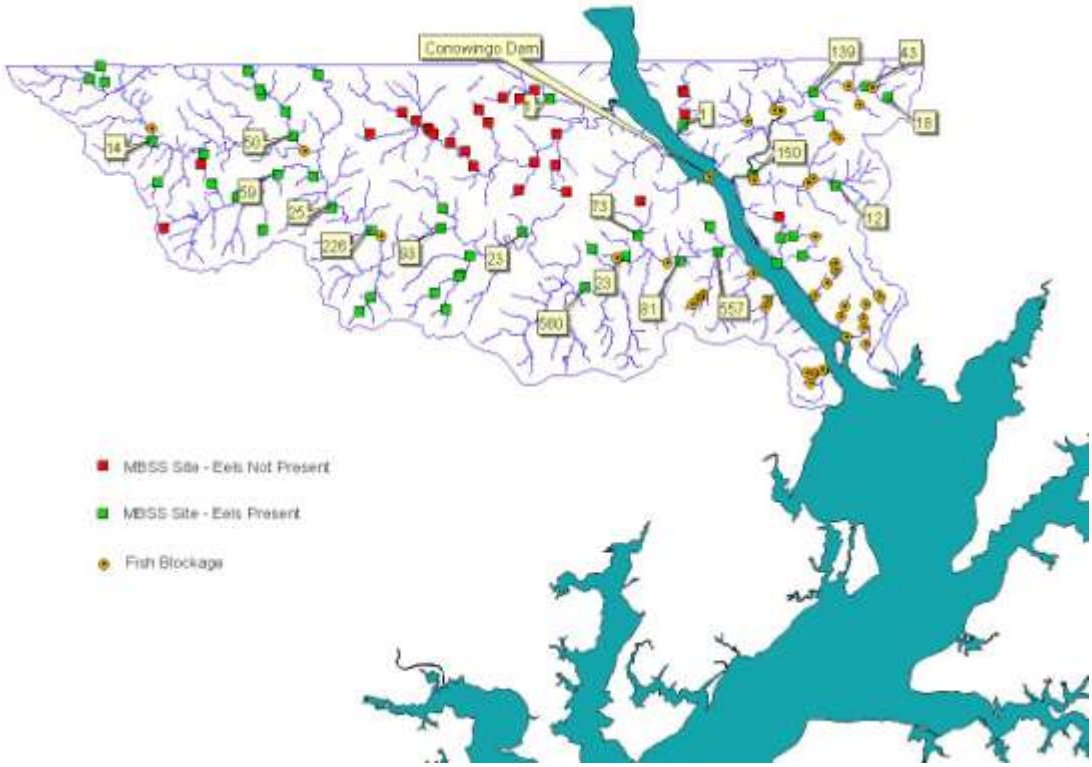

Figure 1. Map of the Maryland Biological Stream Survey (MBSS) sampling sites of tributaries to the Susquehanna River in Maryland (Note the difference in densities of eels in tributaries below Conowingo Dam compared to above the Dam.)

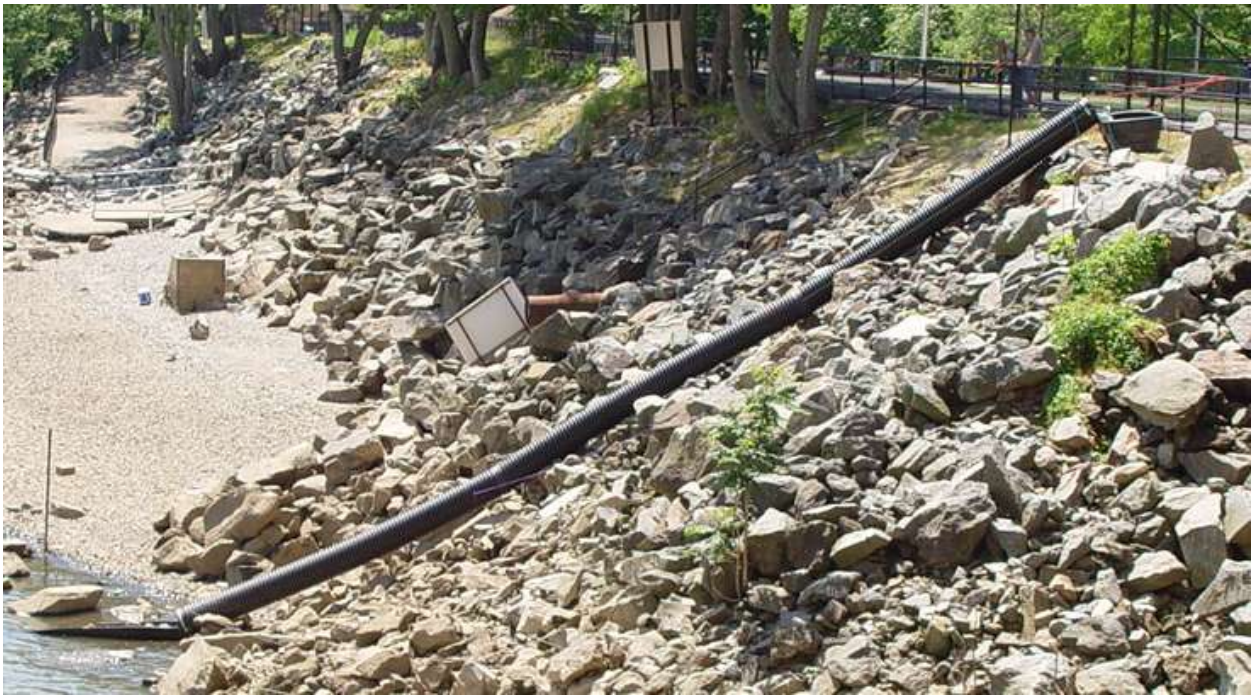

Figure 2. Experimental Eel passage pipe below Conowingo Dam, 2007

Figure 3. Irish elver ramp placed on rip rap in overflow from west fish left

Figure 4. Elvers climbing up rip rap in overflow from west fish lift pumps

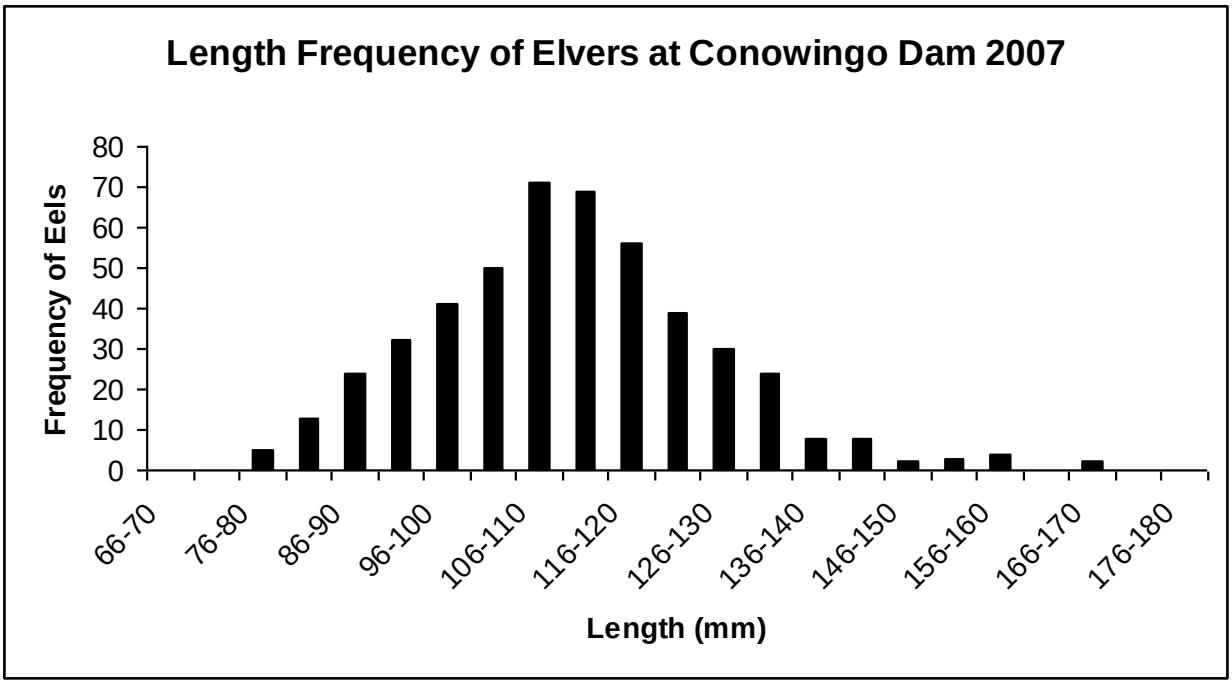

Figure 5. Length frequencies of elvers captured at the base of Conowingo Dam during 2007

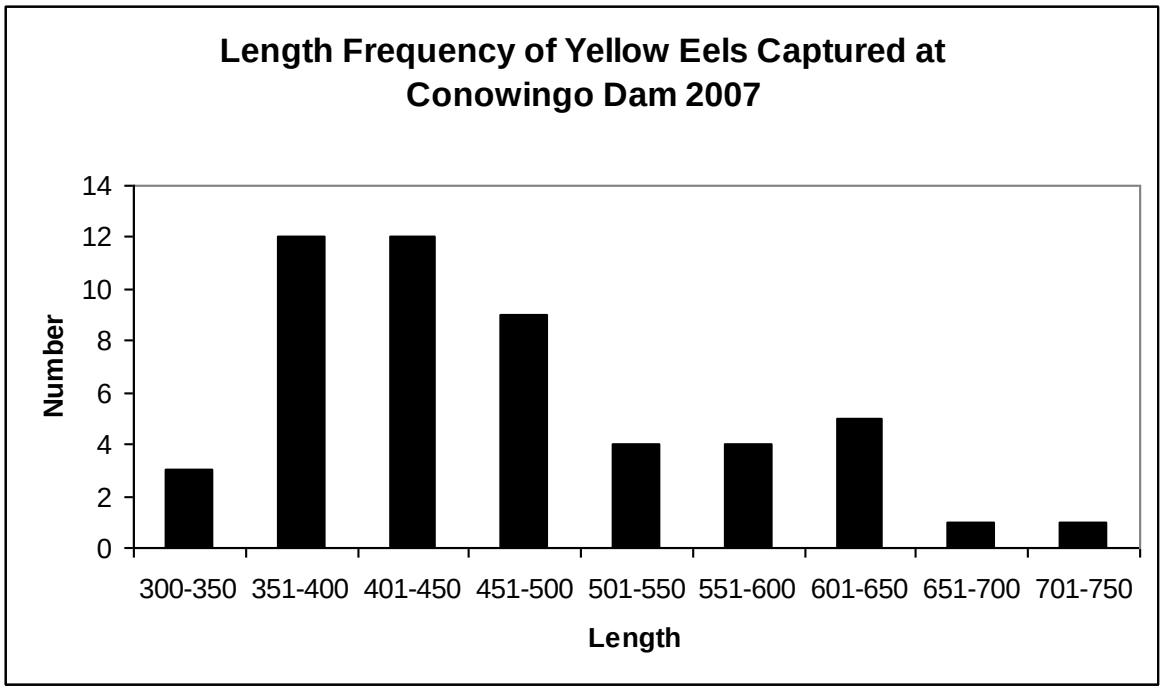

Figure 6. Length frequency of yellow eels captured at Conowingo Dam, 2007

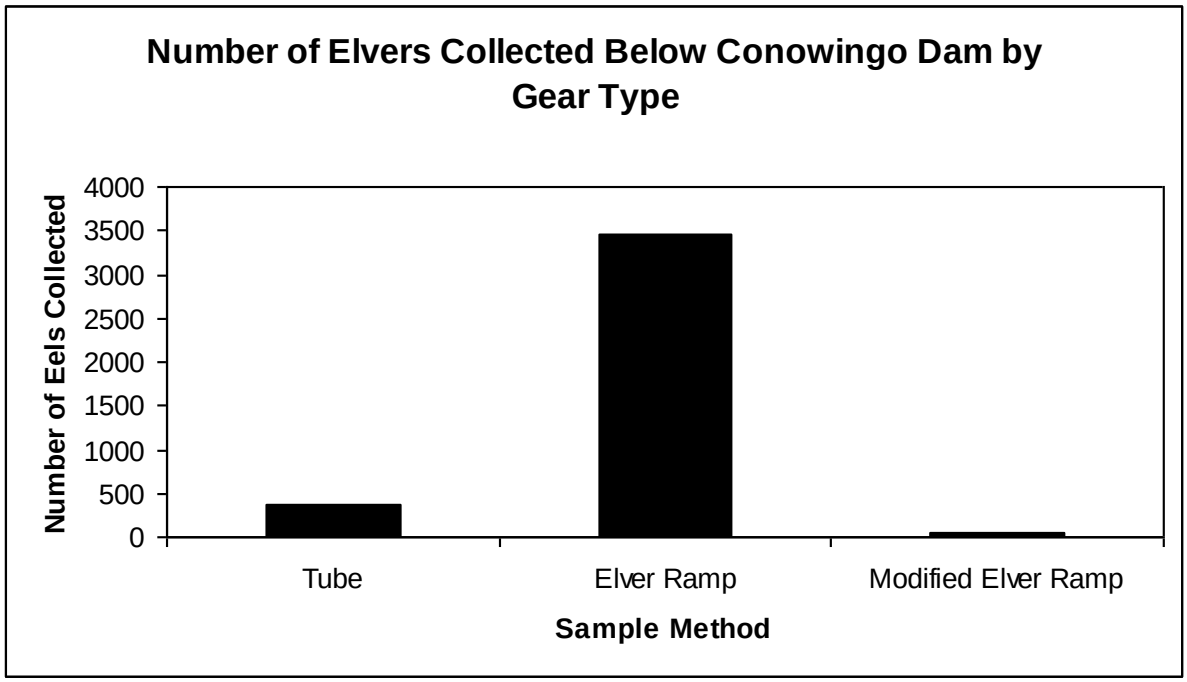

Figure 7. Number of elvers collected below Conowingo Dam by gear type

13.0 JOB 6: POPULATION ASSESSMENT OF AMERICAN SHAD IN THE UPPER CHESAPEAKE BAY 2007

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13.1 INTRODUCTION

The Maryland Department of Natural Resources has conducted annual sampling targeting adult American shad in the upper Chesapeake Bay since 1980 and hickory shad since 1998. The purpose of this sampling is to define stock characterizations including relative abundance indices, age and spawning history and reproductive success.

Since closure of the American and hickory shad fisheries to recreational and commercial fishing in 1980 and 1981, respectively, these stocks have increased significantly in the lower Susquehanna River but, American shad abundance has decreased in the last five years. The Maryland Department of Natural Resources (DNR) is committed to restoring these species to the Susquehanna River Basin to sustainable, self-producing populations.

13.2 METHODS AND MATERIALS

13.2.1 Adults

13.2.1.1 American Shad

13.2.1.1.1 Field Operations

American shad were angled from the Conowingo tailrace (Figure 1) on the Susquehanna River two to five times per week from 30 April through 23 May 2007. Two rods were fished simultaneously, with each rod rigged with two shad darts and lead weight added, when necessary, to achieve proper depth.

All adult American shad sampled were sexed by expression of gonadal products (when possible) and fork length measured (mm). Scale samples were removed below the insertion of the dorsal fin. A minimum of three scales per fish 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 since it was assumed that each fish had completed a full year's growth at the time of capture. Fish in good physical condition and females not spent or running ripe were quickly tagged and released. A Maryland DNR Fisheries Service hat was given to fishers as reward for returned tags.

13.2.1.1.2 Statistical Analysis

Chapman's modification of the Petersen statistic was used to calculate relative abundance of adult American shad in the Conowingo tailrace. The equation was:

$$N = \frac{(C+1)(M+1)}{(R+1)}$$

Where N = equal to the population
C = the number of fish examined
M = the number of fish marked
R = the number of marked fish recaptured (Ricker 1975).

The Conowingo tailrace estimate utilized American shad captured in the tailrace and tagged and subsequently recaptured by the east fish lift. Fish caught in the east lift were dumped into a trough and directed past a 4'x10' counting window, identified to species, and enumerated by experienced Normandeau technicians. Hourly catch logs by species were subsequently produced and distributed to DNR personnel. American shad possessing a tag were counted and the tag color noted. Annual catch-per-unit-effort (CPUE) for American shad was calculated as the geometric mean of fish caught per lift hour.

Time series analysis of the Petersen relative population estimates (1980-2007) were examined using a linear growth model. Annual CPUE of upper Bay American shad captured by hook and line was calculated as the geometric mean of fish caught per boat hour.

Data was also collected from two creel surveys targeting American shad in the lower Susquehanna River. One survey was a roving creel whereby tailrace anglers were visited on site and asked a series of questions regarding effort and success. The second survey required anglers to record their daily catch, location and hours fished in a logbook that was returned to the Department at the end of the spring fishing season. For both surveys, CPUE was calculated as the number of fish caught per hour fished.

13.2.1.2 Hickory Shad

13.2.1.2.1 Relative Abundance

The annual CPUE of Deer Creek hickory shad was calculated as the number of fish caught- per-angler-hour and was obtained from spring logbook data returned from volunteer anglers.

13.2.1.2.2 Mortality Estimates

Two methods were utilized to estimate total instantaneous mortality of hickory shad based on scale repeat spawning marks. For the first method, hickory shad total instantaneous mortalities (Z) were estimated by the $\log_e$-transformed spawning group frequency, plotted against the corresponding number of times spawned (assuming consecutive spawning; ASMFC 1988);

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

where S_{fx} = number of fish with 1,2,...f spawning marks in year x;

a = y-intercept;
W_{fx} = frequency of spawning marks (1,2,...f) in year x.

The second method averaged the differences between the natural logs of the spawning group frequency to provide an overall Z between age groups. The Z calculated for these fish represents mortality associated with repeat spawning.

13.2.2 Juveniles

Juvenile American and hickory shad were sampled in the Susquehanna River from early July to mid October using a 30.5 x1.2m x 6.4mm mesh haul seine. Six sites were chosen based on availability of beaches situated a minimum of 0.1 river miles apart from the river's mouth upstream to Robert's Island (Figure 2). Sampling was conducted biweekly and all fish collected were enumerated, fork length measurements recorded and American and hickory shad were retained for OTC analysis.

13.3 RESULTS

13.3.1 Adults

13.3.1.1 American Shad

13.3.1.1.1 Sex and Age Composition

The 2007 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.70:1. Of the 468 fish sampled by this gear, 449 were scale-aged (Table 1). Those American shad not aged directly because of regenerated scales, were not assigned ages.

Males were present in age groups 3-8 while females were found in age groups 4-9 (Table 1). The 2003 year-class of males (age IV) was the most abundant age group sampled, accounting for 53% of the total catch. For females, the 2002 (age V) was the most abundant age group, accounting for 43%, of the total catch.

13.3.1.1.2 Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line in 2007 was 14.1% for males and 17.4% for females (Table 1). The arcsine-transformed proportions of these repeat spawners (sexes combined) had been increasing through 2002 but has been decreasing in recent years (Figure 3).

13.3.1.1.3 Relative Abundance

During east lift operations from 23 April to 31 May 2007, clerks counted 24,464 American shad passing the viewing window. Peak passage was on 08 May when 3,025 American shad were recorded. Breakdown of the 72 marked fish observed is listed below.

East Lift		
Tag Color	Year Tagged	Number Recaptured
Pink	2007	66
Orange	2006	6
West Lift		
Tag Color	Year Tagged	Number Recaptured
Pink	2007	31

In 2007, the west lift at Conowingo Dam operated from 30 April to 31 May. The 4,272 American shad caught in the west lift were returned to the tailrace, used for experimentation or retained for hatchery operations. Peak capture from the west lift was on 20 May when 668 American shad were recorded. Thirty-one tagged American shad were recaptured in 2007 from the west lift.

The Conowingo tailrace American shad relative population estimate in 2007 was 158,148 (95% confidence intervals 200,377-124,717; Table 2 and Figure 4). This estimate was adjusted for 3% tag loss as suggested by Leggett (1976).

Estimates of hook and line geometric mean CPUEs have decreased significantly since 2002 (hook and line: r^2=0.75, P= 0.012; Table 3 and Figure 5) while fish lifts geometric mean CPUEs have decreased significantly since 2002 (r^2=0.80, P=0.007; Table 3 and Figure 6).

Data from both creel surveys targeting American shad in the Susquehanna River have also shown significant decreases in catch-per-hour in the last five years (Tables 4 and 5). However, since river flows highly influence catch, conclusions drawn from these creels should be considered somewhat tenuous.

13.3.1.2 Hickory Shad

13.3.1.2.1 Relative Abundance

Estimates of annual recreational hook and line (1998-2007) catch-per-angler-hour (CPAH) in Deer Creek ranged from 4.3 to 8.3 and have varied without trend since 1998 (r^2=0.18, P=0.22; Table 6).

13.3.1.2.2 Mortality Estimates

Richardson (et al 2004) noted that ninety percent of hickory shad in Deer Creek have spawned by age four and this stock generally consisted of few virgin fish. The oldest fish in their sample was eight years old and using Hoenig's (1983) estimation of natural mortality ($\ln (M_x) = 1.46 - 1.01\{\ln (t_{max})\}$), M was 0.53.

If Z is calculated using the freshwater spawning marks as in American shad, then mortality estimates for hickory shad estimated from the spawning group frequency plotted against the

corresponding number of times spawned resulted in a Z of 0.25. The average difference between the natural logs of the spawning group frequency produced a Z of 0.32. In general, the resultant Z was attributed to natural mortality since both recreational and commercial fishing for hickory shad were banned.

13.3.1.3 Juvenile American and Hickory Shad

13.3.1.3.1 Relative Abundance

No juvenile American shad were caught in the Susquehanna River during the inriver summer seining, in 2007. Young-of-the-year bluegill and gizzard shad were the predominate fish species caught.

13.4 DISCUSSION

13.4.1 Anadromous Species

13.4.1.1 American Shad

13.4.1.1.1 Adults

Prior to 1997, American shad captured from both fish lifts were individually handled so that all fish, both marked and unmarked, could be totaled. Beginning in 1997, the east fish lift became fully automated. Consequently, two trained observers stationed at the east lift-viewing window recorded both total counts and number of tagged American shad. This change in operating procedure at the east lift increased the chances of missing both tagged and untagged American shad and misidentifying tag colors. These errors could, therefore, affect the accuracy of the Petersen population estimates.

All American shad commercial fisheries in the Atlantic Ocean were closed on 31 December 2004. Since this fishery resulted in landings of mixed stocks in excess of 1.2 million lbs (ASMFC 1998) and a moratorium exists for American shad in the Chesapeake Bay, increases in relative abundances were expected. However, the three indicators of relative abundance (tailrace relative population estimates, hook and line geometric mean CPUEs, and Conowingo Dam lift geometric mean CPUEs) have shown declines since 2003.

Several factors contributing to this decline in abundance could be related to poor recruitment, Striped bass predation (Crecco et al 2006) and American shad harvested in the ocean as “bait”. Because of the difficulty in identifying and differentiating the four alosines, many subadults may be caught as bycatch, appearing as bait in various markets particularly in New England and southern Canada (K Hattala pers. comm, NY Dept. Env. Cons.).

13.4.1.1.2 Juveniles

Baywide juvenile American shad indices have decreased since 2004 (Figure 7). These decreases were primarily driven by the upper Chesapeake Bay (Figure 8) and Potomac River indices. In the

upper Chesapeake Bay during 2006, only ten juvenile American shad were captured at seven permanent sites by the Juvenile Striped Bass Recruitment Assessment in forty-two hauls while three were captured from the six auxiliary sites. These low juvenile indices in the last two years for the upper Chesapeake Bay may demonstrate the decreasing trend in adult abundance.

Sampling for juvenile American shad from the six sites in the Susquehanna River during 2006 was unsuccessful. Possible reasons for the absence of juveniles include high floodwaters in late June, downstream migration related to food availability, lower salinity gradient, adverse water temperatures and predation.

13.4.1.2 Hickory Shad

13.4.1.2.1 Adults

Hickory shad are difficult to capture because of their aversion to fishery independent (fish lifts and traps) and fishery dependent (commercial pound and fyke nets) gears. Consequently, angler effort and success was collected from logbooks provided to anglers targeting hickory shad. Biological data and scale samples were obtained from hickory shad collected during electrofishing from Lapidum to the mouth of Deer Creek by DNR aquaculture personnel.

Deer Creek, a tributary to the Susquehanna River in Harford County has the greatest densities of hickory shad in Maryland (Richardson et al 2004). Natural mortality is approximately equal to the estimate of total mortality, demonstrating minimum mortality by hook and line and ocean bycatch.

13.4.1.2.2 Juveniles

Haul seine sampling during the mid summer and fall likely missed hickory shad because of their large size, avoidance to the gear and their preference for deep water. Since adults may spawn from mid March through late April, up to six weeks before American shad, juvenile hickory shad reach a larger size earlier. Consequently, in order to accurately represent their juvenile abundance, sampling would need to be initiated by early June.

13.5 LITERATURE CITED

ASMFC (Atlantic States Marine Fisheries Commission). 1988. Supplement to the fishery management plan for the anadromous alosid stocks of the eastern United States: American shad, hickory shad, alewife, and blueback herring. Washington, D.C.

ASMFC (Atlantic States Marine Fisheries Commission). 1998. American shad stock assessment peer review report. Washington, D.C. 217 pp.

Crecco, V., T. Savoy and J. Benway. 2006. Stock Assessment of Connecticut River Shad: Examination of Fishing and Predation Effects on the Recent Stock Decline. Connecticut Marine Fisheries Division. Report to the American Shad Stock Assessment Subcommittee.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82(1):898-903.

Leggett, W. C. 1976. The American shad *Alosa sapidissima* with special reference to its migration and population dynamics in the Connecticut River. American Fisheries Society Monograph 1:169-225.

Richardson, B.M., R.P. Morin, M.W. Baldwin and C. P. Stence. 2004. Restoration of American shad and hickory shad in Maryland's Chesapeake Bay, Maryland Department of Natural Resources, Annapolis, Maryland.

Ricker, W.E. 1975. *Computation and interpretation of biological statistics of fish populations*. Fisheries Research Board of Canada Bulletin 191.

13.6 TABLES AND FIGURES

Table 1. Numbers of adult American shad and repeat spawners by sex and age sampled from the Conowingo tailrace in 2007

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	0	0	0	0	
3	17	0	0	0	17	0
4	98	0	64	0	162	0
5	59	21	113	11	172	32
6	9	3	79	28	88	31
7	1	1	5	4	6	5
8	1	1	2	2	3	3
9	0	0	1	1	1	1
Totals	185	26	264	46	449	72
Percent Repeats	14.1%		17.4%		16.0%	

Table 2. Conowingo tailrace population estimate of adult American shad in 2007

Chapman's Modification of the Petersen estimate (Chapman 1951):

$$N = \frac{(C + 1)(M + 1)}{R + 1}$$

where N = population estimate
M = number of fish tagged
C = number of fish examined for tags
R = number of tagged fish recaptured

2007 survey results:

C = 24,246
M = 436
R = 66

Therefore:

$$N = \frac{(24{,}246 + 1)(436 + 1)}{(66 + 1)} = 158{,}148$$

From Ricker (1975): Calculation of 95% confidence limits based on sampling error using the number of recaptures in conjunction with Poisson distribution approximation.

Using Chapman (1951):

$$N = \frac{(C + 1)(M + 1)}{(R^t + 1)}$$

where: R^t = tabular value (Ricker p343)

$$\text{Upper } N = \frac{(24{,}246 + 1)(436 + 1)}{(51.88 + 1)} = 200{,}377$$

$$\text{Lower } N = \frac{(24{,}246 + 1)(436 + 1)}{(83.96 + 1)} = 124{,}717$$

Table 3. Conowingo Dam tailrace hook and line data, 1982-2007

Year	Total Catch	Hours fished	CPUE	GM CPUE
1982	88	N/A	N/A	N/A
1983	11	N/A	N/A	N/A
1984	126	52	2.42	1.07
1985	182	85	2.14	1.05
1986	437	147.5	2.96	1.85
1987	399	108.8	3.67	6.71
1988	256	43	5.95	6.54
1989	276	42.3	6.52	7.09
1990	309	61.8	5.00	3.6
1991	437	77	5.68	5.29
1992	383	62.75	6.10	5.05
1993	264	47.5	5.56	4.8
1994	498	88.5	5.63	5.22
1995	625	84.5	7.40	7.1
1996	446	44.25	10.08	9.39
1997	607	57.75	10.51	10.2
1998	337	23.75	14.19	9.86
1999	823	52	15.83	15.94
2000	730	35.75	20.42	13.98
2001	972	65.75	14.78	15.12
2002	812	60	13.53	15.94
2003	774	69.3	11.17	9.4
2004	474	38.75	12.23	9.48
2005	412	57.92	7.11	9.2
2006	360	33.75	10.28	7.61
2007	468	52.91	8.85	8.13

Table 4. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2007

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

Table 5. Summary of the spring American shad logbook data, 1999-2007

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American Shad Caught	Mean Number of American Shad Caught Per Hour (CPAH)
1999	7	160.5	463	2.88
2000	10	404.0	3137	7.76
2001	8	272.5	1647	6.04
2002	8	331.5	1799	5.43
2003	9	530.0	1222	2.31
2004	18	750.0	1035	1.38
2005	18	567.0	533	0.94
2006	19	820.5	747	0.91
2007	10	285.5	853	2.99

Table 6. Summary of the spring hickory shad log book data from Deer Creek, 1998-2007

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad Caught	Mean Number of Hickory Shad Caught per Hour (CPAH)
1998	19	600	4980	8.30
1999	15	817	5115	6.26
2000	14	655	3171	4.84
2001	13	533	2515	4.72
2002	11	476	2433	5.11
2003	14	635	3143	4.95
2004	18	750	3225	4.30
2005	18	272.5	1699	6.23
2006	19	762	4905	6.43
2007	17	782.5	3395	4.34

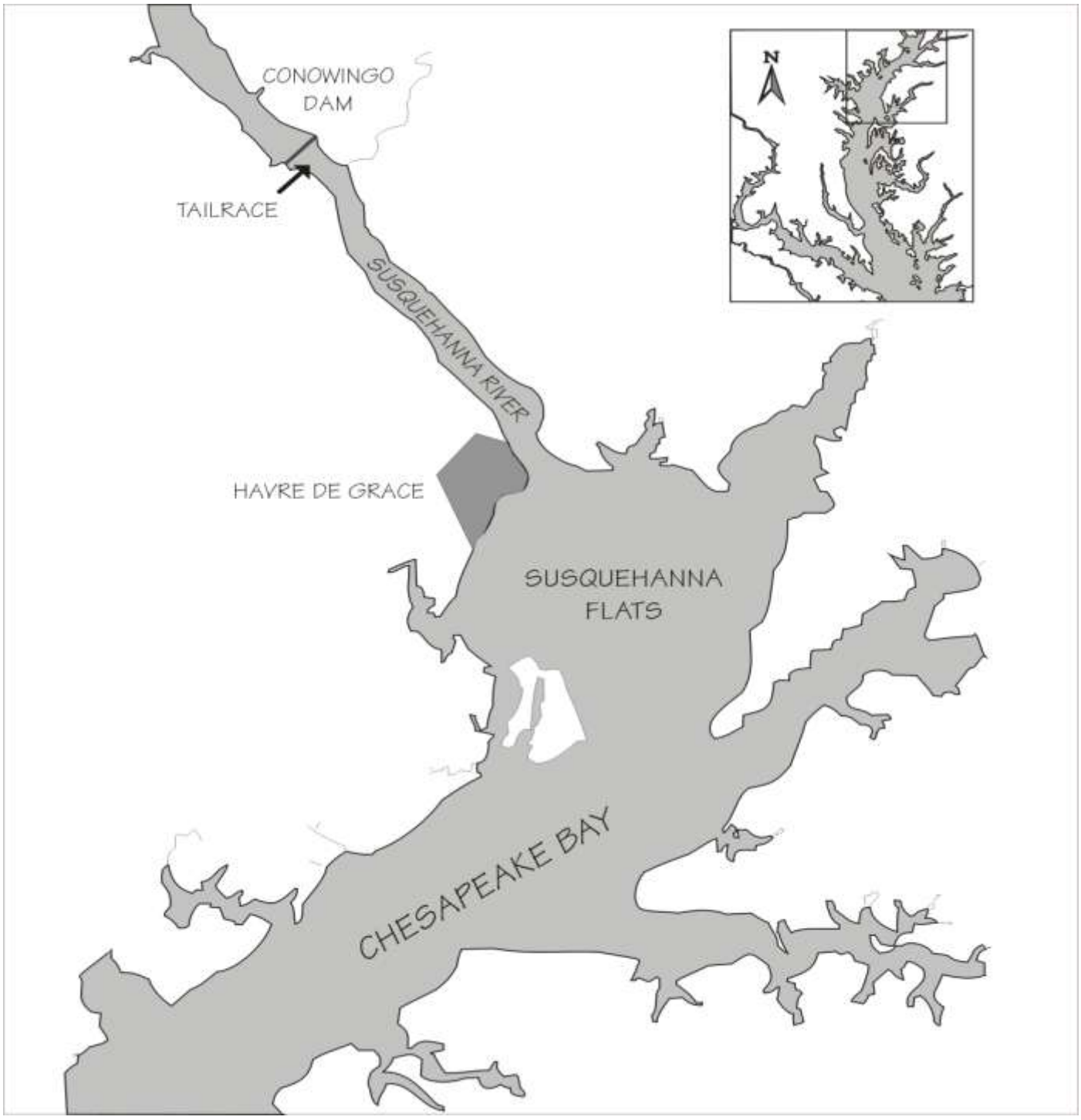

Figure 1. Location of the hook and line sampling in Conowingo Dam tailrace in 2007

Figure . Seining sampling sites in the Susquehanna River during 2005.

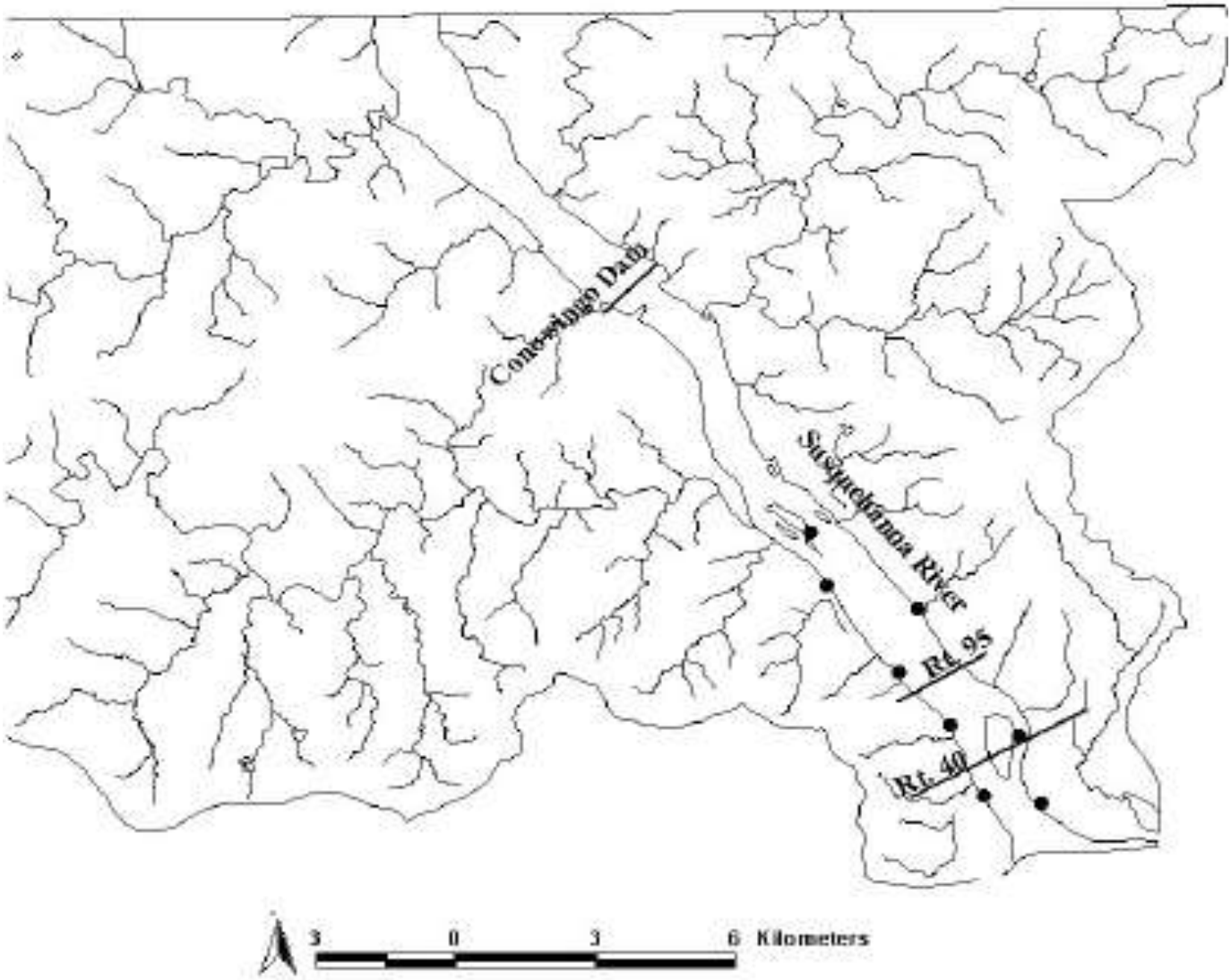

Figure 2. Distribution of the 2007 seine sites (black circles) on the Susquehanna River

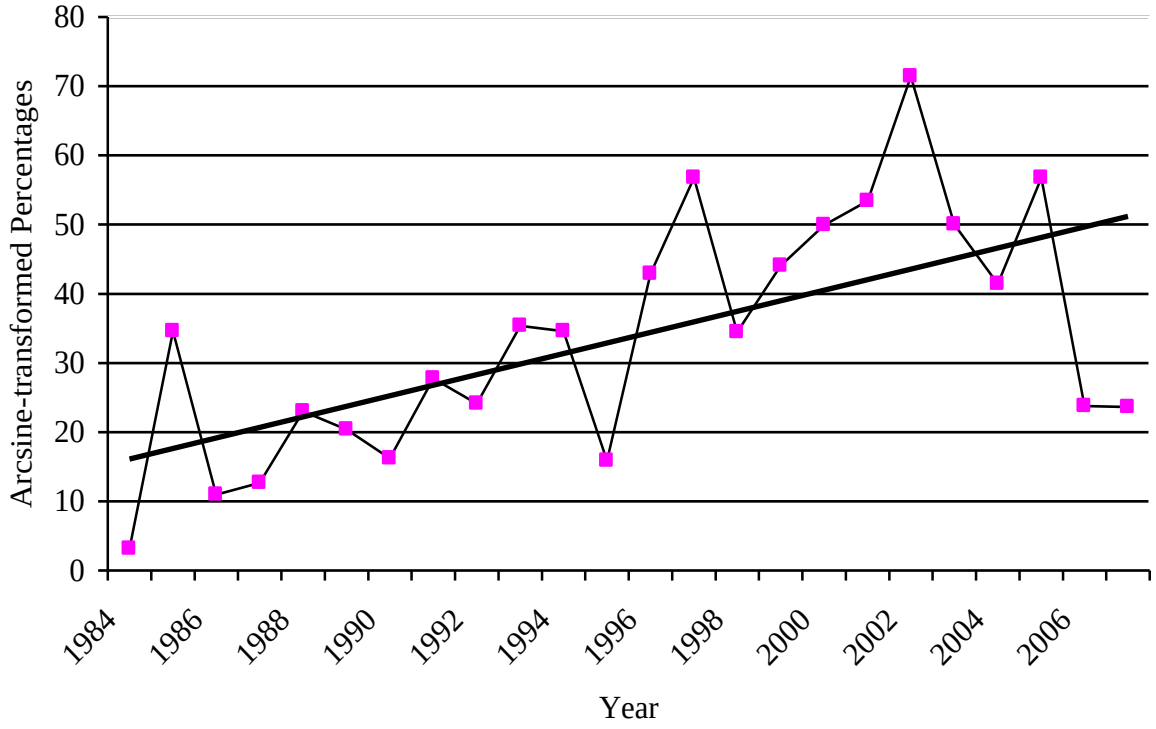

Figure 3. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2007)

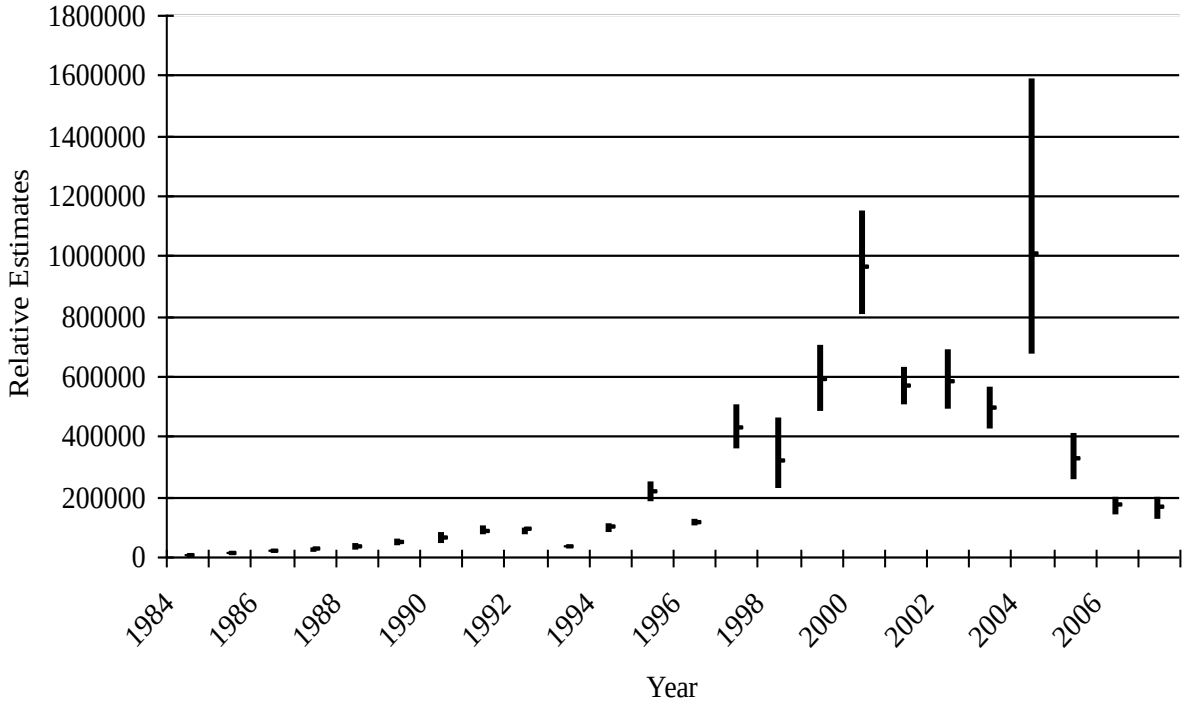

Figure 4. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2007

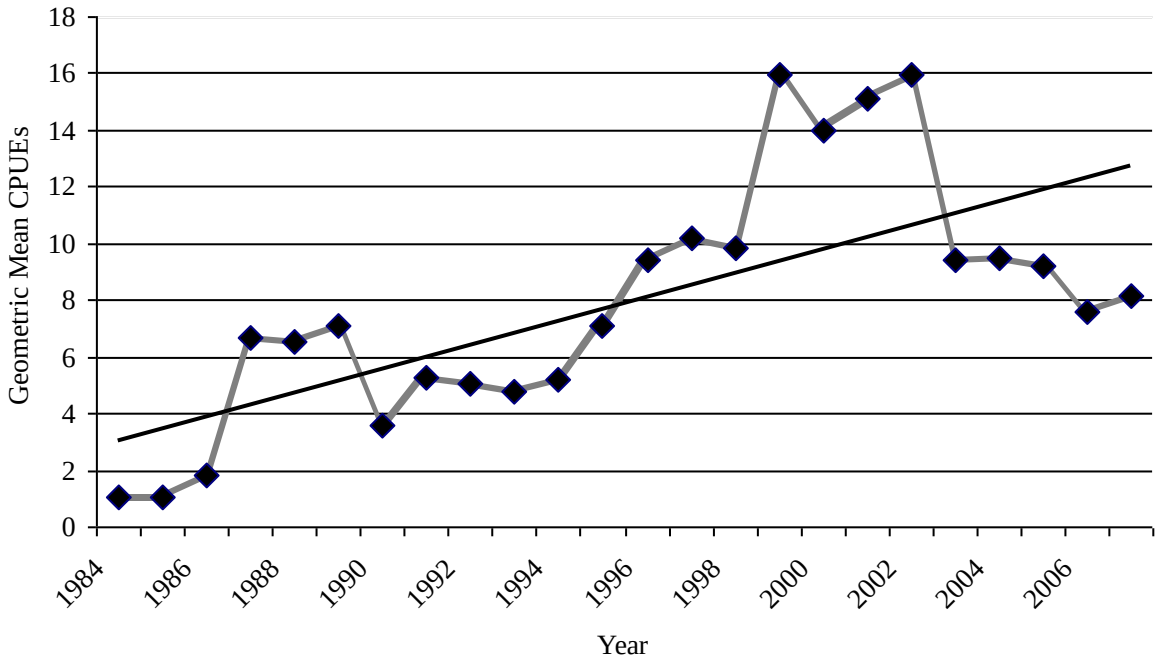

Figure 5. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2007

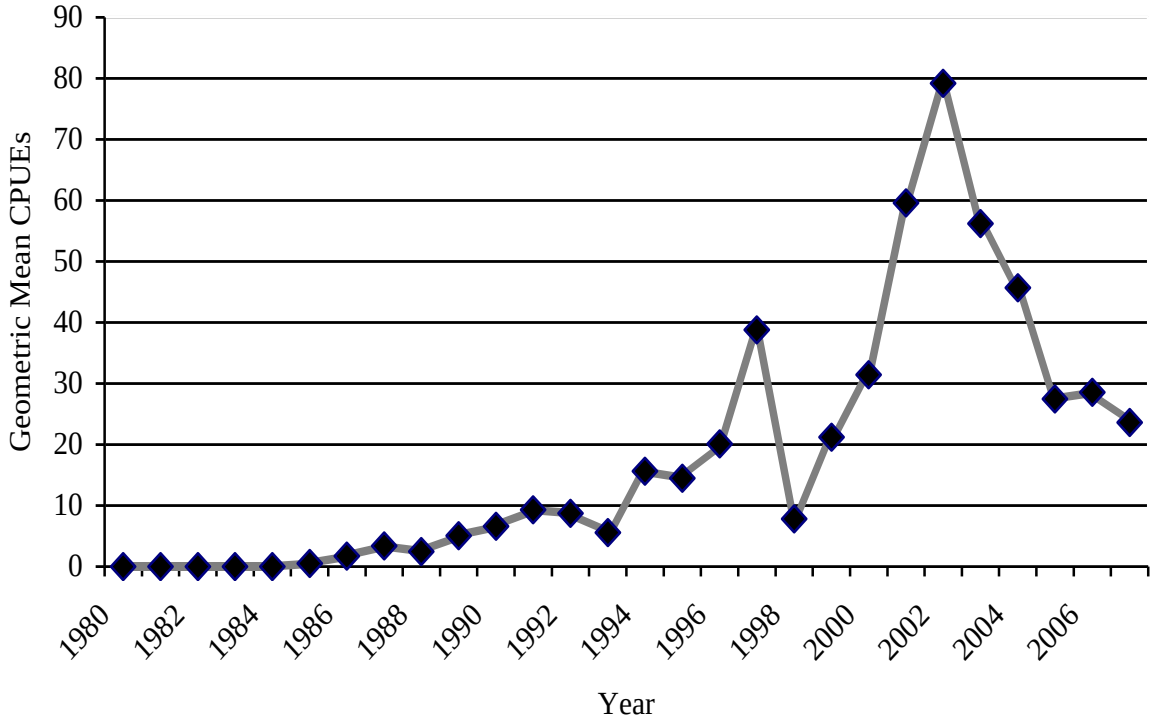

Figure 6. Geometric mean CPUE of American shad from the lifts at Conowingo Dam

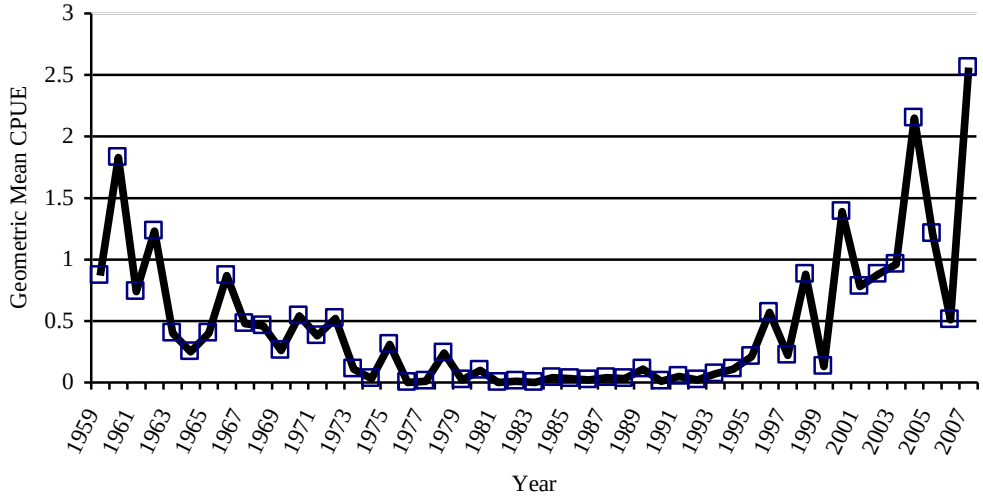

Figure 7. Baywide juvenile American shad geometric mean CPUEs, 1959-2007

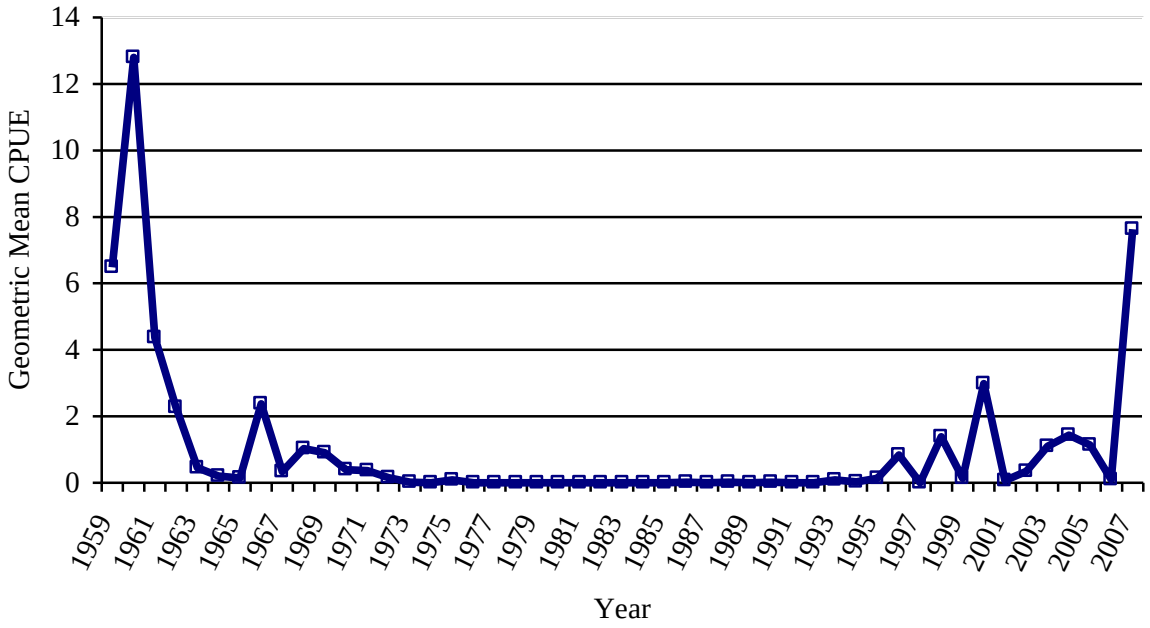

Figure 8. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1959-2007