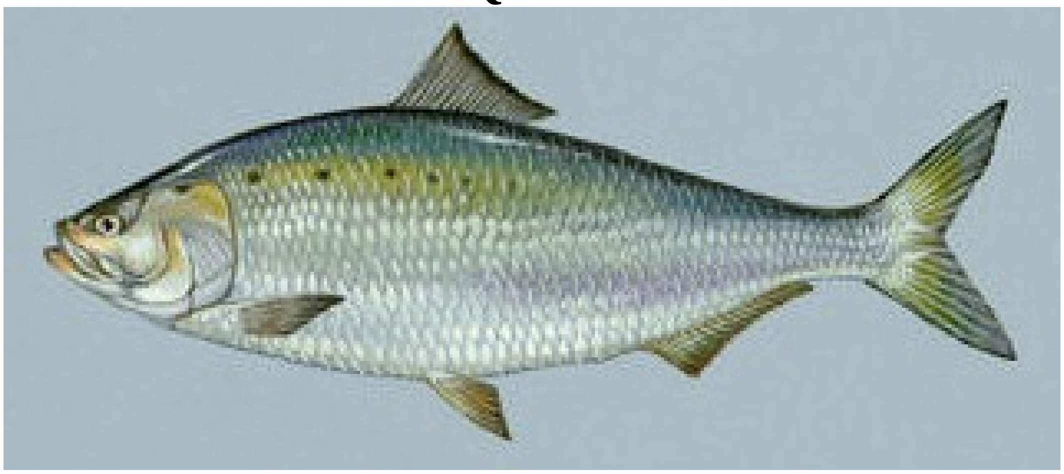
RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2006

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

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

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EXECUTIVE SUMMARY

This 2006 Annual Report of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) presents results from activities and studies directed at restoring American shad to the Susquehanna River. Rebuilding anadromous American shad and river herring stocks is based on hatchery releases and natural reproduction of adult fish passed directly through fish lifts at Conowingo, Holtwood, Safe Harbor dams and a fish ladder at York Haven dam. The restoration program represents a continuing commitment among all of the SRAFRC parties and its partners to return migratory fishes to historic spawning and nursery habitat upstream of dams in the Susquehanna River.

Spring 2006 water temperatures during fish passage operations were warmer than in 2005 (63-72 vs. 60-70° F) and river flows were higher in 2006 compared to 2005 (18,000-69,000 vs. 12,000-50,000 cfs). The Conowingo East lift began operations on April 3, shad first appeared in abundance on April 7, and the lift operated every day thereafter through June 7 when high water and low catch terminated operations. For the season the East lift operated 61 days, made 619 lifts and passed 714,918 fish. Gizzard shad (655,990) and American shad (56,899) comprised over 99% of all fish passed. Other alosines included only 4 hickory shad, and no alewives or blueback herring. American shad were collected at water temperatures of 52.7 to 75.6°F and at natural river flows of 19,500 to 69,000 cfs (Table 2 and Figure 1). The natural river flow and water temperature during the five highest days of shad passage, (22, 23 April, 3, 5 and 7 May), ranged from 24,200 cfs to 34,500 cfs and 63.1°F to 69.0°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 28,541 cfs. The average daily river flow during the operational season was 29,864 cfs. During the 2006 season, the East fish lift passed a total of 84 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the MDDNR. Of these floy-tagged fish, 80 tags were orange (2006 hook and line), 2 blue (2005 gill net), 1 yellow (2006 gill net), and 1 green (2005 hook and line).

West lift operations began on April 19 and occurred on 37 of the next 45 days through June 2. Total fishing effort over this period amounted to 394 lifts and a fishing time of 214.5 hours. Total catch amounted to 163,131 fish (38 taxa). Gizzard shad comprised 91% of the total catch and the next four most numerous species, channel catfish, walleye, brown bullhead and white perch comprised 4% of the total. Alosine catch included 3,970 American shad (2.4% of the total catch), 8 river herring, and no hickory shad. Catch of American shad averaged 107 per operating day with peak day catches of 753 and 339 shad on May 7 and 14, respectively. Every 50^{th} shad collected throughout the season was killed for otolith analysis and scale samples. Of the 180 shad sacrificed for hatchery vs. wild analysis by PFBC, 50% were shown to be of hatchery origin. A total of 1,557 American shad were used for tank spawning on-site at Conowingo Dam.

Fishway operations at Holtwood Dam began on 11 April 2006, the earliest start date at Holtwood since fish passage operations began in 1997. The tailrace lift was operated for 57 days while the spillway lift operated on 20 days. The lifts passed 296,038 fish of 27 taxa plus two hybrids. Gizzard and American shad (35,968) dominated the catch, and comprised nearly 89% of the total fish collected and passed. A total of 33,088 American shad (92% of total catch) was passed in the tailrace lift while the spillway lift accounted for 2,880 American shad (8% of total catch). Collection and passage of shad varied daily with 57% of total shad (20,551) passed during the 14 day period from 2 through 15 May. The 2006 American shad passage rate at Holtwood versus Conowingo (63.2% of fish passing Conowingo passed Holtwood) was the highest observed since operations commenced in 1997. The passage rate may have been the product of stable river flows, minimal equipment malfunctions, and the longest passage season recorded to date at Holtwood.

The Safe Harbor fish lift operated for 503.2 hours during 53 days between April18 and June 9 and made 573 lifts. A total of 244,907 fish of 23 species and 2 hybrids passed upstream into Lake Clarke. Gizzard shad (179,150) was the dominant species passed and comprised 73% of the catch. Some 24,929 American shad were passed upstream through the fish way and comprised 10% of the catch. Other predominant fishes passed included quillback (14,754), walleye (14,079), channel catfish (4,673), and smallmouth bass (3,307). Peak passage occurred on 12 May, when 15,996 fish were passed. Passage of other alosines, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2006. Safe Harbor passed about 69% of the American shad counted at Holtwood.

The York Haven fish ladder was opened on 31 March allowing volitional (unmanned) passage. Manned Fishway operation started on 22 April and ended on 12 June. During this 52 day period a total of 195,410 fish of 18 taxa were enumerated as they passed upstream though the ladder into Lake Frederic. Gizzard shad (164,869) was the dominant fish species passed and comprised over 84% of the fish passed. Passage varied daily and ranged from 961 fish on 24 May to 10,045 fish on 6 May. A total of 1,913 American shad were counted as they passed through the ladder.

Maryland DNR collected shad for tag and release by angling in the Conowingo tailrace. The 2006 male-female ratio for Conowingo tailrace adult American shad was 0.63:1. Of the 360 fish sampled by angling, 338 (94.2%) were aged directly from their scales. Males were present in age groups 3-7 while females were found in age groups 3-9. The 2002 year-class of males (age IV) was the most abundant age group sampled, accounting for 48% of the total catch. For females, the 2002 (age IV) was the most abundant age group, accounting for 46%, of the total catch. The percentages of Conowingo tailrace repeat spawning American shad was 16.2% for males and 16.3% for females. The arcsine-transformed proportions of Conowingo tailrace American shad repeat spawners (sexes combined) had been increasing until 2006 when it decreased The Conowingo tailrace American shad relative population estimate in 2006 was 168,165 (95% confidence intervals 135,455-199,493).

A total of 180 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2006. Based on tetracycline marking, 50% of the 177 readable otoliths were identified as wild and 50% 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 1986-2000 year classes, stocking of approximately 314 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 2.10 adults to upstream areas was required to return one wild fish to the lifts. Actual survival is even higher since not all surviving adults enter the lifts.

The U.S. Fish and Wildlife Service (USFWS) was contracted by Pennsylvania Fish and Boat Commission (PFBC) to collect American shad eggs from the Potomac and Hudson Rivers.   The purpose of the collection was to supply viable eggs to the Van Dyke American Shad Hatchery in support of ongoing Susquehanna River American shad restoration efforts. Over 29 sampling days, 99.3 L (44% viable) and 60.0 L (69% viable) of eggs were delivered from the Potomac and Hudson Rivers, respectively, with a potential yield of ≈ 3.2 million individuals. The Potomac River catch was dominated by gizzard shad (39%), American shad (29%) and striped bass (27%). Green female, ripe female, and male shad represented 13%, 12% and 5% of the catch, respectively. The Hudson River catch was dominated by American shad (64%) and brown bullhead (17%). Male, ripe female, and green female shad represented 34%, 18% and 12% of the catch, respectively. On average, the Potomac River yielded more ripe/running male and female American shad per unit effort than did the Hudson River, which was offset by the Hudson's increased egg viability.

The PFBC also collected shad eggs from the Delaware River at Smithfield Beach, PA. Fishing occurred from 3 May through 1 June 2006. Eggs were collected and shipped on 12 of the 15 nights of fishing. A total of 358 adult shad were captured and 64.9 liters of eggs were shipped for a hatchery count of 2.3 million eggs. Overall, the viability for Delaware River American shad eggs was 50%.

Hormone induced spawning trials with hickory shad at Conowingo Dam began on April 11 and concluded on April 19, 2006. During this interval, 4 spawning trials, (3 pellet, 1 liquid), were conducted with 398 adult hickory shad. A total of 26.8 liters of eggs was collected from the hickory shad trials and shipped to the Van Dyke Hatchery. The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 60.6%.   A total of 20 on-site spawning trials with 1557 American shad from April 20 to 3 June produced 169.3 liters of eggs. All eggs were shipped to the Van Dyke Hatchery and none were released into the river below Conowingo Dam. Fourteen of the trials were conducted with pelletized implants and six with liquid injections. 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. Both sexes received an identical dosage of $LHRH_a$ (150 ug). The total volume of eggs produced per female in individual 2006 trials (0.27 liters) was below the average of 0.43 liter observed for the previous four years. When adjusted for viability, the volume of viable eggs produced per female in the 2006 trials ranged from 0.01 to 0.14 liter in all trials. The overall estimated viability of the eggs shipped to Van Dyke was 22%.

The results of the hickory shad hormone-induced spawning trials at Conowingo Dam in 2006 showed a continuation of the high quality levels achieved in 2005. The estimated overall egg viability of 60.6% is similar to the 61.4% experienced in 2005. This was the sixth year of hormone induced American shad spawning trials at the Conowingo West Fish. The results of the 2006 spawning trials were similar to last year's results and were within the range of results of previous years.

Five shipments of hickory shad eggs (15 million eggs) were received at Van Dyke in 2006. Egg viability was 61% and 9.2 million hickory shad larvae were stocked in Conowingo Reservoir and in the Delaware River and its tributaries, Pennypack Creek and Ridley Creek. A total of 46 shipments of American shad eggs (19 million eggs) was received at Van Dyke in 2006. Total egg viability was 35% and survival of viable eggs to stocking was 74%, resulting in production of 4.9 million larvae. Larvae were stocked in the Juniata River, the Susquehanna River near Montgomery Ferry, the West Branch Susquehanna River, the North Branch Susquehanna River in Pennsylvania, Conodoguinet Creek, the Conestoga River, Swatara Creek, West Conewago Creek, the North Branch Susquehanna River in New York, and the Chemung River in New York. Delaware River source larvae were stocked in the Lehigh River, the Schuylkill River and the Delaware River. Overall survival of larvae was 74%. No episodes of major mortality occurred as a result of larvae lying on the bottom of the tank but unexplained mortalities occurred in 12 tanks late in the season. Van Dyke jars with foam bottom screens were used seven times with no mortality problems. 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.

As was the case in 2002-2005, juvenile shad collections continued to be relatively weak in 2006. One juvenile American shad of hatchery origin was captured by haul seine on October 18, resulting in a Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) of 0.01 (Tables 1 and 2). Lift-netting at Holtwood Dam inner fore-bay resulted in 8 juvenile American shad captured in 300 lifts. All shad were captured on October 24. Geometric Mean CPUE (individual lift) was 0.01 while GM CPUE (combined daily) was 0.03. Peach Bottom intake screens produced 59 juvenile American shad and one blueback herring between October 23 and November 10. Cooling water intake strainers at Conowingo produced 4 American shad, collected between 26 October and 8 November, but only 2 specimens were suitable for analysis. Four alewives were collected in strainer samples in 2006. In 2006, 20 juvenile American shad were captured at seven permanent sites by Maryland DNR's juvenile finfish haul seine survey during 24 hauls, and 3 juvenile American shad were captured at the auxiliary sites during 36 hauls.

A total of 70 juvenile American shad were collected in haul seines, lift nets, Peach Bottom intakes and Conowingo strainers. Of the 70 specimens evaluated for hatchery tags, 10% were wild and 90% were hatchery. Represented in the catch were YOY shad from releases in the Juniata River (Potomac River egg source), Juniata River (Susquehanna River egg source), Conodoguinet Creek, Swatara Creek, Conestoga River, Chemung River, and the West Branch Susquehanna River. No shad were recaptured from releases in West Conewago Creek, or the North Branch Susquehanna River (either PA or NY releases).

The second year of a 2-year genetic assessment of Susquehanna shad was completed by USFWS Northeast Fishery Center (NEFC). The objective of the study was to use a combination of molecular markers to quantify current estimates of genetic diversity of the adult shad population on the Susquehanna relative to two neighboring populations. A total of 15 new microsatellite markers were developed for American shad (Julian and Bartron *in press*) and these were used to evaluate the partitioning of genetic diversity among adults returning to two sites in the lower portion of the Susquehanna River (Conowingo and Lapidum) as well as two neighboring rivers that are current sources of eggs for stocking (Delaware and Hudson rivers).

Genotypes were obtained for a total of 387 American shad. All collections exhibited a high level of genetic diversity as a total of 256 alleles were observed over all 14 loci. Some genetic structure was evident among the sampling collections. Pairwise tests of differences in allele frequencies between collections revealed significant genetic differentiation. Pairwise tests of allele heterogeneity revealed significant differences ($P<0.001$) between the Delaware and Hudson collections and also between the Delaware and both Susquehanna collections. Significant differences in allele heterogeneity were not observed between Hudson and Susquehanna collections. Unique alleles were present in all populations (18 in Susquehanna, 22 in Delaware, and 10 in Hudson). Maximum likelihood assignment tests were performed to determine the likelihood of a genotype being assigned back to the correct collection of origin. Assignment success was highest for the Delaware collection, with 51.68% of animals correctly assigned (approximately twice what would be expected by chance alone). Assignment was lowest for the Susquehanna collections with only 36.46% (Conowingo) and 19.35% (Lapidum) correctly assigned back to origin. Less than 10% incorrect assignment occurred between the Delaware and Hudson collections which suggest genetic differentiation between those two rivers and mixing of genetic stocks in the Susquehanna. Simulations were performed using Structure (Version 2.1; Pritchard et al. 2000) and samples were assigned to infer the number of contributing source populations. These results may indicate historically high amounts of gene flow between the three drainages (natural or directed), and lack of overall significant genetic population differentiation may reflect contemporary demographic events. The data from mitochondrial regions cyt *b* and ND1 do not support genetic differentiation between the three rivers.

It is likely that the proportional contribution of stocking source and return rates from each stocking source has a large influence on gene frequencies and the current genetic structure within the Susquehanna. The long term adaptive potential of the Susquehanna population seems limited given the current management strategy of stocking from outside sources. As a naturally-reproducing American shad population becomes established within the Susquehanna River, continued introductions of multiple stocks will not allow for local adaptation and reduce the potential for increased fitness (due to local adaptation) within the Susquehanna American shad population. If feasible, managers may want to consider increasing supplementation efforts from wild adults returning to the Susquehanna or using only one outside source river in order to minimize the potential for outbreeding depression. Additional sampling and analysis of geographically distant American shad populations may also provide more insight into relative levels of population genetic differences given the history of out-of-basin stocking for the populations sampled for this study.

USFWS staff from Maryland Fishery Resources Office in Annapolis sampled for American immediately downstream for Conowingo Dam from May 8 through June 26, 2006. Sampling was limited to the west side of the dam. 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. The West Fish Lift was also operated for six lifts, in an attempt to determine the feasibility of sampling for juvenile eels. Stream flow, temperature and other water quality parameters were monitored at collection sites. A data logger was deployed to collect water temperature four times per day during the sample period. 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/). Eels were captured throughout the period sampled. Length frequencies ranged from 83 to 735 mm TL. Captured eels were sedated, measured, fin clipped and released. Sub samples of juvenile eels were collected for oxytetracycline (OTC) marking of otoliths to validate aging techniques. These eels were marked by immersing them in a 550 ppm OTC bath for 6 hours. They were then held in a pond for one year. Otolith samples from these eels are currently being processed. The largest capture of elvers occurred during a period of low lunar fraction on July 16. Captures of eels in pots during 2006 also showed a correlation to lunar fraction.

Fish passage facility maintenance, operations, fish counting and reporting were paid by each of the affected utility companies in accordance with guidelines established by separate fish passage advisory committees. American shad egg collections from the Hudson and Potomac Rivers, Van Dyke hatchery culture and marking, juvenile shad netting and other surveys above Conowingo Dam, and otolith mark analysis were funded by the PA Fish and Boat Commission. Maryland DNR funded the adult shad population assessment, stock analysis, and juvenile shad seining in the upper Chesapeake Bay. USFWS covered most costs associated with the eel survey at Conowingo. Costs related to Conowingo West fish lift operations including tank spawning and hormones were paid from a SRAFRC contributed funds account administered by USFWS. This account also paid for genetics supplies and analysis at NEFC. Contributions to the special account in 2006 came from Maryland DNR and PFBC.

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

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Job I – Part 1

SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY, SPRING 2006

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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 2006 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.

CONOWINGO OPERATION

Project Operation

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

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

Fishway Operation

The East lift operation began 3 April with the passage of four American shad recorded. Two days later, on 5 April, four more American shad were passed, which seemed to indicate that the shad season would follow previous years of migration which started off slow, but had shad numbers increasing into late spring. That philosophy was changed, however, when 507 American shad were passed on 7 April, triggering everyday operations. The season continued until 5 June, when a combination of high water temperatures, dwindling shad numbers, and the late season condition of the shad ultimately required operations to cease. The lift operated a total of 61 days during the 2006 season, only experiencing mechanical problems during the last lift on 3 May, which halted operations on 4 May. Repairs were successfully completed, enabling operations to resume on 5 May.

Daily operation times where 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 2006 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, entrances C or A was utilized throughout the 2006 season to attract fishes.

Fish Counts

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

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

RESULTS

Relative Abundance

The number of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 1. A total of 714,918 fish of 30 species and two hybrids was passed upstream into Conowingo Pond. Gizzard shad (655,990), American shad (56,899), walleye (641) quillback (407), white perch (277), smallmouth bass (165), were the dominant species passed. Gizzard shad and American shad comprised 91.75% and 7.95% respectively of the season total; the two species together accounted for 99.7% of the total fish passed. Other common fishes included carp (108), channel catfish (75). striped bass (73) and shorthead redhorse (10). Alosids, (American shad, and Hickory shad) comprised 7.6 % of the total catch. Peak passage occurred on 24 April when 36,297 fish, (nearly 99% gizzard shad), were passed.

American Shad Passage

The East lift collected and passed 56,899 American shad (Table 1). The first shad was passed on 3 April. Collection and passage of shad varied daily with 34.2% (19,446) of the shad passed from 3 to 30 April, 42.4% (24,152) passed from 1 to 10 May, 11.2 % (6,399) passed from 11 to 20 May, 10.1% (5,764) passed from 21 to 30 May, and 2.0% (1,138) passed from 31 May to 5 June (Figures 1 and 2). On 5 of the 61 days of operation, American shad passage exceeded 3,000 fish. Peak passage occurred on 3 May when 6,130 American shad were passed.

American shad were collected at water temperatures of 52.7 to 75.6°F and at natural river flows of 19,500 to 69,000 cfs (Table 2 and Figure 1). The natural river flow and water temperature during the five highest days of shad passage, (22, 23 April, 3, 5 and 7 May), ranged from 24,200 cfs to 34,500 cfs and 63.1°F to 69.0°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 28,541 cfs. The average daily river flow during the operational season was 29,864 cfs.

The hourly passage of American shad for the East lift is given in Table 3. Peak passage of shad (49,720 or 87% of total passage) occurred between 1000 and 1759 h. The highest hourly shad passage rate, (8,505), was recorded from 1600 to 1659 h. Generally, shad passage increased during the morning hours, peaked and remained steady throughout the day, then sharply declined after 1800 hrs.

Job I – Part 1

Alosids

No alewife or blueback herring were passed during the 2006 season. Only 4 Hickory shad were collected and passed in spring 2006.

SUMMARY

East fish lift operation was initiated on 3 April with the passage of 4 American shad recorded that day. The East fish lift passed 56,899 American shad from 3 April through 5 June. The total number of American shad passed during the 2006 season was the lowest passage total for East lift operations since 1998, and is the second in seven years, (two years in a row) where the lift did not surpass the 100,000 mark (Table 4).

During the 2006 season, the East fish lift passed a total of 84 American shad that were captured, floy-tagged and released downstream of Conowingo dam by the MDDNR. Of these floy-tagged fish, 80 tags were orange (2006 hook and line), 2 blue (2005 gill net), 1 yellow (2006 gill net), and 1 green (2005 hook and line).

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 171 American shad lift mortalities, (0.30% of the total shad passed), were observed in 2006, similar to lift mortalities observed in recent years (0.2% to 1.0%) and less than values observed during trap and transport operations (1.5% to 10.5%).

RECOMMENDATIONS

1) Continue to operate the 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.

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

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

LITERATURE CITED

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

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

Table 1: Page 1 of 8

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2006. No operation on April 12th and May 4th.

Date:	*4/3*	*4/5*	*4/7*	*4/8*	*4/9*	*4/10*	*4/11*	*4/13*
Start Fishing Time:	*11:30*	*11:15*	*10:30*	*9:45*	*10:30*	*11:00*	*10:30*	*10:00*
End Fishing Time:	*16:00*	*16:00*	*17:00*	*16:10*	*17:10*	*15:30*	*16:30*	*18:00*
Hours of Operation:	*4.5*	*4.8*	*6.5*	*6.4*	*6.7*	*4.5*	*6.0*	*8.0*
Number of Lifts:	*6*	*6*	*8*	*8*	*8*	*5*	*6*	*10*
Water Temperature (°F):	*52.7*	*48.6*	*55.1*	*54.5*	*53.6*	*55.1*	*55.4*	*57.2*
American Shad	4	4	507	429	227	55	28	850
Gizzard shad	278	1,398	4,392	5,593	2,236	1,150	204	5,415
Hickory Shad	2	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
White Crappie	0	1	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	6
American eel	0	0	0	0	0	0	0	0
Sea lamprey	0	0	2	0	2	1	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	0	0	0	1	0	0	0
Quillback	0	0	0	0	0	0	0	0
White sucker	1	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	1	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	0	0	0	0
Redbreast 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	1	8	7	0	0	1	0
Largemouth bass	0	0	0	0	0	0	0	3
Yellow perch	1	3	1	1	0	0	0	0
Walleye	0	1	0	0	0	0	0	1
Yellow bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	1	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*286*	*1,408*	*4,910*	*6,032*	*2,466*	*1,206*	*233*	*6,275*

Table 1: Page 2 of 8

Continued.

Date:	*4/14*	*4/15*	*4/16*	*4/17*	*4/18*	*4/19*	*4/20*	*4/21*
Start Fishing Time:	*10:30*	*10:00*	*10:00*	*11:00*	*10:00*	*9:50*	*9:30*	*9:00*
End Fishing Time:	*17:45*	*17:00*	*17:00*	*17:35*	*17:20*	*17:30*	*18:25*	*18:45*
Hours of Operation:	*7.3*	*7.0*	*7.0*	*6.6*	*7.3*	*7.7*	*8.9*	*9.8*
Number of Lifts:	*9*	*10*	*9*	*9*	*10*	*9*	*12*	*13*
Water Temperature (°F):	*57.2*	*59*	*59.4*	*59*	*60*	*60.8*	*61.7*	*62.6*
American Shad	1149	884	628	2042	500	22	1,054	1,211
Gizzard shad	6,906	8,153	1,811	6,153	7,052	10,664	23,040	15,944
Hickory Shad	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	0
American eel	0	0	0	0	0	0	0	0
Sea lamprey	8	4	1	1	4	2	2	3
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	1
Tiger musky	0	0	0	1	0	0	0	1
Carp	0	0	1	2	0	0	2	0
Quillback	0	0	2	0	2	0	1	3
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	0	0	0	0	1
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	1	0	0	0
Redbreast 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	31	6	4	4	2	14	8	5
Largemouth bass	0	0	0	1	0	0	0	0
Yellow perch	0	0	0	1	0	0	0	0
Walleye	1	0	1	0	0	0	1	1
Yellow bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden Shiner	1	0	0	0	0	0	0	0
Spottail Shiner	0	0	0	2	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*8,096*	*9,047*	*2,448*	*8,207*	*7,561*	*10,702*	*24,108*	*17,170*

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Continued.

Date:	*4/22*	*4/23*	*4/24*	*4/25*	*4/26*	*4/27*	*4/28*	*4/29*
Start Fishing Time:	*8:00*	*7:50*	*8:00*	*7:30*	*8:00*	*8:00*	*8:00*	*8:00*
End Fishing Time:	*17:30*	*18:00*	*17:45*	*14:45*	*16:00*	*16:00*	*17:00*	*17:30*
Hours of Operation:	*9.5*	*10.2*	*9.8*	*7.3*	*8.0*	*8.0*	*9.0*	*9.5*
Number of Lifts:	*15*	*15*	*14*	*7*	*9*	*9*	*11*	*12*
Water Temperature (°F):	*62.6*	*61.7*	*61.7*	*61.7*	*59*	*59*	*59*	*59*
American Shad	3,182	3,861	388	24	3	87	395	284
Gizzard shad	5,469	24,762	35,861	26,113	22,786	29,202	24,357	18,816
Hickory Shad	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	1
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	1	0	0	0	0	0
White perch	0	0	0	3	46	15	18	11
American eel	0	0	0	0	0	0	0	0
Sea lamprey	4	7	12	6	9	2	2	2
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0
Tiger musky	0	1	0	0	0	0	0	0
Carp	3	0	4	0	1	0	0	0
Quillback	0	0	0	0	0	0	0	0
White sucker	0	0	1	0	0	0	0	0
Shorthead redhorse	0	0	2	1	0	0	0	1
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	1	0	0	0	2	0
Rock bass	0	0	0	0	0	4	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	1	0
Bluegill	0	0	0	0	2	0	0	0
Smallmouth bass	1	0	5	5	6	4	2	0
Largemouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	4	0	1	0	0	0
Walleye	0	3	18	11	16	14	18	7
Yellow bullhead	0	1	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden Shiner	0	0	0	0	1	0	0	0
Spottail Shiner	0	0	0	0	0	0	0	1
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*8,659*	*28,635*	*36,297*	*26,163*	*22,871*	*29,328*	*24,795*	*19,123*

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Continued.

Date:	*4/30*	*5/1*	*5/2*	*5/3*	*5/4*	*5/5*	*5/6*	*5/7*
Start Fishing Time:	*7:00*	*8:30*	*8:00*	*8:00*	*7:00*	*9:00*	*8:00*	*8:30*
End Fishing Time:	*18:15*	*17:00*	*17:00*	*18:30*	*7:00*	*18:45*	*18:00*	*18:00*
Hours of Operation:	*11.3*	*8.5*	*9.0*	*10.5*	*0.0*	*9.8*	*10.0*	*9.5*
Number of Lifts:	*14*	*11*	*13*	*17*	*0*	*16*	*15*	*15*
Water Temperature (°F):	*59*	*59*	*60.8*	*62.3*	*62.4*	*64.4*	*64.8*	*65.3*
American Shad	1,628	2,051	2,865	6,130	16	4,649	1,529	3,814
Gizzard shad	20,966	12,942	17,284	24,861	18	19,466	24,053	13,210
Hickory Shad	0	0	0	2	0	0	0	0
Striped bass	0	0	0	0	0	0	1	0
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	1	0	0	0	0
White perch	6	1	4	6	0	6	5	6
American eel	0	0	0	0	0	0	0	0
Sea lamprey	1	4	5	3	0	9	3	3
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	1	0	0
Tiger musky	0	0	0	1	0	0	0	0
Carp	0	1	1	1	1	2	1	16
Quillback	0	0	0	0	0	1	11	28
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	2	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	2	0	10	0	0
Rock bass	1	0	0	1	0	1	2	1
Redbreast sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	1
Bluegill	0	0	0	1	0	0	0	0
Smallmouth bass	0	0	4	10	0	6	4	0
Largemouth bass	0	0	0	1	0	0	0	0
Yellow perch	0	1	1	0	0	0	0	0
Walleye	4	6	7	30	0	91	26	12
Yellow Bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*22,606*	*15,006*	*20,171*	*31,052*	*35*	*24,242*	*25,635*	*17,091*

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Continued.

Date:	*5/8*	*5/9*	*5/10*	*5/11*	*5/12*	*5/13*	*5/14*	*5/15*
Start Fishing Time:	*8:00*	*8:30*	*9:00*	*7:45*	*8:00*	*8:00*	*7:45*	*8:30*
End Fishing Time:	*18:00*	*17:30*	*17:45*	*17:00*	*17:20*	*17:30*	*17:30*	*17:00*
Hours of Operation:	*10.0*	*9.0*	*8.8*	*9.3*	*9.3*	*9.5*	*9.8*	*8.5*
Number of Lifts:	*12*	*12*	*13*	*13*	*14*	*12*	*12*	*11*
Water Temperature (°F):	*64.8*	*66.2*	*67*	*66.6*	*67.7*	*68.2*	*67.1*	*67.1*
American Shad	1473	642	983	1620	425	650	1076	294
Gizzard shad	18,378	32,359	11,482	16,302	25,769	12,305	12,534	15,594
Hickory Shad	0	0	0	0	0	0	0	0
Striped bass	0	1	0	1	0	1	0	0
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	1	0	0	0	0	0
White perch	1	8	0	3	5	2	2	0
American eel	0	0	0	0	0	0	3	0
Sea lamprey	4	3	2	2	2	3	3	0
Rainbow trout	0	0	1	1	0	1	0	0
Brown trout	1	1	0	0	1	0	0	0
Tiger musky	1	0	0	0	0	0	0	0
Carp	0	1	6	1	3	1	3	1
Quillback	9	8	59	70	10	2	57	1
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	1	0	0	1	0
Brown bullhead	0	0	0	0	0	0	1	0
Channel catfish	5	0	7	0	1	1	2	1
Rock bass	2	0	1	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	1
Bluegill	0	1	2	2	0	0	4	0
Smallmouth bass	1	2	3	2	3	0	1	0
Largemouth bass	0	1	0	0	0	3	1	0
Yellow perch	0	2	5	0	1	0	0	0
Walleye	39	7	20	17	18	12	5	18
Yellow Bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*19,914*	*33,036*	*12,572*	*18,022*	*26,238*	*12,981*	*13,693*	*15,910*

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Continued.

Date:	*5/16*	*5/17*	*5/18*	*5/19*	*5/20*	*5/21*	*5/22*	*5/23*
Start Fishing Time:	*8:00*	*7:45*	*8:00*	*8:00*	*8:00*	*7:45*	*8:00*	*8:00*
End Fishing Time:	*17:00*	*17:00*	*17:45*	*17:00*	*17:08*	*16:50*	*17:00*	*17:00*
Hours of Operation:	*9.0*	*9.3*	*9.8*	*9.0*	*9.1*	*9.1*	*9.0*	*9.0*
Number of Lifts:	*12*	*13*	*13*	*12*	*8*	*9*	*9*	*9*
Water Temperature (°F):	*66.2*	*66.6*	*66.2*	*66.2*	*64.4*	*64.1*	*63*	*62.6*
American Shad	418	587	336	543	450	1296	409	358
Gizzard shad	10,160	13,430	11,187	7,682	737	2,045	5,636	2,205
Hickory Shad	0	0	0	0	0	0	0	0
Striped bass	1	1	0	9	5	3	2	5
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	2	0	3	3	0	5	2	6
American eel	5	0	0	0	0	0	2	0
Sea lamprey	0	1	1	0	0	0	0	0
Rainbow trout	0	0	1	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	1	2	0	0	0	0	0
Quillback	0	0	2	0	0	0	1	0
White sucker	1	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	2	0	5	2	0	1	0	0
Rock bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	1	0	1	0	0	0
Smallmouth bass	2	1	0	0	0	0	0	0
Largemouth bass	0	1	0	1	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	23	58	43	62	18	34	32	21
Yellow Bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	0	0	0
Atlantic Needlefish	0	0	0	0	0	0	0	0
TOTAL	*10,614*	*14,080*	*11,581*	*8,302*	*1,211*	*3,384*	*6,084*	*2,595*

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Continued.

Date:	*5/24*	*5/25*	*5/26*	*5/27*	*5/28*	*5/29*	*5/30*	*5/31*
Start Fishing Time:	*8:00*	*8:00*	*7:30*	*7:00*	*7:45*	*7:00*	*6:45*	*7:30*
End Fishing Time:	*18:00*	*17:00*	*17:30*	*17:00*	*17:00*	*15:00*	*15:00*	*17:00*
Hours of Operation:	*10.0*	*9.0*	*10.0*	*10.0*	*9.3*	*8.0*	*8.3*	*9.5*
Number of Lifts:	*10*	*9*	*10*	*9*	*9*	*8*	*8*	*8*
Water Temperature (°F):	*62.3*	*64.4*	*65.3*	*64.4*	*66.2*	*68*	*70*	*71.3*
American Shad	509	614	735	715	506	517	105	501
Gizzard shad	5,986	3,522	4612	6223	4369	4557	1328	2553
Hickory Shad	0	0	0	0	0	0	0	0
Striped bass	3	7	3	3	1	2	3	7
White Crappie	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	3	6	4	16	4	2	2	4
American eel	0	0	0	0	0	0	0	0
Sea lamprey	0	0	1	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	1
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	0	0	0	1	0	1	0
Quillback	0	0	1	0	45	20	3	37
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	3	0
Channel catfish	0	2	1	0	1	1	4	4
Rock bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	1	0	0	0	2
Pumpkinseed	0	0	0	0	0	0	0	1
Bluegill	0	0	0	0	0	1	0	8
Smallmouth bass	0	0	7	0	0	0	0	1
Largemouth bass	0	1	0	0	0	0	1	0
Yellow perch	0	0	1	0	1	0	0	2
Walleye	47	26	25	26	15	11	5	11
Yellow Bullhead	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Black Crappie	0	0	0	0	0	1	0	0
Atlantic Needlefish	0	0	0	0	0	0	1	0
TOTAL	6,548	4,178	5,390	6,984	4,943	5,112	1,456	3,132

Table 1: Page 8 of 8

Continued.

Date:	*6/1*	*6/2*	*6/3*	*6/4*	*6/5*	***Total***
Start Fishing Time:	*7:00*	*7:00*	*7:00*	*7:30*	*7:30*	
End Fishing Time:	*15:00*	*15:00*	*14:00*	*14:00*	*12:00*	
Hours of Operation:	*8.0*	*8.0*	*7.0*	*6.5*	*4.5*	**429.8**
Number of Lifts:	*8*	*7*	*7*	*7*	*4*	**619**
Water Temperature (°F):	*73.6*	*77*	*77*	*75.6*	*75.2*	
American Shad	256	190	122	61	8	**56,899**
Gizzard shad	698	980	1807	685	310	**655,990**
Hickory Shad	0	0	0	0	0	**4**
Striped bass	2	3	0	3	5	**73**
White Crappie	0	0	0	0	0	**1**
Hybrid striped bass	0	0	1	0	0	**4**
White perch	1	1	0	34	25	**277**
American eel	0	0	1	0	0	**11**
Sea lamprey	0	0	0	1	3	**128**
Rainbow trout	0	0	0	0	1	**5**
Brown trout	0	0	0	0	0	**6**
Tiger musky	0	0	0	0	0	**5**
Carp	0	29	0	10	11	**108**
Quillback	2	15	7	7	3	**407**
White sucker	0	0	0	0	0	**3**
Shorthead redhorse	0	0	0	0	0	**10**
Brown bullhead	1	0	0	0	0	**5**
Channel catfish	5	2	1	8	4	**75**
Rock bass	0	0	0	0	0	**14**
Redbreast sunfish	0	2	0	0	0	**5**
Pumpkinseed	0	0	0	0	0	**4**
Bluegill	0	1	1	0	0	**25**
Smallmouth bass	0	0	0	0	4	**165**
Largemouth bass	0	0	0	0	0	**14**
Yellow perch	0	0	0	0	0	**26**
Walleye	3	4	0	23	5	**641**
Yellow Bullhead	0	0	0	0	0	**1**
Muskellunge	0	0	0	0	0	**1**
Golden shiner	0	0	0	0	0	**2**
Spottail shiner	0	0	0	0	0	**2**
Black Crappie	0	0	0	0	0	**1**
Atlantic Needlefish	0	0	0	0	5	**6**
TOTAL	968	1,227	1,940	832	384	**714,918**

Table 2: Page 1 of 3

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 2006. No operation on April 12, and May 4.

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
3-Apr	4	*0*	19,500	*56.1*	36	2	C	310	18.0-18.5	108.4	0
5-Apr	4	*0*	19,900	*56.6*	25	5	C	310	18.5-20.0	107.9	0
7-Apr	507	*0*	23,500	*55.0*	20	6	C,A	310	18.0-22.0	107.2	0
8-Apr	429	*1B*	25,800	*54.7*	28	6	C,A	310	18.0-20.0	107.5	0
9-Apr	227	*0*	27,800	*53.1*	25	5	A	310	18.0-21.0	108.3	0
10-Apr	55	*0*	27,700	*53.3*	22	7	A	310	19.0-20.5	107.5	0
11-Apr	28	*0*	28,600	*53.6*	25	4	A	310	19.0-19.5	108.5	0
13-Apr	850	*0*	28,700	*56.2*	25	7	C,A	310	18.5-22.0	107.5	0
14-Apr	1149	*0*	27,700	*58.7*	26	5	C,A	310	19.0-21.0	108.5	0
15-Apr	884	*0*	27,000	*59.9*	30	5	C,A	310	19.0-21.5	107.7	0
16-Apr	628	*0*	26,100	*61.2*	30	2	A	310	17.5-18.5	108.2	0
17-Apr	2042	*0*	25,800	*62.0*	31	7	A,C	310	19.5-22.5	108.5	0
18-Apr	500	*0*	26,500	*62.6*	36	5	A	310	19.0-20.5	107.3	0
19-Apr	22	*0*	26,500	*63.1*	36	6	C	310	20.5-21.5	108.7	0
20-Apr	1024	*0*	24,200	*63.7*	36	8	A,C	310	19.5-22.5	107.5	0
21-Apr	1211	*0*	23,900	*64.8*	30	5	C,A	310	19.5-21.0	107.3	0
22-Apr	3182	*0*	26,400	*64.2*	30	4	A	310	18.5-19.5	106.2	0
23-Apr	3861	*0*	34,500	*63.1*	30	11	A	310	20.0-21.0	108.9	0
24-Apr	388	*0*	46,100	*61.4*	30	11	C	310	22.0-23.0	107.3	0
25-Apr	24	*0*	59,100	*60.1*	30	11	C	310	23.00	107.3	0
26-Apr	3	*0*	65,200	*60.6*	17	11	C	310	23.0-23.5	106.8	0
27-Apr	87	*0*	69,000	*60.2*	30	11	C	310	23.50	108.0	0
28-Apr	395	*0*	60,200	*59.7*	27	11	C	310	23.50	107.4	0
29-Apr	284	*0*	50,400	*59.8*	18	11	C	310	23.25-23.75	107.6	0
30-Apr	1628	*1O*	45,700	*60.2*	25	8	A,C	310	18.5-22.0	108.4	0

Table 2: Page 2 of 3

Continued.

Date	American Shad Catch	MD DNR Recaptures*	Holtwood River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Crest Gates
1-May	2051	*0*	39,700	*60.7*	30	11	C,A	310	19.5-23.0	108.6	0
2-May	2865	*0*	34,500	*62.0*	30	11	C,A	310	20.0-23.5	107.5	0
3-May	6130	*1G,1O,1B*	32,200	*63.4*	36	7	C	310	20.0-23.0	108.0	0
4-May	16	*0*	30,300	*64.9*	36	0	0	310	0.00	108.1	0
5-May	4649	*8O*	28,000	*66.9*	36	7	C	310	22.0-22.5	108.5	0
6-May	1529	*4O*	22,900	*67.9*	36	5	A,C	310	19.0-21.0	107.4	0
7-May	3814	*18O,1Y*	24,200	*69.0*	36	2	A	310	18.0	106.7	0
8-May	1473	*8O*	21,500	*69.0*	36	5	C,A,C	310	19.5-21.5	106.8	0
9-May	642	*1O*	19,800	*68.6*	36	5	C	310	21.00	107.8	0
10-May	983	*7O*	18,800	*68.4*	36	5	C,A,C	310	19.5-20.5	107.0	0
11-May	1620	*10O*	18,400	*67.8*	36	6	C,A	310	19.0-21.0	107.2	0
12-May	425	*2O*	22,400	*66.6*	36	7	A,C	310	19.5-22.0	107.3	0
13-May	650	*3O*	24,100	*67.1*	36	4	A	310	19.50	106.5	0
14-May	1076	*3O*	26,300	*67.3*	36	6	A,C	310	18.0-21.5	107.7	0
15-May	294	*1O*	30,800	*67.0*	36	7	C	310	19.5-21.0	107.7	0
16-May	418	*2O*	33,100	*66.4*	36	7	C,A	310	19.5-22.0	107.4	0
17-May	587	*2O*	30,500	*64.8*	28	7	C	310	20.5-22.0	107.8	0
18-May	336	*0*	32,400	*64.2*	36	7	C	310	20.5-22.0	107.1	0
19-May	543	*0*	28,900	*64.3*	36	7	C	310	20.5-22.0	108.1	0
20-May	450	*0*	30,100	*64.3*	36	4	A	310	19	107	0
21-May	1296	*2O*	29,300	*64*	34	4	A	310	19	107.7	0
22-May	409	*0*	28,500	*62.9*	32	6	C	310	20.5-21.0	107.7	0
23-May	358	*1O*	27,300	*62.2*	34	6	C,A	310	19.0-21.0	107.8	0
24-May	509	*0*	24,400	*61.9*	36	6	C,A	310	19.5-21.0	108.1	0
25-May	614	*0*	24,900	*62.4*	33	8	A,C	310	18.5-22.5	108.3	0
26-May	735	*3O*	22,000	*63.2*	32	6	A,C	310	19.5-21.5	108.1	0
27-May	715	*1O*	25,000	*65.1*	34	5	A,C	310	18.5-20.5	108.2	0

Table 2: Page 3 of 3

Continued.

Date	American Shad Catch	MD DNR Recaptures*	Holtwood River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Crest Gates
28-May	506	*0*	22,400	66.93	36	5	A,C	310	17.0-20.	107.8	0
29-May	517	*0*	19,400	69.71	36	5	A,C	310	18.50	107.7	0
30-May	105	*0*	19,500	72.58	36	11	A,C	310	18.0-23.0	108.2	0
31-May	501	*0*	17,900	75.24	36	7	A,C	310	17.5-22.0	106.2	0
1-Jun	256	*1O*	24,200	*77.2*	36	6	A,C	310	17.5-22.0	107.0	0
2-Jun	190	*0*	26,100	*79.5*	36	8	A,C	310	17.5-22.5	108.7	0
3-Jun	122	*0*	24,900	*80.6*	36	7	A	310	17.0-22.0	108.6	0
4-Jun	61	*0*	30,400	*79.6*	36	5	A,C	310	17.0-20.50	107.9	0
5-Jun	8	*1O*	40,800	*77.3*	35	5	C	310	21.00	108.4	0

* Tag color: B = blue, G = green, O = orange, Y = yellow

Table 3: Page 1 of 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2006. No operation on April 12 and May 4.

Date:	*4/3*	*4/5*	*4/7*	*4/8*	*4/9*	*4/10*	*4/11*	*4/13*	*4/14*	*4/15*	*4/16*	*4/17*
Observation Time-Start:	*12:30*	*11:15*	*11:00*	*10:30*	*10:25*	*10:45*	*10:30*	*11:00*	*11:00*	*10:30*	*10:00*	*10:30*
Observation Time-End:	*16:30*	*16:30*	*17:30*	*16:45*	*17:30*	*16:30*	*17:30*	*18:20*	*18:15*	*17:00*	*17:30*	*18:00*
Military Time (hrs)												
0700 to 0759												
0800 to 0859												
0900 to 0959												
1000 to 1059				23	55					50	25	1
1100 to 1159		0		2	5	5	1		14	51	7	57
1200 to 1259		0		4	6	1	2	1	22	17	6	35
1300 to 1359	1	1	35	42	0	0	5	20	57	100	28	47
1400 to 1459	0	1	185	138	6	5	5	106	106	241	74	305
1500 to 1559	2	0	178	86	101	17	3	315	160	189	133	449
1600 to 1659	1	2	86	0	42	27	12	270	401	185	196	661
1700 to 1759			23	134	12			125	285	51	159	487
1800 to 1859								13	104			
1900 to 1959												
Total	4	4	507	429	227	55	28	850	1149	884	628	2042

Date:	*4/18*	*4/19*	*4/20*	*4/21*	*4/22*	*4/23*	*4/24*	*4/25*	*4/26*	*4/27*	*4/28*	*4/29*
Observation Time-Start:	*10:05*	*10:00*	*9:45*	*9:30*	*8:00*	*8:10*	*8:15*	*8:00*	*8:15*	*8:00*	*8:00*	*8:15*
Observation Time-End:	*17:50*	*18:00*	*19:00*	*19:15*	*18:00*	*18:30*	*18:15*	*15:30*	*16:30*	*16:30*	*17:30*	*18:00*
Military Time (hrs)												
0700 to 0759												
0800 to 0859					78	28	221	2	2		40	14
0900 to 0959				48	307	10	47	3	0		9	35
1000 to 1059	81	4	13	24	521	12	34	5	0		3	9
1100 to 1159	59	0	3	4	772	2	8	5	0	2	6	4
1200 to 1259	27	2	22	2	814	11	9	3	0	3	6	3
1300 to 1359	17	0	47	1	271	31	16	3	0	0	30	5
1400 to 1459	22	0	38	1	141	111	17	3	1	9	85	32
1500 to 1559	187	2	220	42	201	486	14			30	79	64
1600 to 1659	70	3	221	466	41	1,361	18			43	98	66
1700 to 1759	37	11	242	370	36	1,456	4				39	52
1800 to 1859			248	175		353						
1900 to 1959				78								
Total	500	22	1,054	1,211	3,182	3,861	388	24	3	87	395	284

Table 3: Page 2 of 3

Continued.

Date:	*4/30*	*5/1*	*5/2*	*5/3*	*5/4*	*5/5*	*5/6*	*5/7*	*5/8*	*5/9*	*5/10*	*5/11*
Observation Time-Start:	*8:00*	*8:30*	*8:00*	*8:00*	*8:00*	*9:00*	*8:00*	*9:00*	*8:00*	*8:15*	*8:30*	*8:10*
Observation Time-End:	*19:00*	*17:30*	*17:30*	*19:00*	*9:45*	*19:30*	*18:30*	*18:30*	*18:30*	*18:00*	*18:15*	*17:30*
Military Time (hrs)												
0700 to 0759												
0800 to 0859	42	58	40	64	7		81	326	37		16	24
0900 to 0959	11	90	33	55	9	30	76	690	69	35	108	142
1000 to 1059	18	30	96	371		309	32	596	138	85	50	234
1100 to 1159	20	25	136	604		755	17	589	135	98	19	234
1200 to 1259	36	62	156	522		971	49	503	19	44	49	314
1300 to 1359	46	261	504	780		803	98	471	43	59	83	209
1400 to 1459	195	277	635	734		538	368	186	151	75	143	214
1500 to 1559	240	608	631	715		556	165	139	336	122	333	151
1600 to 1659	236	469	428	883		213	121	222	406	69	97	81
1700 to 1759	296	171	206	1,015		230	316	92	128	55	80	17
1800 to 1859	488			387		126	206		11		5	
1900 to 1959						118						
Total	1,628	2,051	2,865	6,130	16	4,649	1,529	3,814	1473	642	983	1620

Date:	*5/12*	*5/13*	*5/14*	*5/15*	*5/16*	*5/17*	*5/18*	*5/19*	*5/20*	*5/21*	*5/22*	*5/23*
Observation Time-Start:	*8:00*	*8:00*	*8:00*	*8:30*	*8:00*	*8:15*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*
Observation Time-End:	*18:00*	*18:00*	*18:00*	*17:30*	*17:30*	*17:30*	*18:30*	*17:30*	*18:00*	*17:30*	*17:50*	*17:30*
Military Time (hrs)												
0700 to 0759												
0800 to 0859	9	27	13	4	15	2	20	11	19	7	8	13
0900 to 0959	29	66	96	29	3	2	21	15	11	40	16	13
1000 to 1059	28	104	211	28	3	10	35	24	20	129	47	24
1100 to 1159	30	49	151	27	4	28	64	61	19	193	54	25
1200 to 1259	39	88	68	27	96	53	41	83	103	244	63	51
1300 to 1359	60	71	124	11	67	236	32	76	21	254	55	61
1400 to 1459	49	51	127	57	51	121	47	61	55	161	88	31
1500 to 1559	59	94	130	74	86	72	42	86	56	129	34	67
1600 to 1659	76	43	130	24	72	50	14	85	68	80	36	47
1700 to 1759	46	57	26	13	21	13	14	41	78	59	8	26
1800 to 1859							6					
1900 to 1959												
Total	425	650	1076	294	418	587	336	543	450	1296	409	358

Table 3: Page 3 of 3

Continued.

Date:	*5/24*	*5/25*	*5/26*	*5/27*	*5/28*	*5/29*	*5/30*	*5/31*	*6/1*	*6/2*	*6/3*	*6/4*
Observation Time-Start:	*8:00*	*8:00*	*7:30*	*8:00*	*8:00*	*7:00*	*7:30*	*8:00*	*7:00*	*7:30*	*7:30*	*7:30*
Observation Time-End:	*18:30*	*17:30*	*18:00*	*17:30*	*17:30*	*15:30*	*15:30*	*17:30*	*15:30*	*15:30*	*14:15*	*14:30*
Military Time (hrs)												
0700 to 0759			11			4	15			1		1
0800 to 0859	7	7	27	52	15	174	18	173	91	51	69	31
0900 to 0959	7	18	88	136	22	73	17	168	68	53	28	11
1000 to 1059	3	70	74	164	44	89	3	86	50	37	9	5
1100 to 1159	17	132	56	133	100	60	36	22	19	2	3	3
1200 to 1259	8	140	97	169	94	54	5	18	4	31	1	6
1300 to 1359	43	87	74	32	62	33	6	14	16	13	12	2
1400 to 1459	87	51	95	5	89	17	3	9	5	1		2
1500 to 1559	3	43	78	5	29	13	2	11	3	1		
1600 to 1659	127	45	77	7	29							
1700 to 1759	162	21	58	12	22							
1800 to 1859	45											
1900 to 1959												
Total	509	614	735	715	506	517	105	501	256	190	122	61

Date:	*6/5*	*Season*
Observation Time-Start:	*7:30*	*Total*
Observation Time-End:	*12:00*	
Military Time (hrs)		
0700 to 0759		**32**
0800 to 0859	2	**1,945**
0900 to 0959	2	**2,839**
1000 to 1059	3	**4,119**
1100 to 1159	1	**4,928**
1200 to 1259		**5,304**
1300 to 1359		**5,576**
1400 to 1459		**6,411**
1500 to 1559		**8,071**
1600 to 1659		**8,505**
1700 to 1759		**6,806**
1800 to 1859		**2,167**
1900 to 1959		**196**
Total	8	**56,899**

Table 4:

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2006.

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**	**0.7149**	**32**	**56,899**	**0**	**0**	**4**

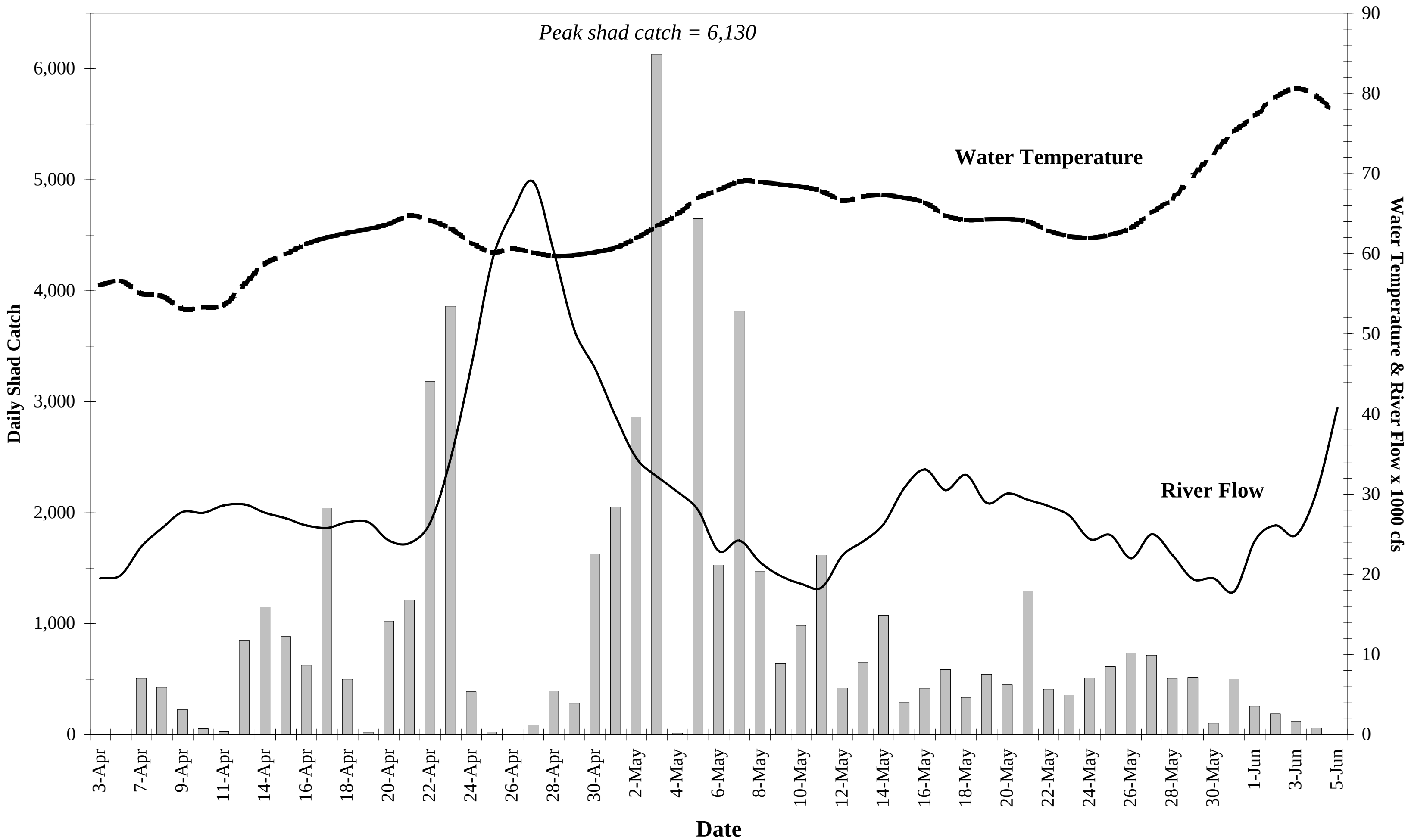

Fig. 1

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 2006. No operation on April 12 and May 5.

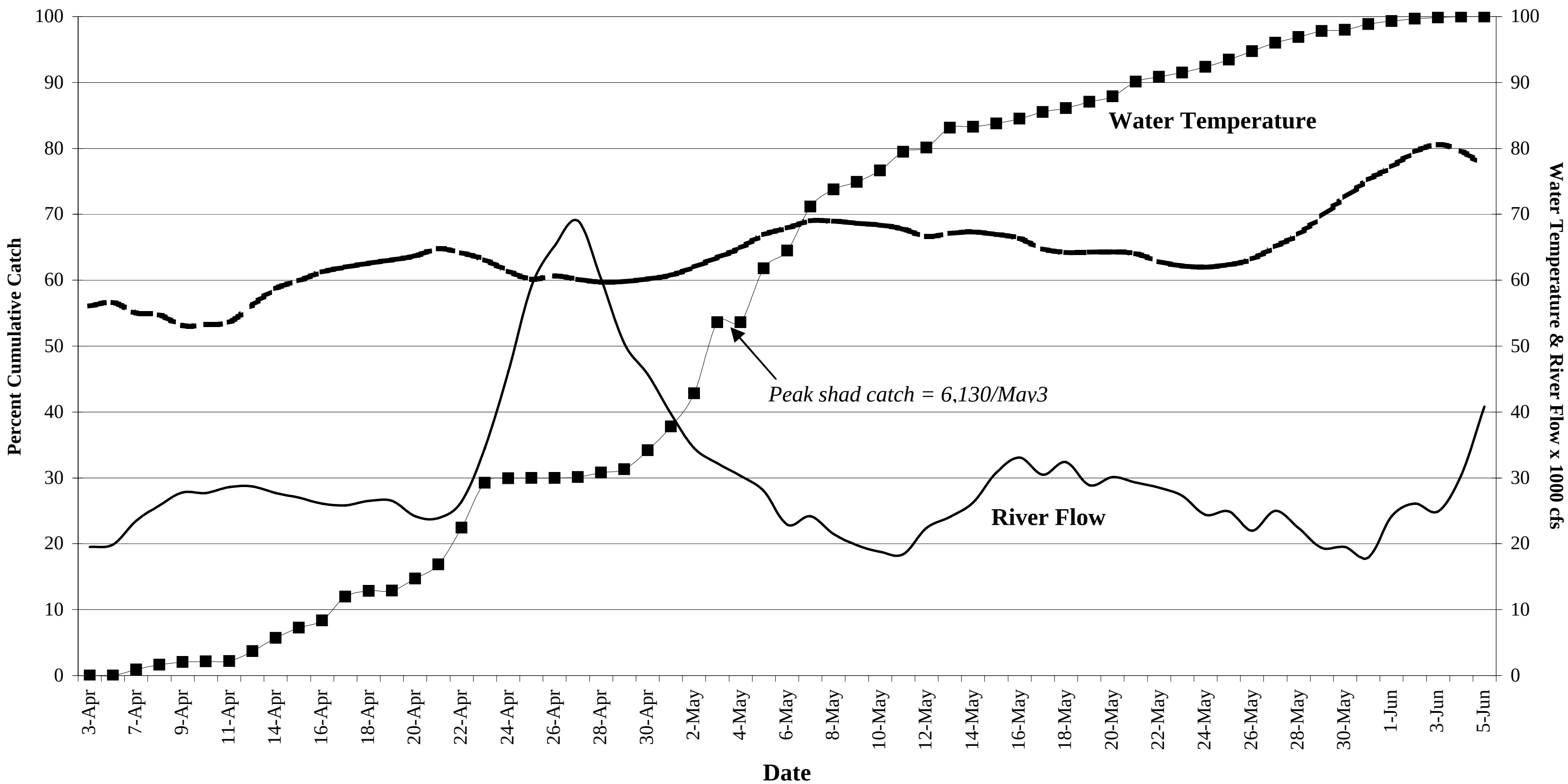

Fig. 2

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 2006. No operation on April 12 and May 5.

Job I - Part 2

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2006

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INTRODUCTION

The shore-based trapping device at Conowingo Dam known as the West Fish Lift has operated every spring since 1972 for the purpose of collecting and counting American shad, river herring, other migratory species and resident fishes in the tailrace. Since 1985, most shad collected here have been sorted from the daily catch, placed into circular transport tanks, and stocked into suitable spawning waters upstream of the mainstem hydroelectric dams. During the spring runs of 1991 through 1996 the newer East Fish Lift at Conowingo Dam also served this purpose.

With fish passage available at Holtwood and Safe Harbor dams since 1997, the Conowingo East Fish Lift was operated to pass all fish into the project head pond in spring 2006 (see Part 1). Upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam but Susquehanna Electric Company (SECO) has agreed to keep the West Fish Lift operational and to administer an annual contract for West Fish Lift trapping operations. Project details are coordinated with the resource agencies through the Susquehanna River Technical Committee (SRTC). Funding to reimburse SECO for contractor expenses for these operations, as well as shad tank spawning trials in 2006 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, and annual contributions by the PA Fish and Boat Commission and Maryland DNR. These contributed funds have been administered by the USFWS Susquehanna Coordinator.

The objectives of Conowingo West Fish Lift operations in 2006 included: collection and enumeration of shad, river herring, and other migratory and resident fishes; and obtaining shad for an on-site tank spawning and shad egg collection program conducted at Conowingo Dam. Shad taken here are also monitored for DNR tags and sex ratios, and scale and head samples are taken for age and otolith analysis. No fish were trucked upstream in 2006.

METHODS

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

Average daily river flow at Conowingo during the West Fish Lift operating period declined rapidly from a high of about 70,000 cfs in late April to a low of 40,000 cfs by May 1. Average daily flow then fluctuated gradually between 40,000 and 20,000 cfs for the remainder of the West Fish Lift operating period. Water temperature during the same period increased more or less gradually from 63 to 72° F. Lift operations began on April 19 and occurred on 37 of the next 45 days through June 2. Total fishing effort over this period amounted to 394 lifts and a fishing time of 214.5 hours.

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 Maryland DNR for tank spawning in 2006. 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.

Job I - Part 2

RESULTS

Figure 1 shows daily West Fish Lift shad catch, river flow and water temperatures for the 2006 season. Total catch at the West Fish Lift amounted to 163,131 fish of 38 taxa, including hybrids (Table 1). Gizzard shad comprised 91% of the total catch and the next four most numerous species, channel catfish, walleye, brown bullhead and white perch comprised 4% of the total. Alosine catch included 3,970 American shad (2.4% of the total catch), 8 river herring, and no hickory shad. Catch of American shad averaged 107 per operating day with peak day catches of 753 and 339 shad on May 7 and 14, respectively. Daily operating parameters and catch by major species is shown in Table 2.

Normandeau Associates used 1,557 American shad at the lift site for tank spawning (Job II, Part 3). Of the 180 shad sacrificed for hatchery vs. wild analysis by PFBC, 50% were shown to be of hatchery origin. Males averaged 450 mm in total length and 860 g while females averaged 506 mm and 1311 g. A total of 14 Maryland DNR 2006 tags were recovered at the West Fish Lift. No fish tagged in previous years by Maryland DNR were recaptured at the West Fish Lift. Overall male to female sex ratio of shad in the West Fish Lift in 2006 was 1.0 to 1.0 (Table 3).

DISCUSSION

Spring 2006 water temperatures during West Fish Lift operations were warmer than in 2005 (63-72 vs. 60-70° F) and river flows were higher in 2006 compared to 2005 (18,000-69,000 vs. 12,000-50,000 cfs). Peak day catches occurred on May 7 and 14 and overall, daily shad abundance was lower in 2006 with greater than 200 being taken on only 5 dates vs. 7 in 2005 despite there being a 25% increase in the number of lifts and seven additional operational days in 2006. Most shad collected in 2006 were released alive back to the tailrace.

West Fish Lift catch per effort of 18.5 shad per fishing hour, 10 shad per lift, and 107 shad per day were the lowest recorded since 1994 (Table 4). Operations and fish catch at the West Fish Lift during 1985-2006 are summarized in Table 5.

Table 1:

Catch of fishes at the Conowingo Dam West Fish Lift, 2006.

Number of Days	**37**
Number of Lifts	**394**
Fishing Time (hours : minutes)	**214h:54min**
Number of Taxa	**38**
AMERICAN SHAD	3,970
HICKORY SHAD	0
BLUEBACK HERRING	6
ALEWIFE	2
GIZZARD SHAD	149,250
STRIPED BASS	383
Hybrid Striped Bass	3
White Perch	1,001
American Eel	12
Brook Trout	2
Brown Trout	11
Rainbow Trout	3
Splake	2
Tiger Musky	1
Carp	716
Comely Shiner	548
Spottail Shiner	15
Spotfin Shiner	1
Quillback	289
White Sucker	7
Shorthead Redhorse	109
White Catfish	9
Yellow Bullhead	29
Brown Bullhead	1,060
Channel Catfish	2,880
Flathead Catfish	42
Rock Bass	51
Redbreast Sunfish	148
Green Sunfish	2
Pumpkinseed	23
Bluegill	145
Smallmouth Bass	306
Largemouth Bass	21
White Crappie	6
Black Crappie	10
Yellow Perch	54
Walleye	1,962
Atlantic Needlefish	9
Sea Lamprey	43
Total	**163,131**

Table 2: Page 1 of 3

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 19 April - 2 June, 2006.

Date:	19-Apr	20-Apr	21-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
Day:	WEDNESDAY	THURSDAY	FRIDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Number of Lifts:	9	12	4	18	16	17	16	15
Time of First Lift:	8:55	9:18	8:35	10:11	9:34	9:40	11:05	9:29
Time of Last lift:	14:43	15:58	11:16	15:45	14:46	14:54	15:54	14:50
Operating time (hours):	5:48	6:40	2:41	5:34	5:12	5:14	4:49	5:21
Average Water Temperature (°F):	63.1	64.0	63.8	64.9	64.4	61.8	62.5	61.7
American shad	37	104	57	30	5	6	10	16
Blueback herring	0	0	0	0	0	0	0	1
Alewife	0	0	0	0	2	0	0	0
Gizzard shad	2950	3750	1800	11900	14475	13400	7750	5675
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	2	1	0	0	2	0	2	2
Carp	1	5	0	30	7	6	12	2
Other species	257	71	54	447	217	169	191	229
Total	3247	3931	1911	12407	14708	13581	7965	5925

Date:	1-May	2-May	3-May	4-May	5-May	7-May	8-May	9-May
Day:	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY	MONDAY	TUESDAY
Number of Lifts:	19	18	15	13	11	10	7	8
Time of First Lift:	10:00	9:35	9:40	10:20	9:25	9:20	11:20	9:25
Time of Last lift:	15:30	15:55	16:00	16:10	15:55	15:30	15:50	15:45
Operating time (hours):	5:30	6:20	6:20	5:50	6:30	6:10	4:30	6:20
Average Water Temperature (°F):	61.8	61.5	63.1	64.6	64.9	66.6	66.2	67.9
American shad	18	38	119	213	116	753	138	99
Blueback herring	0	1	0	1	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	19050	14100	4400	5975	4950	1975	1650	1610
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	3	9	13	7	7	2	3	0
Carp	3	7	16	5	2	4	7	15
Other species	462	317	534	288	217	304	115	203
Total	19536	14472	5082	6489	5292	3038	1913	1927

Table 2: Page 2 of 3

Continued.

Date:	10-May	11-May	12-May	14-May	15-May	16-May	17-May	18-May
Day:	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY
Number of Lifts:	7	14	9	8	12	11	7	10
Time of First Lift:	12:20	9:35	12:05	9:20	11:35	9:25	10:25	9:30
Time of Last lift:	15:50	15:45	16:00	15:45	16:25	16:05	16:00	16:00
Operating time (hours):	3:30	6:10	3:55	6:25	4:50	6:40	5:35	6:30
Average Water Temperature (°F):	68.2	67.9	69.2	68.0	69.6	68.1	68.0	67.6
American shad	45	236	31	339	54	76	88	180
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	1930	3075	4050	1526	5080	2375	1175	1495
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	1	8	13	1	6	8	9	19
Carp	6	0	12	1	25	3	3	1
Other species	128	248	172	89	174	118	106	139
Total	2110	3567	4278	1956	5339	2580	1381	1834

Date:	19-May	21-May	22-May	23-May	24-May	25-May	26-May	28-May
Day:	FRIDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY
Number of Lifts:	6	8	9	8	10	8	6	9
Time of First Lift:	9:55	9:40	9:30	9:40	9:30	9:35	9:25	9:45
Time of Last lift:	16:03	16:00	16:30	16:00	16:15	16:30	15:30	16:00
Operating time (hours):	6:08	6:20	7:00	6:20	6:45	6:55	6:05	6:15
Average Water Temperature (°F):	67.2	65.9	65.7	65.3	65.4	65.4	66.1	66.2
American shad	17	60	141	83	268	42	17	93
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	1225	1300	725	690	1630	1385	1190	1355
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	47	10	18	11	3	15	1	19
Carp	0	0	1	1	1	1	0	1
Other species	159	62	129	84	79	350	158	136
Total	1448	1432	1014	869	1981	1793	1366	1604

Table 2: Page 3 of 3

Continued.

Date:	29-May	30-May	31-May	1-Jun	2-Jun	
Day:	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	**Total for the Year**
Number of Lifts:	9	10	10	7	8	**394**
Time of First Lift:	8:30	9:35	8:30	8:38	9:00	
Time of Last lift:	15:00	15:55	15:00	14:00	15:00	
Operating time (hours):	6:30	6:20	6:30	5:22	6:00	**214 h 54 min**
Average Water Temperature (°F):	66.7	69.6	68.8	70.6	72.5	
American shad	107	45	49	142	98	**3970**
Blueback herring	0	0	3	0	0	**6**
Alewife	0	0	0	0	0	**2**
Gizzard shad	930	1320	825	312	247	**149250**
Hickory shad	0	0	0	0	0	**0**
Striped bass	3	112	16	9	1	**383**
Carp	0	528	8	0	2	**716**
Other species	170	1597	252	158	221	**8804**
Total	1210	3602	1153	621	569	**163131**

Table 3:

American shad sex ratio information, Conowingo West Fish Lift, 2006. No operation on 22, 23, 29, 30 April, and 6, 13, 20, 27, May.

Date	Sample size	Males	Females	Male:Female Ratio
19-Apr	37	25	12	1: 0.5
20-Apr	102	67	35	1: 0.5
21-Apr	57	32	25	1: 0.8
24-Apr	30	23	7	1: 0.3
25-Apr	5	3	2	1: 0.7
26-Apr	4	3	1	1: 0.3
27-Apr	10	6	4	1: 0.7
28-Apr	16	8	8	1: 1.0
1-May	17	10	7	1: 0.7
2-May	38	18	20	1: 1.1
3-May	95	55	40	1: 0.7
4-May	119	79	40	1: 0.5
5-May	80	48	32	1: 0.7
7-May	189	99	90	1: 0.9
8-May	138	72	66	1: 0.9
9-May	98	58	40	1: 0.7
10-May	44	17	27	1: 1.6
11-May	141	69	72	1: 1.0
12-May	30	19	11	1: 0.6
14-May	164	81	83	1: 1.0
15-May	54	25	29	1: 1.2
16-May	76	37	39	1: 1.1
17-May	88	48	40	1: 0.8
18-May	178	79	99	1: 1.3
19-May	17	8	9	1: 1.1
21-May	60	24	36	1: 1.5
22-May	141	64	77	1: 1.2
23-May	83	41	42	1: 1.0
24-May	123	59	64	1: 1.1
25-May	42	11	31	1: 2.8
26-May	17	5	12	1: 2.4
28-May	93	34	59	1: 1.7
29-May	107	51	56	1: 1.1
30-May	45	11	34	1: 3.1
31-May	49	16	33	1: 2.1
1-Jun	142	56	86	1: 1.5
2-Jun	98	27	71	1: 2.6
Total	**2827**	**1388**	**1439**	1: 1.0

Table 4:

Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods,* 1985-2006.

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**

*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 - 2006.

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

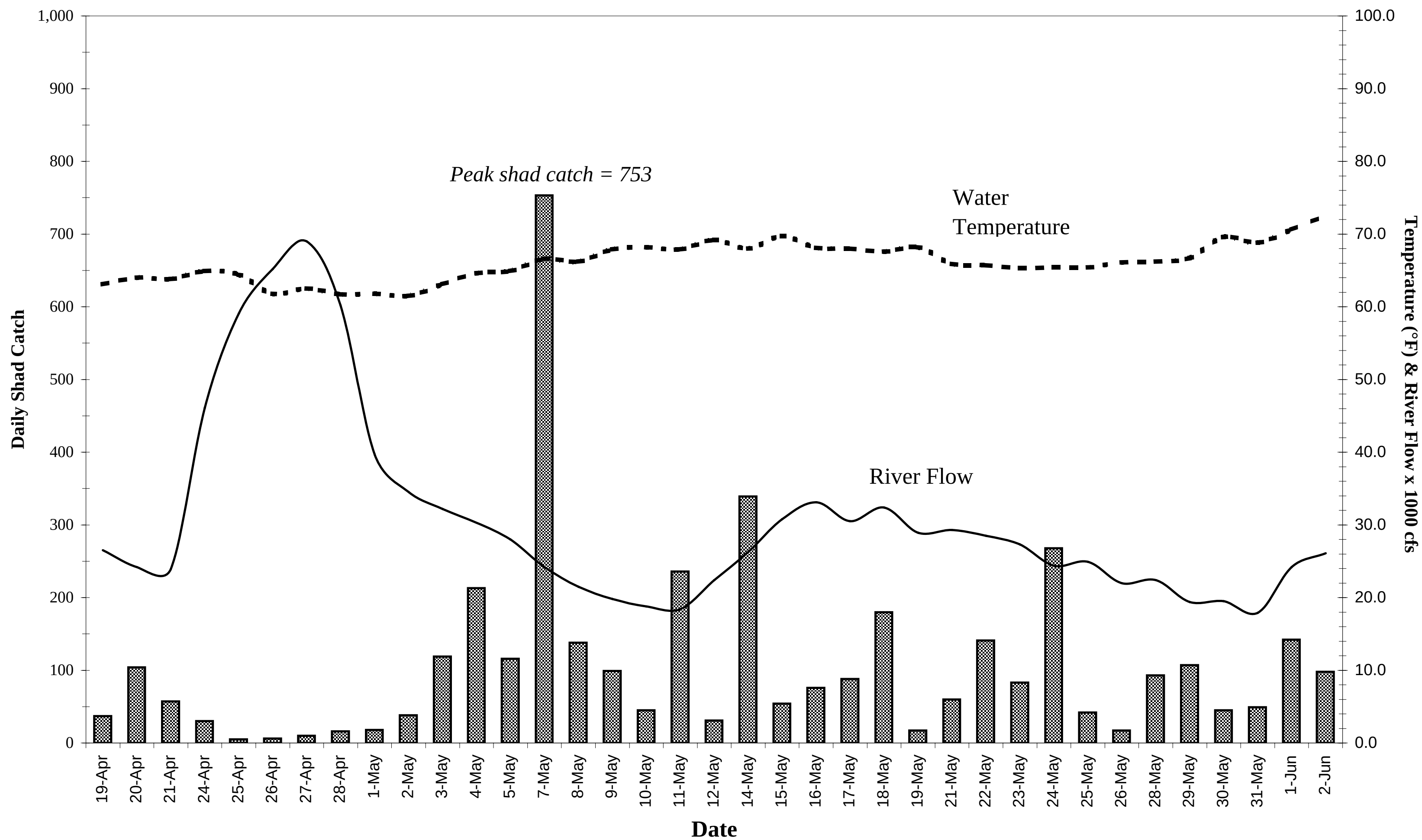

Figure 1. A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 2006.

Job I – Part 3

SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY, SPRING 2005

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EXECUTIVE SUMMARY

Fishway operations at Holtwood Dam began on 11 April 2006, the earliest start date at Holtwood since fish passage operations began in 1997. The tailrace lift was operated for 57 days while the spillway lift operated on 20 days. We terminated lift operations for the season, with agency concurrence, on 6 June. The tailrace lift, except for a crowder door malfunction, operated flawlessly for most of the passage season and passed 33,088 American shad. Although the spillway entrance gate was unable to be repaired prior to or during the season, operation of the spillway lift resulted in the passage of 2,880 American shad. The 2006 fish passage season marks the tenth year of operation at Holtwood as well as the longest passage season to date.

The lifts passed 296,038 fish of 27 taxa plus two hybrids. Gizzard and American shad dominated the catch, and comprised nearly 89% of the total fish collected and passed. The sole *Alosa* species captured included 35,968 American shad; no river herring were observed at Holtwood in 2006.

A total of 33,088 American shad (92% of total catch) was passed in the tailrace lift while the spillway lift accounted for 2,880 American shad (8% of total catch). Collection and passage of shad varied daily with 57% of total shad (20,551) passed during the 14 day period from 2 through 15 May. The highest daily shad catch occurred on 9 May when 2,557 shad moved upstream during 11.6 hours of operation. On a daily basis, shad passage was consistent through the fishway between 0900 hrs and 1759 hrs. Fishway operations were conducted at water temperatures ranging from 54.0°F to 80.5°F and river flows between 17,900 and 69,000 cfs. Spill events occurred on 17 days, 9 of which occurred continuously from 23 April through 1 May, and river water temperatures did not rise above 70°F until 30 May.

Job I – Part 3

In 2006, due to favorable river flow conditions, our fishway efforts focused on maximizing American shad passage with minimal interruptions to passage operations due to equipment breakdowns or malfunctions.

Stable or decreasing river flows throughout the passage season, coupled with river water temperatures below 70°F for most of the season, resulted in the second highest American shad passage total and the highest percent shad passage value since fishway start-up in 1997. Future operations will build on the past ten years of operational experience.

INTRODUCTION

On 1 June 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (Holtwood) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by the spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream passage facility consisting of a tailrace and spillway lift successfully operated during spring 1997 through spring 2006. This year marked the tenth operational season.

Objectives of 2006 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.

Job I – Part 3

HOLTWOOD OPERATION

Project Operation

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

Fishway operations at Holtwood began on 11 April 2006. In spring 2006, river flows less than station capacity allowed repairs of the damaged flashboards prior to the start of fish lift operations. During the fish passage season, the majority of spill events occurred from 23 April through 1 May, and during the last two days of operation, 5 and 6 June. Passage operations ended on 6 June due to high water temperatures, a lack of pre-spawned shad available for passage, and increased river flows resulting in spillage at Holtwood.

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).

Job I – Part 3

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 through 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 2006, all four of the rubber crest dams were kept inflated except during heavy spill events on 27 and 28 April, and on 11 and 26 May during controlled spills for recreational kayaking demonstrations.

Design guidelines for fishway operation included 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 in the first year of fish lift operation. In 2006, entrance gate A was used almost exclusively in the tailrace to attract American shad, while spillway gate C was operated on a limited basis due to structural damage incurred due to flood waters from the remnants of Hurricane Ivan in September 2004 and three other high flow events that prevented the repair of the spillway gate prior to this year's passage season.

Job I – Part 3

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 2006 to discuss the annual fish lift operational plan.

This year we recorded the highest number of days of continuous operation, (57), since passage operations began in 1997. As mentioned previously in this report, the spillway lift was operated on a limited basis in spring 2006. Damage to the spillway entrance gate from flooding was severe and could not be repaired prior to or during the fish passage season. The tailrace lift was operated everyday during this year's fish passage operation and encountered a crowder door drive mechanism malfunction on 18 May. From 19 to 21 May, repair crews were on site to resolve the crowder door malfunction, but all efforts to repair the crowder door proved unsuccessful. It was determined that a failed door hinge was causing the door to malfunction. Repairing or replacing the door hinge requires dewatering of the tailrace crowder channel and a complete shutdown of the tailrace lift. To prevent a loss of operating time, the tailrace lift was operated in the "fast fish" mode, (no crowding) for the remainder of the operating season. The tailrace crowder door will be repaired prior to lift operations in 2007. Except for the crowder door problem, all other problems were fixed or temporarily repaired as soon as possible to minimize any fish passage delays.

The catch of shad at Conowingo Dam triggered the start of Holtwood operations on 11 April. We operated the tailrace lift for 57 days during the season while the spillway lift operated on 20 days. The 2006 American shad passage rate at Holtwood versus Conowingo (63.2% of fish passing Conowingo passed Holtwood) was the highest observed since operations commenced in 1997. The passage rate may have been the product of stable river flows, minimal equipment malfunctions, and the longest passage season recorded to date at Holtwood. 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).

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

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

RESULTS

Relative Abundance

We present the diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2006 operational period in Table 1. A total of 296,038 fish of 27 taxa and two hybrids passed upstream into Lake Aldred. Gizzard shad (227,443) and American shad (35,968) comprised nearly 89% of the fishes passed. The 2006 American shad passage total was the second highest observed, and based on Conowingo results, the highest passage percentage rate recorded in the ten years of fish lift operations (Tables 1, 5, and 6). Other abundant fishes passed included walleye (19,726), quillback (3,477), channel catfish (2,995), shorthead redhorse (2,661), and smallmouth bass (1,782). The peak one-day passage of all species occurred on 9 May, when 18,087 fish were passed, comprised mostly of gizzard shad (14,524), American shad (2,557), and walleye (992).

The low, stable river flows 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 2006 included 45 orange tags, (2006 Hook & Line), and 1green tag, (2005 Hook & Line).

American Shad Passage

A total of 35,968 American shad were passed at Holtwood during 2006; 33,088 American shad (92% of the total catch) passed in the tailrace lift while the spillway lift accounted for 2,880 American shad (8% of total catch) (Table 4). Collection and passage of shad varied daily with 57% of total shad (20,551) passed during the 14 day period from 2 through 15 May. The highest daily shad catch occurred on 9 May when 2,557 shad moved upstream during 11.6 hours of operation. On a daily basis, shad passage was consistent through the fishway between 0900 hrs and 1759 hrs with the highest passage occurring from 1300 hrs to 1659 hrs (Table 3). Fishway operations were conducted at water temperatures ranging from 54.0°F to 80.5°F and river flows between 17,900 and 69,000 cfs, (Table 2). Spillage occurred on 9 continuous days from 23 April through 1 May and during the last two days of operation, (5 and 6 June). Between 2 May and 4 June, 6 spill events occurred that were of short duration, (approximately 4 hours), and two of those events were demonstrations for recreational kayaking. River water temperatures did not rise above 70°F until 30 May, which may have allowed American shad in pre-spawn condition to swim upstream for a longer period of time prior to spawning. However, when water temperatures did rise above 70°F, shad of advanced or post-spawned condition were frequently observed during fish passage operations.

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 average water elevations ranging from 110 ft. to 119 ft. Typically, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2006, tailrace fishway operation generally coincided with a ten turbine operation/generation scenario due to stable river flows this Spring. Spillway lift operation usually occurred during periods of no or minimal spillage, (elevation 116 ft). Spillage occurred during 17 of the 57 days of operation, with the heaviest events occurring from 23 April to 1 May.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164 ft to 173 ft (Table 2). Visual observations indicated that shad passed through the fishway into Lake Aldred at this range of forebay elevations. After the nine days of continuous spillage, river flows stabilized and forebay elevations during passage operations ranged between 167 ft to 169 ft.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Most shad, (32,048 or 89% of shad passage total) passed through the fishway between 0900 hrs and 1759 hrs. Generally, shad passage was consistent from 0900 hrs to 1759 hrs, then gradually declined until operation was ended each evening. The highest hourly passage rates occurred from 1300 hrs to 1659 hrs, accounting for the passage of 17,629 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. Although the damaged spillway entrance gate was unable to be repaired prior to this passage season, the spillway lift was operated on twenty days in May in an effort to pass any shad attracted into the area adjacent to the damaged spillway entrance gate. 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, 33,088 and 2,880 shad were captured in the tailrace and spillway lifts over the total operating period in 2006, respectively (Table 4).

Passage Evaluation

In spring 2006, 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. In 2006, spill events occurred during 17 of the 57 days of fishway operation. We documented 98.1% of American shad passed at river flows less than 40,000 cfs, with 1.6% passing at river flows greater than 40,000 cfs but less than 60,000 cfs, and the remaining 0.3% of shad passed when river flows were greater than 60,000 cfs (Table 5 and Figure 2). During fish lift operations in 2006, river flows ranged from 17,900 cfs to 69,000 cfs. The

2006 fish passage season was Holtwood's most successful since operations began in 1997 in terms of percent shad passage, (63.2% of American shad passed at Conowingo were passed by Holtwood), based on shad passage numbers observed at Conowingo dam.

We hope to optimize future fishway operations by utilizing knowledge gained through these ten 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 34 mortalities, less than 0.1% of total American shad passage.

SUMMARY

In 2006, the Holtwood tailrace fish lift was operated for 57 days while the spillway lift operated 20 days. The spillway entrance gate was unable to be repaired prior to the season, while the tailrace lift, except for a crowder door malfunction, operated flawlessly during most of the season. Any issues were dealt with as quickly as possible. The problem with the tailrace crowder door, (failed door hinge), could not be resolved without having to dewater the facility, so the decision was made to operate in the "fast fish" mode for the remainder of the season to prevent interruption to the tailrace passage operation. From 18 May until operations ended on 6 June, the tailrace crowder remained in the "fish" position with the crowder doors open.

A total of 35,968 American shad were passed into Lake Aldred, the second highest total and the highest percentage of shad passed (based on Conowingo passage results) since operations started in 1997 (Table 6).

The catch of shad at Conowingo Dam triggered the start of Holtwood operations on 11April, (the earliest start date since operations began in 1997. A total of 33,088 American shad (92% of total catch) was passed in the tailrace lift while the spillway lift accounted for 2,880 American shad (8% of total catch). Collection and passage of shad varied daily with 57% of total shad (20,551) passed during the 14-day period from 2 through 15 May. The highest daily shad catch occurred on 9 May when 2,557 shad moved upstream in 11.6 hours of operation. On a daily basis, shad passage through the fishway was consistent between 0900 hrs and 1759 hrs. American shad were collected and passed at water temperatures ranging from 54.0°F to 80.5°F, and river flows between 17,900 and 69,000 cfs.

A low, stable, river flow appears to be critical for enhancing shad passage rates. The stable river flows and a longer passage season at Holtwood Dam in Spring 2006 resulted in the highest American shad percent passage rate, (numbers of American shad passed at Conowingo versus Holtwood), since operations began in 1997. Future operations of the fishway will build on the past ten years of operation experience.

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.

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.

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Summary of the daily number of fish passed by the Holtwood fish passage facility in 2006.

Date:	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*
Hours of Operation - Tailrace:	*6.0*	*6.8*	*6.8*	*7.4*	*7.3*	*7.8*	*7.8*	*9.5*	*8.7*	*9.0*
Number of Lifts - Tailrace:	*9*	*10*	*11*	*12*	*12*	*13*	*13*	*17*	*13*	*14*
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):	*54.0*	*54.2*	*56.0*	*58.8*	*59.5*	*61.4*	*61.9*	*62.4*	*63.0*	*63.5*
American shad	116	152	207	370	540	493	481	1,000	402	327
Gizzard shad	459	120	197	371	1,179	1,055	1,861	1,713	1,769	1,734
Sea lamprey	0	0	1	0	0	1	0	0	1	0
Rainbow trout	0	0	2	0	0	0	0	0	0	0
Brown trout	0	2	0	2	0	0	2	0	1	2
Brook trout	0	0	0	0	0	0	0	0	1	0
Tiger muskie	0	0	1	0	0	0	0	0	0	0
Carp	0	0	0	0	9	2	2	4	4	64
Quillback	0	6	3	407	64	56	63	105	33	36
White sucker	0	0	0	0	3	1	0	0	1	0
Shorthead redhorse	4	27	63	429	153	148	296	211	272	50
Channel catfish	3	3	4	12	127	3	44	3	123	2
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	2	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	2	0	0	3	16	13	4	8	11	6
Redbreast sunfish	0	0	0	0	0	0	0	1	0	0
Green sunfish	0	0	0	0	0	0	0	0	5	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	3	0	1	0	0	1
Smallmouth bass	18	35	48	262	194	83	151	120	208	54
Largemouth bass	3	0	1	0	6	1	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	1	1	0	2	0	1	2	3	1	1
Walleye	2	68	107	446	636	352	1,151	588	1,206	491
Comely shiner	0	0	0	0	0	0	0	0	0	500
Spottail shiner	0	0	0	0	1	0	0	0	0	0
Total	***608***	***414***	***634***	***2,304***	***2,933***	***2,209***	***4,058***	***3,756***	***4,038***	***3,268***

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Continued.

Date:	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*
Hours of Operation - Tailrace:	*8.6*	*9.9*	*9.2*	*9.2*	*7.8*	*7.8*	*6.1*	*6.0*	*6.9*	*6.4*
Number of Lifts - Tailrace:	*14*	*16*	*16*	*15*	*10*	*9*	*7*	*7*	*8*	*7*
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):	*64.9*	*64.3*	*63.5*	*62.1*	*59.5*	*59.9*	*59.8*	*58.8*	*59.1*	*60.0*
American shad	929	547	1,482	320	56	50	8	15	19	11
Gizzard shad	2,986	3,545	8,757	5,966	3,147	4,813	3,853	1,835	2,410	2,402
Sea lamprey	2	2	2	1	1	3	0	0	0	0
Rainbow trout	0	0	1	0	4	1	0	0	0	0
Brown trout	0	0	2	1	1	1	0	0	0	0
Brook trout	0	0	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	17	7	27	7	6	5	3	3	2	1
Quillback	28	1	66	36	0	3	0	0	0	0
White sucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	124	97	224	44	1	7	2	0	1	0
Channel catfish	35	13	168	16	0	14	5	9	7	24
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	7	6	6	3	0	3	0	2	0	6
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	6	1	2	0	0	1	0	0	0	1
Smallmouth bass	143	56	22	35	2	23	22	13	5	15
Largemouth bass	4	0	0	0	0	0	0	1	0	1
White crappie	0	0	0	0	0	0	3	0	0	0
Yellow perch	0	1	0	0	0	2	0	0	0	0
Walleye	839	564	444	142	178	186	88	74	84	48
Comely shiner	0		0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0	0	0
Total	***5,120***	***4,840***	***11,203***	***6,571***	***3,396***	***5,112***	***3,984***	***1,952***	***2,528***	***2,509***

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Continued.

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:	*8.5*	*10.0*	*10.4*	*11.0*	*11.3*	*11.1*	*11.0*	*10.7*	*11.6*	*10.6*
Number of Lifts - Tailrace:	*11*	*13*	*16*	*18*	*16*	*18*	*18*	*18*	*20*	*15*
Hours of Operation - Spillway:	*2.3*	*8.8*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Number of Lifts - Spillway:	*3*	*12*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*60.4*	*61.9*	*63.6*	*64.4*	*66.5*	*67.4*	*68.7*	*68.8*	*68.5*	*68.0*
American shad	230	731	1,336	2,175	894	2,296	1,920	2,083	2,557	1,388
Gizzard shad	3,976	11,638	7,780	6,457	3,146	7,518	8,201	4,955	14,524	7,144
Sea lamprey	0	1	0	1	0	1	2	3	1	0
Rainbow trout	0	0	0	0	3	1	1	0	0	0
Brown trout	1	6	0	0	0	1	2	1	0	2
Brook trout	0	0	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	4	6	0	6	6	8	3	2	0	27
Quillback	62	175	15	68	96	13	4	8	2	19
White sucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	57	16	12	50	37	4	20	7	1	4
Channel catfish	9	25	5	6	71	20	91	7	4	58
Brown bullhead	0	3	0	0	0	0	0	0	0	3
Yellow bullhead	0	0	0	0	0	0	0	0	0	0
Flathead catfish	0	2	0	0	0	0	0	0	0	0
White perch	0	1	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	0	4	1	2	4	9	3	0	3	0
Redbreast sunfish	0	0	1	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	3	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	2	1	0	0	0
Bluegill	0	0	0	1	10	7	10	3	0	0
Smallmouth bass	10	65	8	19	24	9	3	2	3	0
Largemouth bass	0	0	0	0	1	2	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	167	370	173	406	776	878	1,164	1,474	992	571
Comely shiner	0	0	0	0	0	550	20	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0	0	0
Total	***4,516***	***13,043***	***9,331***	***9,191***	***5,071***	***11,319***	***11,445***	***8,545***	***18,087***	***9,216***

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Continued.

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:	*11.3*	*9.6*	*9.9*	*10.8*	*7.7*	*9.8*	*9.7*	*10.0*	*10.0*	*9.8*
Number of Lifts - Tailrace:	*18*	*15*	*16*	*16*	*11*	*16*	*15*	*18*	*20*	*18*
Hours of Operation - Spillway:	*6.2*	*9.6*	*0.0*	*0.0*	*10.1*	*3.7*	*9.8*	*9.8*	*10.0*	*9.8*
Number of Lifts - Spillway:	*8*	*16*	*0*	*0*	*15*	*3*	*15*	*10*	*17*	*12*
Water Temperature (°F):	*67.9*	*66.9*	*66.4*	*67.6*	*67.0*	*66.8*	*65.0*	*64.1*	*64.1*	*64.2*
American shad	1,522	1,021	322	1,639	667	282	643	344	447	387
Gizzard shad	13,755	7,015	11,846	10,890	8,273	5,066	4,001	1,848	2,280	2,954
Sea lamprey	2	2	4	0	1	0	1	0	0	0
Rainbow trout	0	0	1	0	0	0	1	0	0	1
Brown trout	0	0	0	1	0	0	5	0	1	0
Brook trout	0	0	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	35	0	3	9	9	2	8	0	4	1
Quillback	175	161	6	2	61	7	50	22	53	77
White sucker	0	0	0	0	0	0	2	0	0	0
Shorthead redhorse	57	8	7	10	5	2	18	1	2	3
Channel catfish	140	36	27	27	36	12	102	4	65	63
Brown bullhead	0	0	0	0	0	0	1	0	0	0
Yellow bullhead	0	0	0	0	1	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	1	0	0
White perch	0	0	0	0	0	0	1	0	0	0
Hybrid striped bass	0	0	1	0	0	0	0	0	0	0
Rock bass	0	4	2	2	0	0	0	0	0	1
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	3	0	0	0	0	1	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	9	4	5	6	0	0	0	0	0	7
Smallmouth bass	12	12	2	0	5	2	10	4	6	8
Largemouth bass	1	0	1	0	0	0	2	0	0	1
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	1,406	363	316	448	335	242	209	104	117	144
Comely shiner	0	0	20	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0	0	0
Total	***17,114***	***8,629***	***12,563***	***13,034***	***9,393***	***5,615***	***5,055***	***2,328***	***2,975***	***3,647***

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Continued.

Date:	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*
Hours of Operation - Tailrace:	*10.6*	*7.7*	*10.3*	*10.0*	*9.5*	*10.0*	*10.0*	*10.1*	*9.5*	*9.0*
Number of Lifts - Tailrace:	*10*	*14*	*20*	*16*	*18*	*20*	*19*	*19*	*19*	*19*
Hours of Operation - Spillway:	*10.3*	*7.7*	*4.0*	*9.0*	*0.0*	*4.8*	*10.0*	*9.8*	*9.0*	*9.0*
Number of Lifts - Spillway:	*11*	*8*	*4*	*9*	*0*	*5*	*11*	*9*	*9*	*8*
Water Temperature (°F):	*64.3*	*63.0*	*62.1*	*61.8*	*62.4*	*62.7*	*64.7*	*66.4*	*68.8*	*71.9*
American shad	397	138	338	270	523	297	686	1,023	581	348
Gizzard shad	1,949	575	1,179	834	2,143	2,997	2,662	4,749	2,787	3,333
Sea lamprey	0	0	0	0	1	0	0	1	0	0
Rainbow trout	0	0	1	0	0	0	1	0	2	0
Brown trout	0	0	0	0	0	1	1	0	0	0
Brook trout	0	0	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	3	2	1	1	1	2	1	3	22	5
Quillback	38	0	0	2	0	3	201	282	64	18
White sucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	4	1	0	0	0	0	7	6	0	1
Channel catfish	124	15	7	26	3	5	42	48	11	5
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	0	0	0
Hybrid striped bass	0	0	0	0	0	0	0	0	0	0
Rock bass	1	0	0	0	0	0	0	1	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	3	0	0	0	0	0	4	2	0	0
Smallmouth bass	15	3	3	9	3	6	18	6	3	0
Largemouth bass	0	0	0	1	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	106	49	46	67	61	75	73	78	55	98
Comely shiner	0	0	0	0	0	0	0	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0	0	0
Total	***2,640***	***783***	***1,575***	***1,210***	***2,735***	***3,386***	***3,696***	***6,199***	***3,525***	***3,808***

Table 1: Page 6 of 6

Continued.

Date:	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*8.7*	*7.5*	*7.5*	*5.8*	*6.2*	*7.7*	*7.5*	***507.4***
Number of Lifts - Tailrace:	*17*	*14*	*15*	*11*	*11*	*15*	*11*	***827***
Hours of Operation - Spillway:	*6.7*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	***160.4***
Number of Lifts - Spillway:	*7*	*0*	*0*	*0*	*0*	*0*	*0*	***192***
Water Temperature (°F):	*74.4*	*76.3*	*79.0*	*80.5*	*79.8*	*78.3*	*74.1*	
American shad	307	142	179	55	88	160	27	***35,968***
Gizzard shad	1,306	2,697	1,865	1,553	1,805	1,469	101	***227,443***
Sea lamprey	0	0	0	0	0	0	0	***35***
Rainbow trout	1	0	0	0	0	0	0	***21***
Brown trout	1	0	1	0	0	0	0	***38***
Brook trout	0	0	0	0	0	0	0	***1***
Tiger muskie	0	0	0	0	0	0	0	***1***
Carp	20	4	10	9	58	23	0	***461***
Quillback	100	228	105	303	145	5	0	***3,477***
White sucker	4	0	0	0	0	0	0	***11***
Shorthead redhorse	25	15	11	35	53	29	0	***2,661***
Channel catfish	81	8	31	126	199	549	292	***2,995***
Brown bullhead	0	0	0	0	0	0	0	***7***
Yellow bullhead	0	0	0	0	0	0	0	***3***
Flathead catfish	0	0	0	1	0	0	0	***4***
White perch	0	0	0	0	0	0	0	***2***
Hybrid striped bass	0	0	0	0	0	0	0	***1***
Rock bass	3	0	0	0	0	0	0	***136***
Redbreast sunfish	0	0	0	0	0	0	0	***2***
Green sunfish	0	0	0	0	0	0	0	***12***
Pumpkinseed	0	0	0	0	3	0	0	***6***
Bluegill	0	0	0	5	13	3	0	***108***
Smallmouth bass	1	0	0	1	1	0	0	***1,782***
Largemouth bass	1	0	0	1	0	0	0	***28***
White crappie	0	0	0	0	0	0	0	***3***
Yellow perch	0	0	0	0	0	0	0	***15***
Walleye	104	186	89	43	70	123	54	***19,726***
Comely shiner	0	0	0	0	0	0	0	***1,090***
Spottail shiner	0	0	0	0	0	0	0	***1***
Total	***1,954***	***3,280***	***2,291***	***2,132***	***2,435***	***2,361***	***474***	***296,038***

Table 2: Page 1 of 2

Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in 2006.

	River Flow	Water	Secchi	Number	Weir Gate Operation			Elevation (ft)		
Date	(cfs)	Temp. (°F)	(in)	of Units	A	B*	C**	Tailrace	Spillway	Forebay
11 Apr	28,600	53.62	26	10	X			119	116	166
12 Apr	28,200	54.22	26	10	X			118	116	165
13 Apr	28,700	56.21	24	10	X			118	116	166
14 Apr	27,700	58.74	24	10	X			117	116	165-166
15 Apr	27,000	59.92	26	8-10	X			114-118	116	167
16 Apr	26,100	61.23	30	10	X			116	116	166
17 Apr	25,800	62.00	30	10	X			115-118	116	166-167
18 Apr	26,500	62.59	28	10	X			119	116	166
19 Apr	26,500	63.06	28	10	X			118	116	167
20 Apr	24,200	63.68	28	10	X			116	116	164-168
21 Apr	23,900	64.76	26	10	X			115-118	116	164-166
22 Apr	26,400	64.17	28	10	X			118	116	168
23 Apr	34,500	63.13	18-24	10	X			119	Spill	169
24 Apr	46,100	61.40	24	10	X			119	Spill	170-172
25 Apr	59,100	60.15	24	10	X			119	Spill	172
26 Apr	65,200	60.65	24	10	X	X		119	Spill	172
27 Apr	69,000	60.16	24	10	X			119	Spill	171
28 Apr	60,200	59.70	24	10	X			119	Spill	170
29 Apr	50,400	59.79	24	10	X			119	Spill	169-172
30 Apr	45,700	60.19	26	10	X			119	Spill	172
1 May	39,700	60.73	32	10	X		X	119	Spill	170
2 May	34,500	61.95	36	10	X		X	119	116	169
3 May	32,200	63.44	36	10	X			118-119	116	168
4 May	30,300	64.91	36	10	X			118-119	116	167
5 May	28,000	66.91	26	10	X			117	116	167
6 May	22,900	67.92	36	10	X			117	116	166-169

Table 2: Page 2 of 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number of Units	Weir Gate Operation A	B	C	Elevation (ft) Tailrace	Spillway	Forebay
7 May	24,200	69.03	28	10	X			117-118	116	166-167
8 May	21,500	68.97	30	10	X			115-117	116	168.5
9 May	19,800	68.64	34	10	X			117	116	168
10 May	18,800	68.37	34	10	X			116	116	168
11 May	18,400	67.79	32	4-10	X		X	110-115	Spill***	167-168
12 May	22,400	66.63	26	10	X		X	119	116	167-168
13 May	24,100	67.12	24	10	X			118	116	167-168
14 May	26,300	67.34	26	10	X			117	116	165-168
15 May	30,800	66.97	26	10	X		X	117	116	168
16 May	33,100	66.37	26	10	X		X	119	Spill	170
17 May	30,500	64.78	26	10	X		X	118-119	116	169
18 May	32,400	64.22	26	10	X		X	118.5	116	168-169
19 May	28,900	64.27	26	10	X		X	119	Spill	171
20 May	30,100	64.33	24	10	X		X	118-119	116	168
21 May	29,300	64.02	24	10	X		X	118-119	116	168
22 May	28,500	62.86	24	10	X		X	119	Spill	170-171
23 May	27,300	62.17	24	10	X		X	119	116	168-169
24 May	24,400	61.97	24	10	X		X	117-119	Spill	168-170
25 May	24,900	62.36	28	10	X			117	116	168
26 May	22,000	63.20	28	7-10	X		X	115-118	Spill***	169
27 May	25,000	65.09	28	8-10	X		X	115	116	168
28 May	22,400	66.93	36	10	X		X	116	116	168
29 May	19,400	69.71	36	4-10	X		X	115-116	116	168-169
30 May	19,500	72.58	36	10	X		X	115-118	116	168
31 May	17,900	75.24	36	8-10	X		X	115-117	116	169
1 Jun	24,200	77.21	36	10	X			116-118	116	169-170
2 Jun	26,100	79.47	36	10	X			118	116	168
3 Jun	24,900	80.60	28	10	X			119	116	169
4 Jun	30,400	79.61	28	8-10	X			119	116	168
5 Jun	40,800	77.32	26	10	X			119	Spill	170-171
6 Jun	67,600	73.68	22	10	X			119	Spill	172-173

* Tailrace gate B utilized only once in 2006.

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

*** Spill demonstration for Kayaking

Table 3: Page 1 of 4

Hourly summary of American shad passage at the Holtwood fish passage facility in 2006.

Date:	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*
Observation Time (Start):	*12:00*	*10:00*	*10:45*	*10:10*	*10:30*	*9:40*	*9:50*
Observation Time (End):	*17:45*	*16:45*	*17:50*	*17:45*	*17:20*	*17:40*	*17:45*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	--	--	--	--	--	--	--
0900 to 0959	--	--	--	--	--	16	3
1000 to 1059	--	15	--	29	50	63	62
1100 to 1159	--	28	11	31	134	65	119
1200 to 1259	7	29	40	84	72	107	64
1300 to 1359	11	26	26	49	81	50	32
1400 to 1459	27	23	59	32	81	44	76
1500 to 1559	37	16	27	62	37	66	49
1600 to 1659	25	15	19	33	32	47	33
1700 to 1759	9	--	25	50	53	35	43
1800 to 1859	--	--	--	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**116**	**152**	**207**	**370**	**540**	**493**	**481**

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*
Observation Time (Start):	*8:50*	*8:45*	*9:00*	*9:00*	*8:09*	*8:07*	*8:25*
Observation Time (End):	*18:00*	*17:30*	*18:00*	*17:45*	*18:00*	*17:45*	*17:30*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	4	--	--	--	69	31	36
0900 to 0959	41	22	19	59	67	113	63
1000 to 1059	85	7	28	51	56	74	70
1100 to 1159	70	59	24	65	36	119	30
1200 to 1259	134	79	12	144	18	262	29
1300 to 1359	168	49	17	205	38	293	19
1400 to 1459	202	62	67	112	70	255	23
1500 to 1559	165	67	51	102	55	166	18
1600 to 1659	77	45	62	85	75	121	19
1700 to 1759	54	12	47	106	63	48	13
1800 to 1859	--	--	--	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**1,000**	**402**	**327**	**929**	**547**	**1,482**	**320**

Table 3: Page 2 of 4

Continued.

Date:	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*
Observation Time (Start):	*8:10*	*8:15*	*8:25*	*8:15*	*8:15*	*8:04*	*8:15*
Observation Time (End):	*16:20*	*16:10*	*14:30*	*14:15*	*15:15*	*14:20*	*17:00*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	11	9	5	2	3	--	5
0900 to 0959	3	8	0	2	0	--	41
1000 to 1059	6	11	0	0	0	--	14
1100 to 1159	2	5	0	1	1	3	10
1200 to 1259	2	3	1	2	3	1	8
1300 to 1359	0	2	2	6	1	3	18
1400 to 1459	5	7	0	2	7	4	18
1500 to 1559	9	4	--	--	4	--	72
1600 to 1659	18	1	--	--	--	--	44
1700 to 1759	--	--	--	--	--	--	--
1800 to 1859	--	--	--	--	--	--	--
1900 to 1959	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**56**	**50**	**8**	**15**	**19**	**11**	**230**

Date:	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*
Observation Time (Start):	*8:15*	*8:18*	*8:05*	*8:40*	*8:00*	*8:00*	*8:20*
Observation Time (End):	*18:15*	*19:00*	*19:15*	*19:15*	*19:23*	*19:15*	*19:15*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	5	26	140	62	93	134	80
0900 to 0959	24	93	211	52	118	114	158
1000 to 1059	24	99	206	39	166	108	234
1100 to 1159	33	58	209	86	191	93	132
1200 to 1259	61	109	106	118	152	91	152
1300 to 1359	89	137	311	83	307	70	242
1400 to 1459	165	213	276	88	352	158	140
1500 to 1559	97	189	160	83	264	222	295
1600 to 1659	105	166	221	103	264	395	289
1700 to 1759	71	113	164	63	171	245	177
1800 to 1859	57	133	124	93	165	226	117
1900 to 1959	--	--	47	24	53	64	67
2000 to 2059	--	--	--	--	--	--	--
Total	**731**	**1,336**	**2,175**	**894**	**2,296**	**1,920**	**2,083**

Table 3: Page 3 of 4

Continued.

Date:	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Observation Time (Start):	*8:02*	*8:00*	*8:00*	*8:40*	*8:00*	*8:05*	*8:45*
Observation Time (End):	*19:45*	*18:55*	*18:00*	*18:30*	*18:05*	*19:00*	*18:50*
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	--
0800 to 0859	173	105	430	33	75	20	13
0900 to 0959	211	57	175	75	52	43	31
1000 to 1059	73	19	125	116	27	109	7
1100 to 1159	279	--	89	84	13	103	10
1200 to 1259	220	76	48	90	12	122	36
1300 to 1359	291	411	115	103	29	241	39
1400 to 1459	121	211	153	182	27	245	103
1500 to 1559	222	204	161	145	24	316	84
1600 to 1659	218	136	138	79	37	173	114
1700 to 1759	298	116	88	80	26	130	113
1800 to 1859	317	53	--	34		137	117
1900 to 1959	134	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--
Total	**2,557**	**1,388**	**1,522**	**1,021**	**322**	**1,639**	**667**

Date:	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*
Observation Time (Start):	*8:05*	*8:10*	*8:00*	*8:00*	*8:05*	*8:00*	*8:25*	*8:20*
Observation Time (End):	*18:08*	*18:05*	*18:20*	*18:10*	*18:10*	*18:10*	*17:40*	*18:24*
Military Time (hrs)								
0700 to 0759	--	--	--	--	--	--	--	--
0800 to 0859	42	11	14	17	17	14	3	6
0900 to 0959	37	99	18	11	52	35	3	6
1000 to 1059	32	73	5	9	57	12	5	21
1100 to 1159	32	51	16	11	24	33	6	29
1200 to 1259	13	73	17	41	15	21	15	42
1300 to 1359	20	81	33	114	45	16	21	19
1400 to 1459	10	84	54	93	27	48	30	18
1500 to 1559	30	97	46	59	47	105	29	30
1600 to 1659	29	34	55	42	55	55	22	84
1700 to 1759	25	34	73	40	40	50	4	60
1800 to 1859	12	6	13	10	8	8	--	23
1900 to 1959	--	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--	--
Total	**282**	**643**	**344**	**447**	**387**	**397**	**138**	**338**

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Continued.

Date:	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*
Observation Time (Start):	*8:00*	*8:40*	*8:00*	*8:00*	*8:10*	*8:00*	*8:20*	*8:20*
Observation Time (End):	*18:10*	*18:15*	*18:10*	*18:10*	*18:30*	*17:40*	*17:15*	*17:15*
Military Time (hrs)								
0700 to 0759	--	--	--	--	--	--	--	--
0800 to 0859	34	1	6	8	1	19	7	2
0900 to 0959	9	24	6	29	66	28	46	42
1000 to 1059	2	63	36	37	101	50	42	20
1100 to 1159	11	50	32	83	47	53	70	60
1200 to 1259	8	90	35	133	82	72	49	46
1300 to 1359	15	87	47	116	97	101	57	41
1400 to 1459	20	47	45	75	176	87	31	28
1500 to 1559	32	35	20	111	185	94	22	37
1600 to 1659	62	67	31	63	162	63	15	27
1700 to 1759	67	54	37	28	69	14	9	4
1800 to 1859	10	5	2	3	37	--	--	--
1900 to 1959	--	--	--	--	--	--	--	--
2000 to 2059	--	--	--	--	--	--	--	--
Total	**270**	**523**	**297**	**686**	**1,023**	**581**	**348**	**307**

Date:	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	
Observation Time (Start):	*8:12*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	
Observation Time (End):	*15:40*	*15:40*	*14:10*	*14:20*	*15:48*	*15:40*	***Total***
Military Time (hrs)							
0700 to 0759	--	--	--	--	--	--	***0***
0800 to 0859	10	29	4	1	6	5	***1,821***
0900 to 0959	25	60	11	20	27	3	***2,528***
1000 to 1059	34	37	14	32	20	6	***2,681***
1100 to 1159	6	23	9	16	19	8	***2,882***
1200 to 1259	8	17	5	6	23	2	***3,307***
1300 to 1359	17	5	9	12	14	3	***4,534***
1400 to 1459	27	8	3	1	30	--	***4,552***
1500 to 1559	15	0	--	--	21	--	***4,488***
1600 to 1659	--	--	--	--	--	--	***4,055***
1700 to 1759	--	--	--	--	--	--	***3,021***
1800 to 1859	--	--	--	--	--	--	***1,710***
1900 to 1959	--	--	--	--	--	--	***389***
2000 to 2059	--	--	--	--	--	--	***0***
Total	**142**	**179**	**55**	**88**	**160**	**27**	***35,968***

Table 4: Page 1 of 2

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2006.

	Shad	Number Collected		Percent Collected	
Date	**Catch**	**Tailrace**	**Spillway***	**Tailrace**	**Spillway**
11-Apr	116	116	--	100%	0%
12-Apr	152	152	--	100%	0%
13-Apr	207	207	--	100%	0%
14-Apr	370	370	--	100%	0%
15-Apr	540	540	--	100%	0%
16-Apr	493	493	--	100%	0%
17-Apr	481	481	--	100%	0%
18-Apr	1,000	1,000	--	100%	0%
19-Apr	402	402	--	100%	0%
20-Apr	327	327	--	100%	0%
21-Apr	929	929	--	100%	0%
22-Apr	547	547	--	100%	0%
23-Apr	1,482	1,482	--	100%	0%
24-Apr	320	320	--	100%	0%
25-Apr	56	56	--	100%	0%
26-Apr	50	50	--	100%	0%
27-Apr	8	8	--	100%	0%
28-Apr	15	15	--	100%	0%
29-Apr	19	19	--	100%	0%
30-Apr	11	11	--	100%	0%
1-May	230	190	40	83%	17%
2-May	731	631	100	86%	14%
3-May	1336	1336	--	100%	0%
4-May	2175	2175	--	100%	0%
5-May	894	894	--	100%	0%
6-May	2296	2296	--	100%	0%
7-May	1920	1920	--	100%	0%
8-May	2083	2083	--	100%	0%
9-May	2557	2557	--	100%	0%
10-May	1388	1388	--	100%	0%
11-May	1522	1222	300	80%	20%
12-May	1021	510	511	50%	50%
13-May	322	322	--	100%	0%
14-May	1639	1,639	--	100%	0%
15-May	667	442	225	66%	34%
16-May	282	280	2	99%	1%
17-May	643	289	354	45%	55%
18-May	344	304	40	88%	12%
19-May	447	134	313	30%	70%
20-May	387	213	174	55%	45%
21-May	397	277	120	70%	30%

Table 4: Page 2 of 2

Continued.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway*	Tailrace	Spillway
22-May	138	100	38	72%	28%
23-May	338	337	1	100%	0%
24-May	270	250	20	93%	7%
25-May	523	523	--	100%	0%
26-May	297	289	8	97%	3%
27-May	686	411	275	60%	40%
28-May	1023	818	205	80%	20%
29-May	581	481	100	83%	17%
30-May	348	305	43	88%	12%
31-May	307	296	11	96%	4%
1-Jun	142	142	--	100%	0%
2-Jun	179	179	--	100%	0%
3-Jun	55	55	--	100%	0%
4-Jun	88	88	--	100%	0%
5-Jun	160	160	--	100%	0%
6-Jun	27	27	--	100%	0%
Total	***35,968***	***33,088***	***2,880***	***92%***	***8%***

* Spillway entrance gate severely damaged by Hurricane Ivan flooding in September, 2004. Operation of Spillway lift during 2006 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
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr	26 Apr	27 Apr	11 Apr
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun	03 Jun	10 Jun	06 Jun
Season duration (days)	58	47	40	40	43	55	36	39	45	57
Number of days of operation	55	41	40	36	42	35	34	39	36	57
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
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
River flow ≤40,000 cfs										
Number of days	48	22	34	19	40	19	15	2	33	48
Percent of season	87%	54%	85%	53%	95%	54%	44%	5%	92%	84%
Number of American shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229	2	34,060	35,302
Daily average of American shad passed	546	341	1,002	1,037	2,733	543	1,348	1	1,032	735
Percent of total passage	93%	91%	98%	67%	99%	59%	80%	0%	99.6%	98.1%
River flow 40,001 to 60,000 cfs										
Number of days	7	2	6	12	2	14	18	20	3	5
Percent of season	13%	5%	15%	33%	5%	40%	53%	51.30%	8.00%	9.00%
Number of American shad passed	1,862	230	633	9,536	634	7,029	5,019	1,943	129	566
Daily average of American shad passed	266	115	106	795	317	502	279	97	43	113
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.8%	56.7%	0.4%	1.6%
River flow >60,000 cfs										
Number of days	0	17	0	5	0	2	1	17	0	4
Percent of season	0%	41%	0%	14%	0%	6%	3%	43.60%	0.00%	7.00%
Number of American shad passed	0	493	0	173	0	171	6	1,483	0	100
Daily average of American shad passed	0	29	0	35	0	86	6	87	0	25
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%	43.3%	0.0%	0.3%

* Denotes seasons of high river flow.

Table 6:

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2006.

	Conowingo	Holtwood		Safe Harbor		York Haven	
	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%**

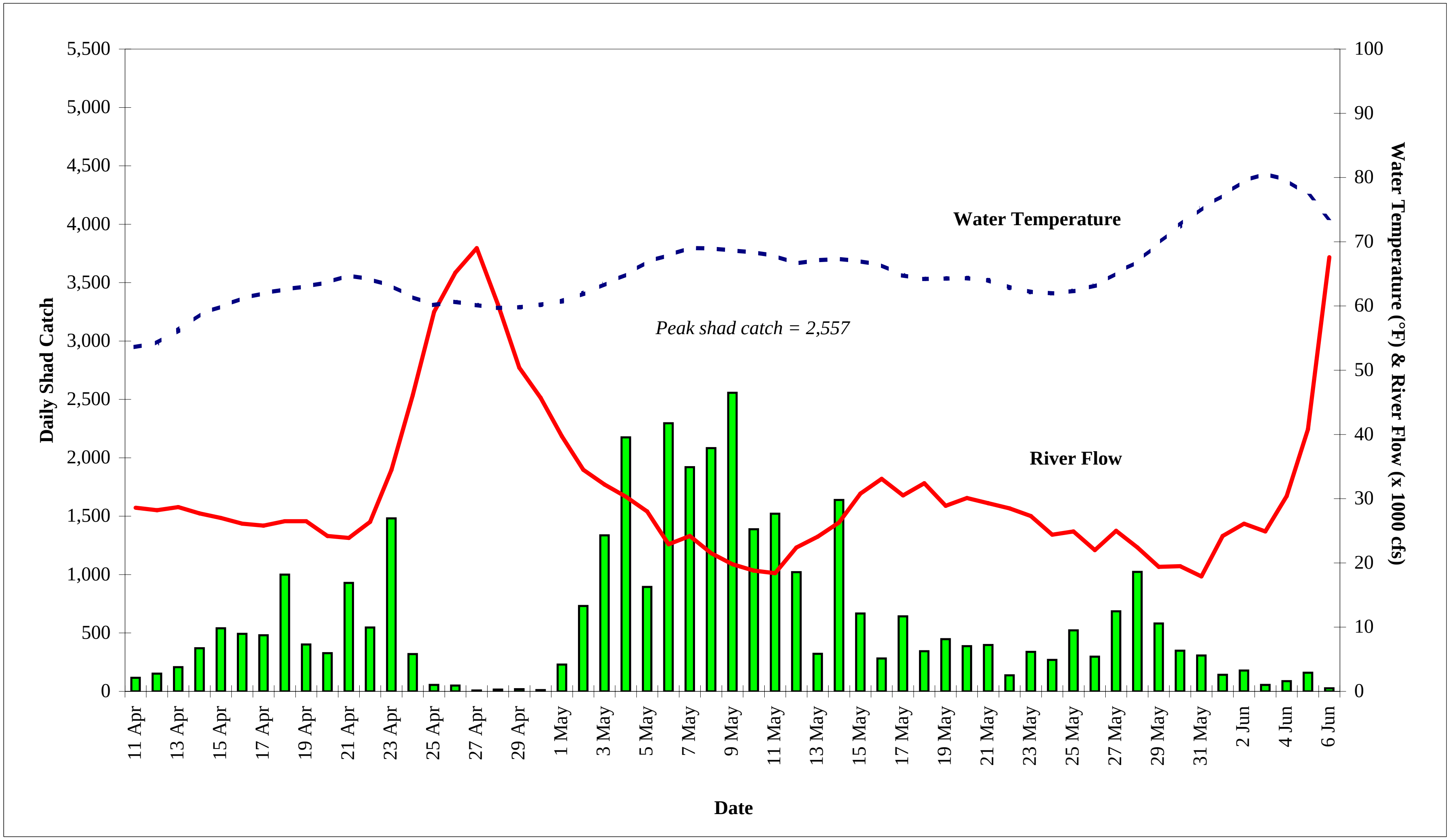

Figure 1

A plot of river flow (x 1000) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2006.

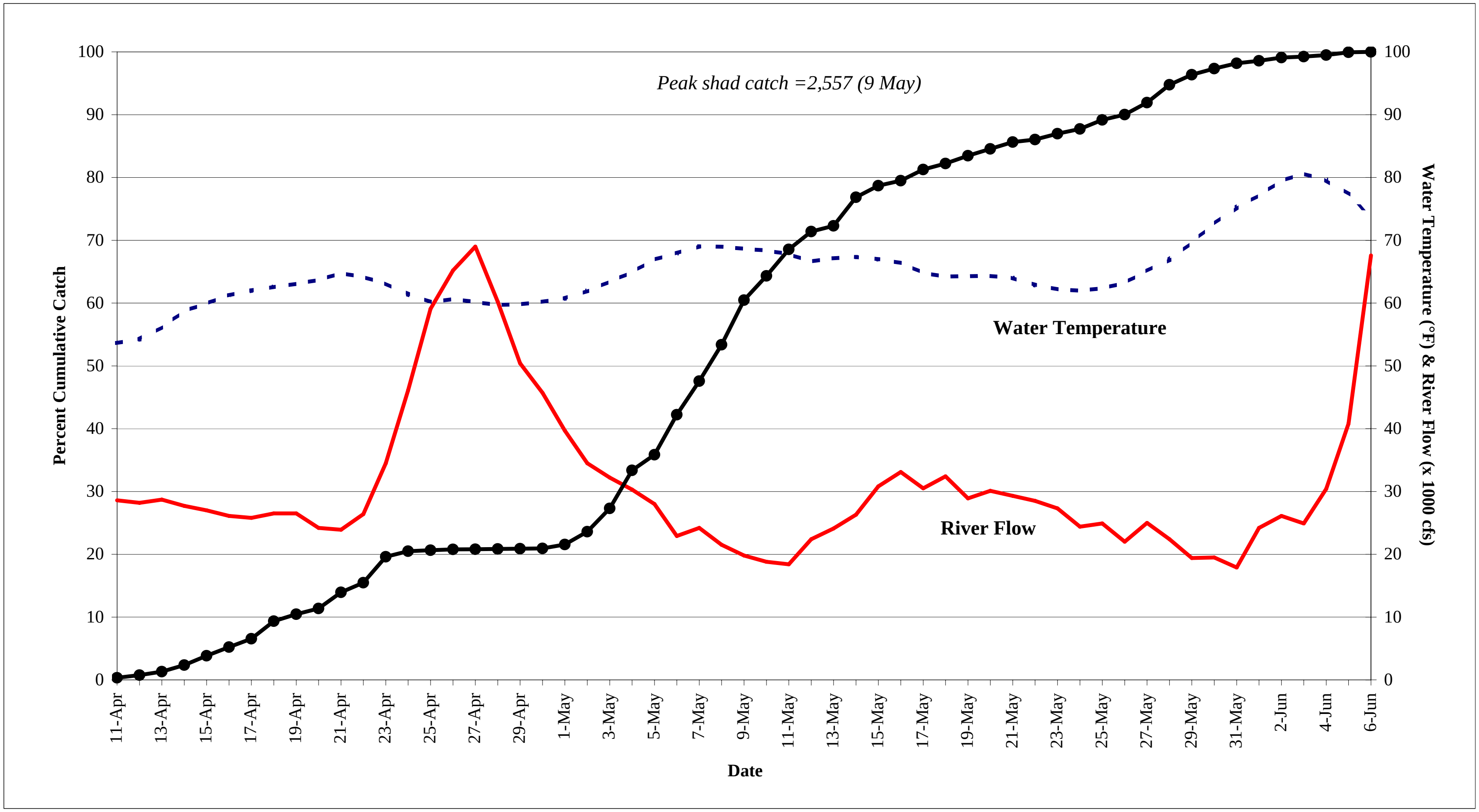

Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Holtwood Fish Passage Facility, spring 2006.

SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY, SPRING 2005

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INTRODUCTION

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

Objectives for 2006 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATION

Project Operation

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

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

Fishway Design

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 2005 season utilized a combination of entrances A and C (Table 2).

Fishway Operation

Fishway operation commences soon after passage of approximately 500 American shad via the Holtwood Fishway. In 2006, due to low river flows in March and April, operations were able to commence in mid-April, earlier than in previous years.

The Safe Harbor fishway began operation on 18 April, with operations ending on 9 June. No shut downs of the facility occurred during operations in spring, 2006. Lift operations ended due to the dwindling fish catch and rising water temperatures; indications that the migration run was ending.

Throughout the 2006 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

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

Fish Counts

Fish lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide channel on the east side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to 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.

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed in 2006 by the Safe Harbor fish way is presented in Table 1. A total of 244,907 fish of 23 species and 2 hybrids passed upstream into Lake Clarke. Gizzard shad (179,150) was the dominant species passed and comprised 73% of the catch. Some 24,929 American shad were passed upstream through the fish way and comprised 10% of the catch. Other predominant fishes passed included quillback (14,754), walleye (14,079), channel catfish (4,673), and smallmouth bass (3,307). Peak passage occurred on 12 May, when 15,996 fish were passed.

American Shad Passage

The Safe Harbor fishway passed 24,929 American shad in 2006 during 53 days of operation (Table 1). Though collection and passage of shad varied daily, shad passage numbers were similar to those recorded in 2005, although this year's operating season was much longer than in recent years, (16 days longer than in 2005). The Conowingo fishway passed 56,899 American Shad, which is their lowest season total since passage operations commenced in 1997. Having lower numbers of shad in the system, and stable river flows, Safe Harbor passed 24,929 American Shad, 69.3% of the shad Holtwood Dam passed (35,968). Moreover, the Safe Harbor fishway passed nearly 44% of the American Shad passed by Conowingo Dam. Peak shad passage occurred on 12 May when 1,548 shad were captured and passed during 11 hours of operation.

American shad were passed at water temperatures of 59.7°F to 80.6°F and river flows of 17,900 to 69,000 cfs (Table 2 and Figures 1and 2). Water temperature and river flow on those 7 days when more than 1,000 American shad were passed averaged 66.8°F (61.0°F to 69.0°F) and 22,200 cfs, (18,400 cfs to 28,000 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 were similar from 0900 to 1659 hr, with a sharp, then steady decrease in catch from 1700 to 1859 hr. The peak passage hour for American Shad during the entire season was observed between 0800-0859 hrs, with a total of 3,136 American shad passed. The highest hourly passage (274) occurred between 0800 and 0859 hr on 5 May.

During the 2006 season, the Safe Harbor fish way passed a total of 7 tagged American shad that had been passed by the downstream fish lift facilities. These shad were captured, tagged and released downstream of Conowingo dam by the MDDNR. Safe Harbor observed the passage of six orange floy tags, (2006 hook and line), and one yellow floy tag.

Other Alosids

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2006.

SUMMARY

The 2006 Safe Harbor fishway operating season was successful with no disruptions to operations due to mechanical problems. The fifty-three days of operation in 2006 marks the longest migration season at Safe Harbor since operations started in 1997. A total of 24,929 American shad were passed into Lake Clarke, or 69.3% 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 ten years of experience.

RECOMMENDATIONS

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

LITERATURE CITED

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

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

Table 1: Page 1 of 6

Number and disposition of fish passed by the Safe Harbor fishway in 2006.

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Hours of Operation:	*9.3*	*9.3*	*8.0*	*8.0*	*8.0*	*9.9*	*9.5*	*9.3*	*8.5*	*8.5*
Viewing Start Time:	*8:00*	*7:30*	*7:30*	*8:00*	*8:00*	*8:00*	*7:40*	*7:45*	*7:40*	*7:20*
Viewing End Time:	*16:45*	*16:20*	*16:00*	*15:35*	*16:00*	*17:40*	*16:50*	*17:15*	*16:30*	*15:50*
Numbers of Lifts:	*11*	*13*	*9*	*7*	*7*	*9*	*9*	*9*	*9*	*9*
Water Temp (F):	*61.0*	*62.0*	*63.0*	*64.0*	*64.4*	*63.0*	*61.0*	*59.0*	*61.0*	*62.5*
American shad	1,110	667	457	228	233	446	482	658	642	182
Gizzard shad	2,823	1,783	1,108	1,402	1,380	5,158	995	770	3,699	1,318
Sea lamprey	0	0	0	0	0	1	0	0	1	0
Rainbow trout	0	1	0	0	0	0	1	0	0	0
Brown trout	2	0	1	1	0	0	0	1	1	0
White perch	0	0	0	0	0	0	0	0	0	0
Carp	81	24	39	139	22	24	11	4	3	3
Quillback	1,034	584	404	1,072	226	169	9	16	55	27
Shorthead redhorse	200	185	177	365	90	92	20	47	131	20
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	0	2	2	9	20	20	16	5	119	20
Rock bass	1	0	0	1	0	0	5	2	5	1
Redbreast sunfish	0	0	0	0	8	1	0	0	0	0
Green Sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	4	3	0	0	0	0	0	0	0	1
Bluegill	1	1	0	1	0	0	0	0	1	0
Smallmouth bass	1,261	398	283	229	79	150	31	31	77	9
Largemouth bass	1	0	0	1	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow Perch	0	0	0	0	0	0	0	0	0	0
Walleye	26	31	22	94	58	109	19	10	59	17
Striped Bass	0	1	0	0	0	0	3	0	2	0
Hybrid Striped Bass	0	0	0	1	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Spotfin shiner	0	0	0	0	0	0	0	0	0	0
Total	**6,544**	**3,680**	**2,493**	**3,543**	**2,116**	**6,170**	**1,592**	**1,544**	**4,795**	**1,598**

Table 1: Page 2 of 6

Continued.

Date:	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*
Hours of Operation:	*6.4*	*8.4*	*9.8*	*8.9*	*8.8*	*9.2*	*8.8*	*10.0*	*9.3*	*8.3*
Viewing Start Time:	*9:06*	*7:30*	*8:00*	*7:40*	*8:30*	*7:30*	*7:50*	*7:30*	*7:40*	*8:00*
Viewing End Time:	*15:45*	*16:00*	*17:20*	*16:45*	*16:45*	*16:50*	*16:45*	*17:30*	*17:00*	*17:15*
Numbers of Lifts:	*6*	*8*	*9*	*8*	*7*	*11*	*11*	*15*	*13*	*11*
Water Temp (F):	*62.4*	*62.1*	*61.9*	*61.8*	*70.0*	*63.0*	*64.4*	*66.2*	*67.8*	*67.9*
American shad	101	175	100	80	160	376	543	1,099	897	888
Gizzard shad	2,255	2,083	2,987	2,196	3,928	5,473	7,591	6,931	4,579	5,481
Sea lamprey	0	0	0	0	0	0	0	1	0	1
Rainbow trout	0	0	0	0	0	0	0	1	0	0
Brown trout	0	1	1	0	0	0	3	0	0	0
White perch	0	0	0	0	0	0	0	0	0	0
Carp	3	1	2	13	32	12	18	14	6	9
Quillback	19	146	312	300	405	530	489	1,498	1,043	482
Shorthead redhorse	53	100	202	105	117	66	101	216	123	76
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	7	2	4	6	2	14	17	75	142	56
Rock bass	7	0	0	0	4	1	9	17	4	6
Redbreast sunfish	0	0	1	0	0	0	0	0	0	0
Green Sunfish	0	0	0	0	1	0	3	0	0	0
Pumpkinseed	1	0	0	0	0	4	2	8	7	2
Bluegill	1	0	0	0	1	3	10	2	5	12
Smallmouth bass	15	19	93	28	75	87	105	105	47	24
Largemouth bass	1	0	0	1	1	2	3	1	2	2
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	1	0
Walleye	13	10	83	93	338	636	1,269	2,198	1,184	600
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
Tiger muskie	0	0	0	0	1	0	0	0	0	0
Spotfin shiner	0	0	1	0	0	0	0	0	0	0
Total	**2,476**	**2,537**	**3,786**	**2,822**	**5,065**	**7,204**	**10,163**	**12,166**	**8,040**	**7,639**

Table 1: Page 3 of 6

Continued.

Date:	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Hours of Operation:	*11.6*	*11.5*	*11.6*	*11.3*	*11.7*	*11.3*	*9.9*	*10.8*	*11.0*	*10.0*
Viewing Start Time:	*7:30*	*7:50*	*7:30*	*8:00*	*7:30*	*7:20*	*8:00*	*7:30*	*7:45*	*7:30*
Viewing End Time:	*18:40*	*18:20*	*18:15*	*18:15*	*18:30*	*18:15*	*18:40*	*18:30*	*18:30*	*18:00*
Numbers of Lifts:	*14*	*14*	*18*	*14*	*18*	*16*	*14*	*12*	*13*	*10*
Water Temp (F):	*68.0*	*69.0*	*69.0*	*67.2*	*67.2*	*67.2*	*67.0*	*66.9*	*66.9*	*66.5*
American shad	1,125	1,175	1,540	1,133	1,548	966	541	364	290	394
Gizzard shad	8,756	8,180	8,231	6,166	13,681	10,025	5,583	7,765	6,164	2,799
Sea lamprey	2	4	0	0	1	1	0	1	0	0
Rainbow trout	0	0	1	1	1	1	1	0	0	0
Brown trout	1	0	0	0	0	0	0	0	1	0
White perch	0	0	0	0	0	0	0	0	1	0
Carp	47	11	5	19	4	30	13	17	1	1
Quillback	758	326	78	183	81	323	91	308	10	3
Shorthead redhorse	62	6	0	6	8	19	3	4	1	1
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	232	46	30	20	59	231	147	293	67	64
Rock bass	7	2	6	0	4	5	6	2	1	1
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green Sunfish	0	0	3	3	3	0	2	0	0	0
Pumpkinseed	8	3	1	1	2	5	0	1	0	2
Bluegill	1	11	0	8	0	1	3	0	0	0
Smallmouth bass	25	4	1	2	3	19	9	6	4	3
Largemouth bass	0	0	0	0	0	0	0	2	0	1
White crappie	1	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	1,058	370	313	379	601	644	211	198	116	68
Striped Bass	0	0	0	1	0	0	0	0	1	0
Hybrid Striped bass	0	0	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Spotfin shiner	0	0	0	0	0	0	0	0	0	0
Total	**12,083**	**10,138**	**10,209**	**7,922**	**15,996**	**12,270**	**6,610**	**8,961**	**6,657**	**3,337**

Table 1: Page 4 of 6

Continued.

Date:	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours of Operation:	*10.2*	*8.3*	*10.9*	*11.3*	*10.8*	*10.0*	*9.5*	*10.3*	*10.7*	*10.3*
Viewing Start Time:	*8:00*	*9:40*	*7:40*	*7:45*	*7:30*	*7:45*	*7:40*	*8:35*	*7:25*	*7:45*
Viewing End Time:	*18:00*	*17:55*	*18:25*	*18:30*	*17:50*	*17:30*	*17:20*	*17:45*	*17:35*	*17:45*
Numbers of Lifts:	*10*	*9*	*30*	*10*	*10*	*10*	*11*	*8.0*	*10*	*10*
Water Temp (F):	*66.0*	*66.0*	*67.0*	*65.8*	*65.4*	*63.0*	*62.0*	*67.0*	*64.0*	*64.0*
American shad	412	441	404	200	150	143	191	388	454	382
Gizzard shad	2,860	1,773	1,862	2,075	1,458	454	674	438	2,579	3,055
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Brown trout	1	0	1	0	0	0	1	1	0	0
White perch	0	0	0	0	0	0	0	0	0	1
Carp	0	1	1	0	0	0	0	1	7	10
Quillback	47	4	18	3	2	3	2	6	38	15
Shorthead redhorse	2	0	8	1	0	0	0	2	5	7
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	10	66	35	32	6	2	4	8	23	69
Rock bass	0	2	1	1	0	1	1	3	1	8
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	1	0	1	1	0	0	0	2	0
Bluegill	5	1	2	1	2	0	0	4	2	0
Smallmouth bass	3	1	9	4	3	4	7	13	9	3
Largemouth bass	0	0	1	2	1	1	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	1
Walleye	71	121	180	141	54	28	19	34	254	796
Striped Bass	0	0	0	0	0	0	0	0	0	0
Hybrid Striped bass	0	0	1	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Spotfin shiner	0	0	0	0	0	0	0	0	0	0
Total	**3,411**	**2,411**	**2,523**	**2,461**	**1,677**	**636**	**899**	**898**	**3,374**	**4,347**

Table 1: Page 5 of 6

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*	*06 Jun*
Hours of Operation:	*10.9*	*9.8*	*10.0*	*9.8*	*9.5*	*9.6*	*7.1*	*7.2*	*8.0*	*7.8*
Viewing Start Time:	*7:30*	*7:30*	*7:45*	*7:30*	*7:50*	*7:30*	*8:00*	*7:45*	*7:45*	*7:30*
Viewing End Time:	*17:40*	*17:30*	*17:30*	*17:25*	*16:50*	*16:55*	*15:25*	*15:20*	*15:15*	*15:20*
Numbers of Lifts:	*11*	*13*	*11*	*11*	*10*	*10*	*7*	*7*	*8*	*8*
Water Temp (F):	*67.0*	*70.0*	*74.0*	*76.0*	*77.0*	*81.0*	*81.0*	*80.0*	*80.0*	*79.0*
American shad	461	830	556	269	210	165	157	99	152	125
Gizzard shad	2,587	3,019	1,603	3,412	1,041	1,875	1,821	1,268	1,238	826
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0	0	0
Brown trout	0	1	1	0	1	0	0	0	0	0
White perch	0	0	2	0	0	0	0	0	0	0
Carp	6	4	4	23	2	13	57	21	7	17
Quillback	36	208	271	1,005	385	577	494	364	84	94
Shorthead redhorse	8	4	8	21	36	25	15	19	1	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	75	218	114	120	180	537	300	350	418	77
Rock bass	1	2	1	1	4	0	1	0	0	2
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	5	2	6	0	3	0	3
Bluegill	3	2	5	8	21	5	3	4	1	1
Smallmouth bass	7	8	1	3	0	3	5	0	1	0
Largemouth bass	0	1	1	0	1	0	0	1	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	216	201	188	188	105	152	36	130	71	61
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
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Spotfin shiner	0	0	0	0	0	0	0	*0*	0	0
Total	**3,400**	**4,500**	**2,755**	**5,055**	**1,988**	**3,358**	**2,889**	**2,259**	**1,973**	**1,206**

Table 1: Page 6 of 6

Continued.

Date:	*07 Jun*	*08 Jun*	*09 Jun*	**Totals**
Hours of Operation:	*8.3*	*8.0*	*8.0*	**503.2**
Viewing Start Time:	*7:25*	*8:00*	*7:45*	**--**
Viewing End Time	*15:30*	*15:25*	*15:15*	**--**
Numbers of Lifts:	*8*	*9*	*8*	**573**
Water Temp (F):	*79.0*	*78.5*	*76.0*	**--**
American shad	57	43	40	**24,929**
Gizzard shad	1,478	387	77	**179,150**
Sea lamprey	0	0	0	**13**
Rainbow trout	0	0	0	**8**
Brown trout	0	0	0	**20**
White perch	0	0	0	**4**
Carp	1	0	2	**785**
Quillback	83	29	5	**14,754**
Shorthead redhorse	5	1	2	**2,766**
Brown bullhead	1	2	0	**3**
Channel catfish	247	29	26	**4,673**
Rock bass	3	2	0	**132**
Redbreast sunfish	0	0	0	**10**
Green Sunfish	0	0	0	**17**
Pumpkinseed	0	0	0	**79**
Bluegill	0	1	3	**136**
Smallmouth bass	0	0	1	**3,307**
Largemouth bass	0	0	0	**27**
White crappie	0	0	0	**1**
Yellow perch	0	0	0	**2**
Walleye	86	48	72	**14,079**
Striped Bass	0	0	0	**8**
Hybrid Striped bass	0	0	0	**2**
Tiger muskie	0	0	0	**1**
Spotfin shiner	0	0	0	**1**
Total	**1,961**	**542**	**228**	**244,907**

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 2006.

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)
18 Apr	26.5	62.6	30	8	1-3,5-7,11,12	A & C	500	168.4	226.0
19 Apr	26.5	63.1	24	11	1 to 3, 5 to 12	A & C	500	170.1	225.8
20 Apr	24.2	63.7	30	4	3, 5 to 7	A & C	500	171.0	225.8
21 Apr	23.9	64.8	30	5	2,3, 5 to 7	A & C	500	168.8	226.0
22 Apr	26.4	64.2	30	9	1,3,5-10,12	A & C	500	169.4	226.0
23 Apr	34.5	63.1	30	4	3, 5 to 7	A & C	500	170.1	225.9
24 Apr	46.1	61.4	30	4	3, 5 to 7	A & C	500	172.1	225.8
25 Apr	59.1	60.2	30	9	1 to 3,5 to 10	A & C	500	172.5	226.5
26 Apr	65.2	60.7	26	10	1 to 3, 5 to 11	A & C	500	174.6	225.8
27 Apr	69.0	60.2	26	10	1,3, 5 to 12	A & C	500	174.3	226.1
28 Apr	60.2	59.7	32	11	1 to 3,5 to 12	A & C	500	173.1	226.3
29 Apr	50.4	59.8	36	8	1,3, 5 to 10	A & C	500	172.4	226.3
30 Apr	45.7	60.2	30	7	3, 5 to 10	A & C	500	173.1	225.7
01 May	39.7	60.7	30	11	1 to 3, 5 to 12	A & C	500	171.7	225.5
02 May	34.5	62.0	36	6	2,3, 5 to 8	A & C	500	171.0	226.2
03 May	32.2	63.4	28	7	1 to 3,5 to 7,11	A & C	500	170.8	226.4
04 May	30.3	64.9	30	6	1 to 3, 5,6,10	A & C	500	170.4	226.2
05 May	28.0	66.9	28	11	1 to 3, 5 to 12	A & C	500	169.5	226.0
06 May	22.9	67.9	24	9	3, 5 to 12	A & C	500	169.0	226.0
07 May	24.2	69.0	25	6	1,3, 5 to 8	A & C	500	169.3	225.7
08 May	21.5	69.0	26	5	2,3, 5 to 7	A & C	500	170.4	226.0
09 May	19.8	68.6	28	4	2, 5 to 7	A & C	500	169.3	225.8
10 May	18.8	68.4	30	3	2, 5, 6	A & C	500	169.3	226.3
11 May	18.4	67.8	28	5	2,3, 5 to 7	A & C	500	169.2	226.0
12 May	22.4	66.6	20	5	2,3, 5 to 7	A & C	500	168.4	226.4
13 May	24.1	67.1	26	4	3, 5 to 7	A & C	500	169.8	226.2
14 May	26.3	67.3	20	5	2,3,5,7, 8	A & C	500	170.1	226.2
15 May	30.8	67.0	20	8	2,3,5-7,10-12	A & C	500	169.8	226.0
16 May	33.1	66.4	20	8	2,3, 5 to 10	A & C	500	171.5	226.1
17 May	30.5	64.8	24	6	2,3, 5 to 8	A & C	500	171.0	226.2
18 May	32.4	64.2	16	11	1 to 3, 5 to 12	A & C	500	170.7	226.4
19 May	28.9	64.3	24	9	1 to 3, 5 to 10	A & C	500	172.2	225.2
20 May	30.1	64.3	20	5	3, 5 to 8	A & C	500	170.3	226.2
21 May	29.3	64.0	18	5	3, 5 to 8	A & C	500	169.5	226.3
22 May	28.5	62.9	20	8	1 to 3, 5 to 9	A & C	500	170.8	226.3
23 May	27.3	62.2	18	8	1 to 3, 5 to 9	A & C	500	170.0	226.2
24 May	24.4	62.0	20	8	1 to 3, 5 to 9	A & C	500	170.9	225.8
25 May	24.9	62.4	30	6	1 to 3,5, 7,8	A & C	500	169.8	226.1
26 May	22.0	63.2	30	5	1 to 3, 5, 7	A & C	500	169.5	225.9
27 May	25.0	65.1	28	1	1	A & C	500	169.9	226.0
28 May	22.4	66.9	18	3	2, 5, 7	A & C	500	169.8	226.5
29 May	19.4	69.7	26	3	2, 5, 7	A & C	500	169.5	226.5
30 May	19.5	72.6	26	5	1 to 3, 7,8	A & C	500	170.0	226.0
31 May	17.9	75.2	26	2	1,2	A & C	500	169.5	226.0
01 Jun	24.2	77.2	30	4	1,2,5,7	A & C	500	171.4	225.8
02 Jun	26.1	79.5	26	4	1,3,5,7	A & C	500	170.0	226.0
03 Jun	24.9	80.6	20	4	3,5,7,8	A & C	500	170.7	226.4
04 Jun	30.4	79.6	20	4	3,5,7,8	A & C	500	169.7	226.5
05 Jun	40.8	77.3	18	11	1 to 3, 5 to 12	A & C	500	172.6	226.2
06 Jun	67.6	73.7	18	10	1-3,5,7-12	A & C	500	174.5	226.0
07 Jun	64.9	73.2	18	10	1,3,5 to 12	A & C	500	173.8	225.7
08 Jun	52.0	71.6	18	9	1 to 3, 5 to 10	A & C	500	172.4	226.2
09 Jun	44.5	71.2	18	7	1 to 3,5, 7-9	A & C	500	171.6	226.6

1 River flow and temperature measured at Holtwood Dam.

Table 3: Page 1 of 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2006.

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Observation Time (Start):	*8:00*	*7:30*	*7:30*	*8:00*	*8:00*	*8:00*	*7:40*	*7:45*	*7:40*	*7:20*
Observation Time (End):	*16:45*	*16:20*	*16:00*	*15:35*	*16:00*	*17:40*	*16:50*	*17:15*	*16:30*	*15:50*
Military time (hrs)										
0700 to 0759		82	48				8	24	49	11
0800 to 0859	142	103	85	27	35	58	30	71	54	42
0900 to 0959	117	95	61	40	28	27	16	19	41	27
1000 to 1059	203	56	58	22	38	11	13	22	39	16
1100 to 1159	105	52	66	18	24	21	28	45	43	11
1200 to 1259	99	38	33	20	23	62	31	40	84	27
1300 to 1359	90	72	33	24	36	31	58	66	93	22
1400 to 1459	142	87	36	50	41	87	83	70	86	21
1500 to 1559	121	66	37	27	8	49	113	130	107	5
1600 to 1659	91	16				58	102	123	46	
1700 to 1759						42		48		
1800 to 1859										
1900 to 1959										
Total	**1,110**	**667**	**457**	**228**	**233**	**446**	**482**	**658**	**642**	**182**

Continued.

Date:	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*
Observation Time (Start):	*9:06*	*7:30*	*8:00*	*7:40*	*8:30*	*7:30*	*7:50*	*7:30*	*7:40*	*8:00*
Observation Time (End):	*15:45*	*16:00*	*17:40*	*16:45*	*16:45*	*16:50*	*16:45*	*17:45*	*17:00*	*17:15*
Military time (hrs)										
0700 to 0759		1		6		2	3	17	24	
0800 to 0859		35	13	3	16	61	61	274	88	57
0900 to 0959	0	20	6	11	10	34	75	156	117	52
1000 to 1059	13	5	3		15	44	71	106	79	80
1100 to 1159	8	4	4	6	6	32	45	113	44	66
1200 to 1259		9	3	3	16	52	42	77	166	68
1300 to 1359		31	11	9	19	36	29	147	75	146
1400 to 1459	31	44	17	24	34	48	65	102	138	196
1500 to 1559	49	26	23	13	33	41	82	52	74	116
1600 to 1659			10	5	11	26	70	25	92	107
1700 to 1759			10					30		
1800 to 1859										
1900 to 1959										
Total	**101**	**175**	**100**	**80**	**160**	**376**	**543**	**1,099**	**897**	**888**

Table 3: Page 2 of 3

Continued.

Date:	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Observation Time (Start):	*7:30*	*7:50*	*7:30*	*8:00*	*7:30*	*7:20*	*8:00*	*7:30*	*7:45*	*7:30*
Observation Time (End):	*18:40*	*18:20*	*18:15*	*18:15*	*18:30*	*18:15*	*18:40*	*18:30*	*18:30*	*18:00*
Military time (hrs)										
0700 to 0759	50	47	41		51	90		3	0	15
0800 to 0859	69	93	270	157	127	119	43	41	38	28
0900 to 0959	98	116	148	84	108	58	67	14	20	24
1000 to 1059	68	45	128	87	115	101	56	46	25	30
1100 to 1159	80	94	106	151	96	25	43	22	26	24
1200 to 1259	124	74	126	117	104	143	61	35	30	42
1300 to 1359	133	103	64	120	113	47	43	42	28	58
1400 to 1459	96	110	109	77	270	97	81	54	19	19
1500 to 1559	120	114	139	97	253	90	37	33	21	69
1600 to 1659	92	190	175	135	151	102	31	41	45	34
1700 to 1759	105	120	160	83	118	76	57	22	38	51
1800 to 1859	90	69	74	25	42	18	22	11	0	
1900 to 1959										
Total	**1,125**	**1,175**	**1,540**	**1,133**	**1,548**	**966**	**541**	**364**	**290**	**394**

Continued.

Date:	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Observation Time (Start):	*8:00*	*9:40*	*7:40*	*7:45*	*7:30*	*7:45*	*7:40*	*8:35*	*7:25*	*7:45*
Observation Time (End):	*18:00*	*17:55*	*18:25*	*18:30*	*17:50*	*17:30*	*17:20*	*17:45*	*17:35*	*17:45*
Military time (hrs)										
0700 to 0759			21	4	4				54	
0800 to 0859	21		40	25	22	30		21	46	86
0900 to 0959	33	4	12	20	8	9		12	49	28
1000 to 1059	32	21	33	21	19	19	20	50	50	26
1100 to 1159	58	20	43	23	9	0	22	34	32	26
1200 to 1259	23	12	53	18	3	12	24	34	61	31
1300 to 1359	12	41	55	20	13	19	19	36	35	36
1400 to 1459	50	78	39	16	20	16	33	58	24	37
1500 to 1559	49	76	38	16	26	6	30	68	21	33
1600 to 1659	44	121	30	14	18	20	26	55	44	53
1700 to 1759	90	68	19	17	8	12	17	20	38	26
1800 to 1859			21	6						
1900 to 1959										
Total	**412**	**441**	**404**	**200**	**150**	**143**	**191**	**388**	**454**	**382**

Table 3: Page 3 of 3

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*	*06 Jun*
Observation Time (Start):	*7:30*	*7:30*	*7:45*	*7:30*	*7:50*	*7:30*	*8:00*	*7:45*	*7:45*	*7:30*
Observation Time (End):	*17:40*	*17:30*	*17:30*	*17:25*	*16:50*	*16:55*	*15:25*	*15:20*	*15:15*	*15:20*
Military time (hrs)										
0700 to 0759	23	51		27	10	1		3		4
0800 to 0859	70	107	158	42	95	30	37	2	33	16
0900 to 0959	26	108	74	12	22	33	33	32	24	15
1000 to 1059	50	115	38	40		27	17	14	6	20
1100 to 1159	44	98	35	22	28	4	25	12	6	6
1200 to 1259	34	103	59	26	5	13	11	11	17	15
1300 to 1359	45	60	67	24	15	21	14	15	18	24
1400 to 1459	42	62	33	18	8	15	7	3	34	16
1500 to 1559	56	41	43	36	10	5	13	7	14	9
1600 to 1659	54	42	25	6	17	16				
1700 to 1759	17	43	24	16						
1800 to 1859										
1900 to 1959										
Total	**461**	**830**	**556**	**269**	**210**	**165**	**157**	**99**	**152**	**125**

Continued.

Date:	*07 Jun*	*08 Jun*	*09 Jun*	
Observation Time (Start):	*7:25*	*8:00*	7:45	***Season***
Observation Time (End):	*15:30*	*15:25*	*15:15*	***Total***
Military time (hrs)				
0700 to 0759	1			**775**
0800 to 0859	4	2	9	**3,136**
0900 to 0959		7	2	**2,252**
1000 to 1059	13		0	**2,226**
1100 to 1159	12	6	1	**1,974**
1200 to 1259	7	5	13	**2,339**
1300 to 1359	11	12	4	**2,395**
1400 to 1459	4	5	9	**2,961**
1500 to 1559	5	6	2	**2,755**
1600 to 1659				**2,363**
1700 to 1759				**1,375**
1800 to 1859				**378**
1900 to 1959				**0**
Total	**57**	**43**	**40**	**24,929**

Table 4:

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2006.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		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	6.90%
2006	**56,899**	**35,968**	**63.2%**	**24,929**	**69.3%**	**1,913**	**7.70%**

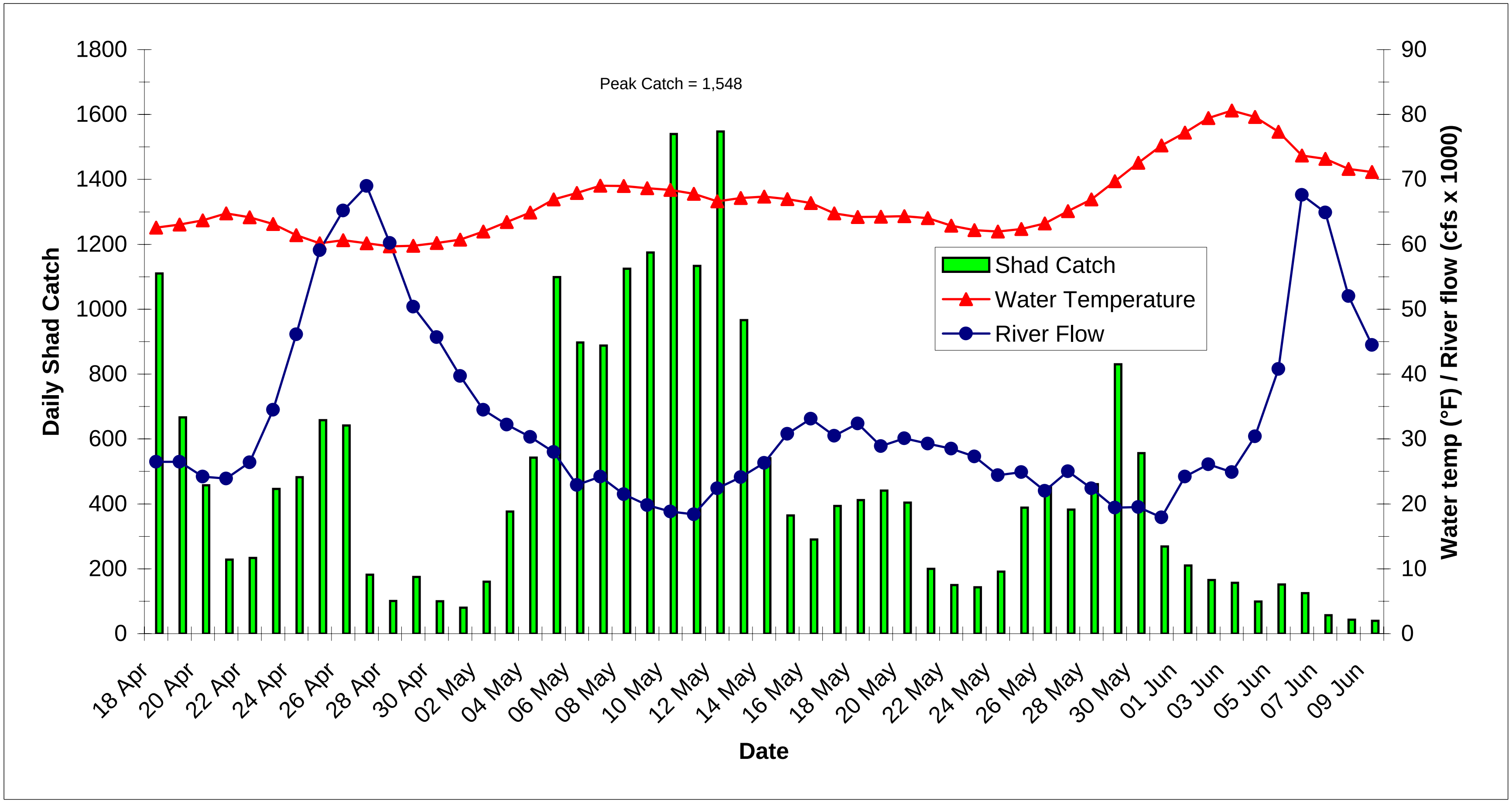

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam in relation to the daily American shad catch at the Safe Harbor fish passage facility, spring 2006.

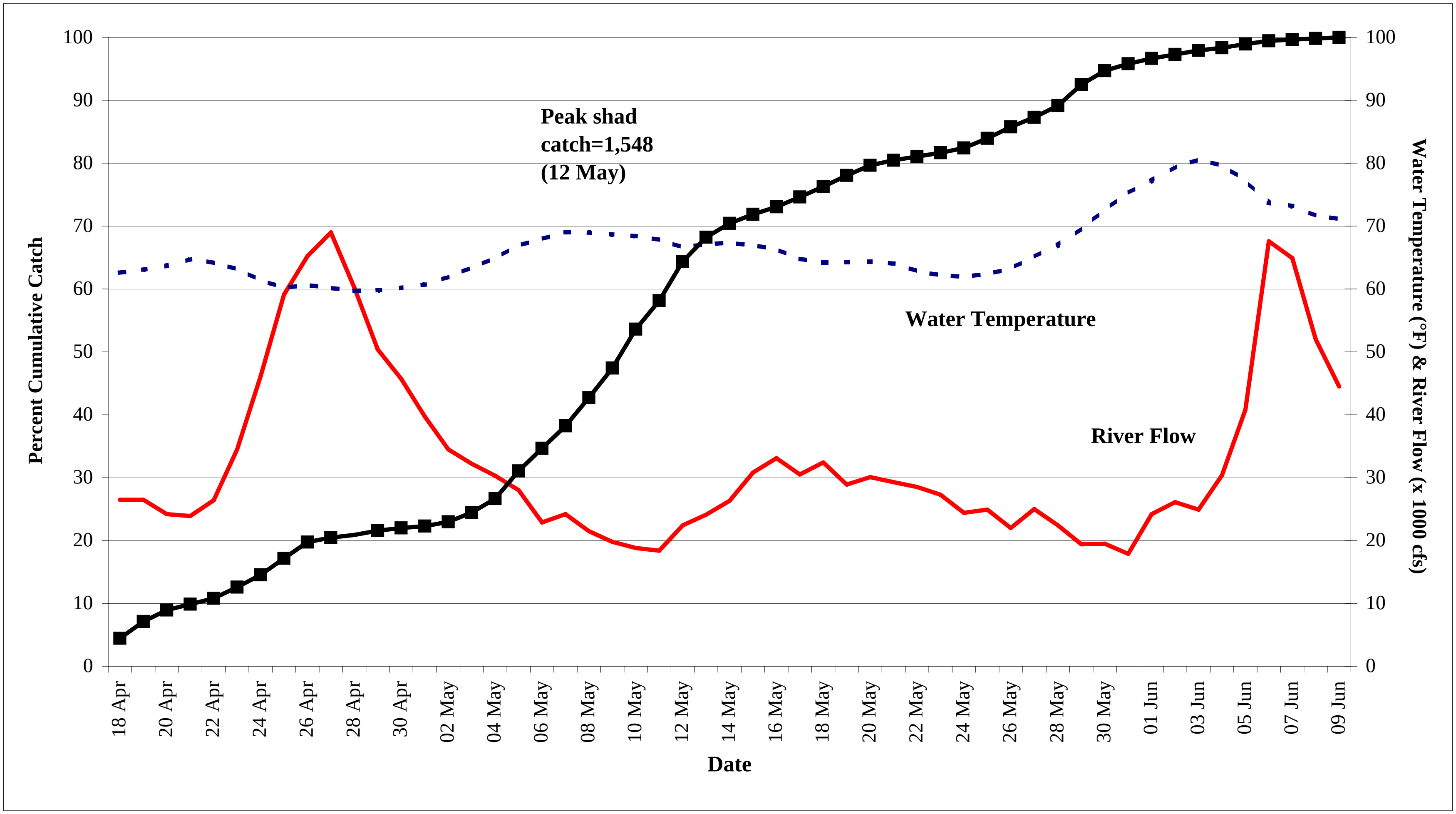

Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) as measured at Holtwood Dam in relation to the percent cumulative American shad catch at the Safe Harbor fish passage facility, spring 2006.

Job I - Part 5

SUMMARY OF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT IN 2005

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2 East Main Street
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EXECUTIVE SUMMARY

The fish ladder was opened on 31 March allowing volitional (unmanned) passage. Manned Fishway operation started on 22 April and ended on 12 June. During this 52 day period a total of 195,410 fish of 18 taxa were enumerated as they passed upstream though the ladder into Lake Frederic. Gizzard shad (164,869) was the dominant fish species passed and comprised over 84% of the fish passed. Passage varied daily and ranged from 961 fish on 24 May to 10,045 fish on 6 May. A total of 1,913 American shad were counted as they passed through the ladder.

A total of 1,913 shad were observed as they passed upstream through the ladder. Some 1,327 shad passed in May while 456 shad passed in June and 130 shad passed in April. American shad were passed at water temperatures of 56.5° F to 78.0° F, and River flows that that ranged from 16,300 cfs to 71,400 cfs and East Channel flows of 2,100 cfs to 13,500 cfs. Water temperature, River flows and East Channel flows when more than 100 American shad were passed averaged 69.8° F (67.5° F to 73.0° F), 19,300 cfs (16,700 cfs to 21,500 cfs), and 2,100 cfs, respectively. Shad passage varied daily with nearly 75% of total shad passed (1,422) in 20 days; 677 passed between 4 and 14 May and 744 shad passed during a nine day period in between 28 May and 5 June.

Most shad (1,274) passed through the ladder between 0800 hrs and 1100 hrs. The peak hourly passage of shad (87) occurred on 28 May between 0800 hrs and 0859 hrs. Over 52% of the shad (1,274) passed between 0800 hrs and 1100 hrs; hourly passage varied from 272 to 428 shad. Some 657 shad passed from 1101 hrs to 1300 hrs. A total of 398 shad passed between 1301 hrs and 1600 hrs.

Some 229 shad passed through the Fishway between 30 May and 1 June, a consecutive 48 hr period of manned operation. A total of 174 shad, 54 shad and 50 shad passed on 30 May, 31 May and 1 June,

respectively. Over 72% of the shad (166) passed on 30 May between 0800 hrs and 1600 hrs. Although time of passage through the ladder during this 48 hr period of manned fishway operation differed from that observed during most of the season and several shad passed prior to 0800 hrs allowing continuous passage during this 48 hr period did not appear to result a increase in the number of shad passing through the Fishway.

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 seven 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 June through mid-August.

The station also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC. Monitoring of the York Haven forebay for the presence of fish began on 24 September when water temperature was 66.0° F. Monitoring continued through 30 October. River flow during this period ranged varied daily and ranged from 11,700 cfs to 103,000 cfs. The detection of fish activity during this period was noted as being generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity. Given that fish activity was non-existent there was no need to implement "Downstream Operation"

Job I - Part 5

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 discussions at the December 7, 2005 FPTAC meeting, a framework was developed for the operation of the York Haven Fishway (Fishway) during the spring migration season. On March 9th, 2006, a draft Fishway Operation Plan was distributed to members of the FPTAC for review and comment and subsequently finalized. As in previous years, YHPC agreed to make 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.

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 2006, the seventh year of Fishway operation incorporated experience gained during the first six seasons, along with FPTAC recommendations. Objectives of 2006 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.

In 2002, YHPC received agency approval (when/if River flows are below 23,000 cfs) to reduce the Main Dam spill to a minimum of 1,000 cfs nightly at the Main Dam once fish passage is shut down each evening (1900 hrs) until 0600 hrs the following morning. In 2001, this reduced nighttime Main Dam spill was shown to enhance shad passage at the Fishway the following day. During 2002, YHP also obtained approval to evaluate (when River flow is less than 23,000 cfs) reducing the 4,000 cfs spill maintained over the Main Dam during Fishway operation (0600 hrs to 1900 hrs) on an alternate day basis. A nominal 2,100 cfs East Channel minimum flow is released through the fishway 24 hrs a day during the entire Fishway operating season. Although YHPC was able to implement these flow changes during the 2005 season no improvements in shad passage were discernable as the results from the 2005 radio telemetry study were inconclusive. Consequentially in 2006 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.

Job I - Part 5

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.

Fishway Design

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

Fishway Operation

Fishway preparations for the 2006 season began in mid-March enabling volitional fish passage (unmanned) through the ladder to commence on 31 March. Only the entrance and exit gate(s) were open the during the 22 day unmanned period of Fishway operation.

Manned Fishway operation, commenced on 22 April, 4 days after the Safe Harbor Fish Lift was placed in service and had passed 2,462 American shad. Fish were normally counted and allowed to pass upstream daily between 0800 hrs and 1600 hrs from 22 April to 12 June; a 52 day period. The Fishway was manned for a 48 hr period beginning on 30 May and ending on 1 June. The decision to stop manned Fishway operation on 12 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 0.5-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 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, the ladder and both fixed wheel gates were left opened until 19 June. At this time, the South fixed wheel gates was closed. On 20 June, the fish ladder and North fixed wheel gate were set to deliver a minimum flow of 400 cfs into the East Channel. The fish ladder and the North wheel gate remained open until October 30, 2006.

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. Excluding the 48 hour period of manned Fishway 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 6 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 2006 passage was conducted, as hourly shad passage never reached the minimum passage requirement of 1,000 shad/hr.

RESULTS

Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 195,410 fish of 18 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad

(164,869) was the dominant fish species passed and comprised over 84% of the fish passed. Some 1,913 American shad were counted as they passed through the ladder. Other predominant fishes passed included Channel catfish (9,097), walleye (7,810) quillback (7,448) shorthead redhorse (1,991), and smallmouth bass (1,032). Passage varied daily and ranged from 10,045 fish on 6 May to 961 fish on 24 May. Five striped bass and 36 flathead catfish, a non-indigenous species, were observed passing through the ladder.

American Shad Passage

A total of 1,913 American shad passed upstream through the ladder in 2006 (Table 1). Shad passed the ladder daily and most shad (1,327) passed in May. Some 456 shad passed in June while 130 shad passed in April. Peak shad passage occurred on 30 May when 174 shad were passed.

American shad were passed at water temperatures of 56.5° F to 78.0° F, and River flows that ranged from 16,300 cfs to 71,400 cfs and East Channel flows of 2,100 cfs to 13,500 cfs (Tables 2 and 3, Figures 3 and 4). Water temperature, River flows and East Channel flows when more than 100 American shad were passed averaged 69°.8 F (67.5° F to 73.0° F), 19,300 cfs (16,700 cfs to 21,500 cfs), and 2,100 cfs, respectively. Shad passage varied daily with nearly 75% of total shad passed (1,422) in 20 days; 677 passed between 4 and 14 May and 744 shad passed during a nine day period in between 28 May and 5 June). Passage during 4 and 14 May occurred at Rivers flows that declined from 28,000 cfs to 16,000 by 11 May and then increased 24,200 cfs. Water temperature during this period averaged 65.0° F and ranged from 63.0° F to 68.0° F. East Channel flows averaged 2,218 cfs (2,100 cfs to 3,400 cfs); during 10 of 11 days the average daily East Channel flow was 2,100 cfs. Passage between 28 May and 5 June occurred at Rivers flows that averaged 23,078 cfs and ranged from 16,300 cfs to 39,000 cfs. Water temperature during this period averaged 72.7° F (67.5° F to 78.0° F) and East Channel flows averaged 2,450 cfs (2,100 cfs to 3,900 cfs).

The hourly passage of American shad through the fish ladder is given in Table 4. Over 52% of the shad (1,274) passed between 0800 hrs and 1100 hrs; hourly passage varied from 272 to 428 shad. Some 657 shad passed from 1101 hrs to 1300 hrs. A total of 398 shad passed between 1301 hrs and 1600 hrs. The peak hourly passage of shad (87) occurred on 28 May between 0800 hrs and 0859 hrs.

Some 229 shad passed through the ladder between 30 May and 1 June, a consecutive 48 hr period of manned Fishway operation (Table 4). A total of 174 shad, 54 shad and 50 shad passed on 30 May, 31 May and 1 June, respectively. Over 72% of the shad (166) passed on 30 May between 0800 hrs and 1600 hrs. Twenty-four shad passed on 30 May between 1601 hrs and 2300 hrs. No shad passed between 2301 hrs on 30 May through 0400 hrs on 31 May and just 10 shad passed between 0401 hrs and 0800 hrs. Six shad passed on 30 May and 1 June between 0801 hrs and 0900 hrs; one passed on 31 May and five passed on 1 June. A total of 52 shad passed between 0901 hrs and 1100 hrs; 19 passed on 31 May and 33 passed on 1 June.

Other Alosids

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

Observations

Once each day visual observations of fish activity were made on a random basis below the Main Dam. On 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.

Job I - Part 5

SUMMARY

The ladder was opened on 31 March allowing unmanned passage. Manned Fishway operation started on 22 April and ended on 12 June. During this 52 day period a total of 195,410 fish of 18 taxa were enumerated as they passed upstream though the ladder into Lake Frederic.

A total of 1,913 shad were observed as they passed upstream through the ladder. American shad were passed at water temperatures of 56.5° F to 78.0° F, and River flows that that ranged from 16,300 cfs to 71,400 cfs and East Channel flows of 2,100 cfs to 13,500 cfs. Shad passage varied daily with nearly 75% of total shad passed (1,422) in 20 days; 677 passed between 4 and 14 May and 744 shad passed during a nine day period in between 28 May and 5 June. Most shad (1,274) passed through the ladder between 0800 hrs and 1100 hrs.

Some 229 shad passed through the fish ladder between 30 May and 1 June, a consecutive 48 hr period of manned Fishway operation (Table 4). A total of 174 shad, 54 shad and 50 shad passed on 30 May, 31 May and 1 June, respectively. Most shad (72%, 166) passed on 30 May between 0800 hrs and 1600 hrs. Twenty-four shad passed on 30 May between 1601 hrs and 2300 hrs. No shad passed between 2301 hrs on 30 May and 0400 hrs on 31 May and just 10 shad passed between 0401 hrs and 0800 hrs. Just six shad passed on 30 May and 1 June between 0801 hrs and 0900 hrs; one passed on 31 May and five passed on 1 June. A total of 52 shad passed between 0901 hrs and 11 hrs; 19 passed on 31 May and 33 passed on 1 June.

Although time of passage through the ladder during this 48 hr period of manned Fishway operation differed from that observed during most of the season and several shad passed prior to 0800 hrs allowing passage during this 48 hr period did not appear to result in an increase in the number of shad passing through the Fishway. Considering shad passage was higher several days immediately before and after this 48 hr period of manned Fishway operation, it does not appear that any change in the current manned operation schedule is warranted at this time.

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 seven years of experience

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.

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, 2006. During this period (2 June to 18 August) station personnel opened the trash sluice opened on 26 days. This observation process will continue in 2007.

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.

Job I - Part 5

In accordance with the protocol, monitoring of the York Haven forebay for the presence of juvenile American shad began on 24 September when water temperature was 66.0° F and River flow at Harrisburg was 14,300 cfs. Monitoring continued through 30 October. River flow during this period varied daily and ranged from 11,700 cfs to 103,00 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 compared to that observed during past seasons. Just one juvenile shad was collected at Columbia while haul seining this year and less than 10 juvenile shad had been collected in the lift net at Holtwood Station by 30 October.

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.

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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.

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 2006.

Date	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	1-May
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)	57.5	58.0	58.5	59.5	58.5	57.0	56.5	57.0	56.0	60.0
AMERICAN SHAD	1	10	5	15	4	25	46	13	11	23
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	666	1,518	508	1,745	1,508	1,671	1,712	1,386	1,275	2,766
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	0	0	0	0	0	1	0	0	0
BROWN TROUT	1	1	0	0	2	5	0	0	0	1
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	149	83	33	29	31	34	19	13	3	19
QUILLBACK	38	186	144	214	341	273	102	157	137	201
WHITE SUCKER	9	40	3	13	10	4	7	3	7	2
SHORTHEAD REDHORSE	48	133	191	158	146	147	119	88	89	97
CHANNEL CATFISH	50	176	348	170	105	65	19	36	11	100
ROCK BASS	0	0	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	10	13	8	2	17	21	51	81	89	135
WALLEYE	14	75	99	29	101	92	120	302	120	317
NOTHERN HOG SUCKER	0	1	1	0	0	0	1	0	0	0
TIGER MUSKELLUNGE	0	1	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**986**	**2,237**	**1,340**	**2,375**	**2,265**	**2,337**	**2,197**	**2,079**	**1,742**	**3,661**

Table 1. Continued

Date	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May
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 (^oF)	60.5	64.0	65.0	66.0	68.0	65.0	64.0	63.0	66.0	65.5
AMERICAN SHAD	26	23	53	28	109	59	41	52	37	73
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	1610	1016	3153	5505	8551	7226	3785	4957	6741	8198
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	0	0	1
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	0	0	0	0	0	0	0	0	0
BROWN TROUT	2	4	1	0	0	1	0	0	0	0
MUSKELLUNGE	0	0	1	0	1	0	0	0	0	0
CARP	50	11	12	22	40	35	12	3	6	15
QUILLBACK	252	250	151	369	556	226	232	115	329	552
WHITE SUCKER	5	8	8	7	10	6	0	0	0	1
SHORTHEAD REDHORSE	134	67	64	61	61	15	15	27	24	23
CHANNEL CATFISH	204	147	188	372	204	182	49	83	151	217
ROCK BASS	0	1	3	2	5	2	0	0	1	0
PUMKINSEED	0	0	0	1	0	0	0	0	0	0
SMALLMOUTH BASS	107	80	56	49	69	26	24	17	19	20
WALLEYE	469	419	483	597	438	463	368	324	406	455
NOTHERN HOG SUCKER	0	0	0	0	0	0	0	0	0	0
TIGER MUSKELLUNGE	0	0	0	0	1	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**2,859**	**2,026**	**4,173**	**7,013**	**10,045**	**8,241**	**4,526**	**5,578**	**7,714**	**9,555**

Table 1. Continued

Date	**12-May**	**13-May**	**14-May**	**15-May**	**16-May**	**17-May**	**18-May**	**19-May**	**20-May**	**21-May**
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 (^oF)	64.0	65.5	64.5	62.5	62.0	62.5	65.5	63.0	62.0	61.5
AMERICAN SHAD	45	94	86	9	11	4	6	1	8	7
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	3,785	5,270	8,231	4,761	3,090	3,502	4,706	4,174	3,786	3,464
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	1	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	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	1	0	2	0	0	0	0	0	0
CARP	6	11	8	2	3	3	6	6	0	8
QUILLBACK	46	119	150	37	32	22	19	25	12	47
WHITE SUCKER	0	3	1	1	0	0	0	0	0	1
SHORTHEAD REDHORSE	1	14	28	7	12	14	12	2	5	5
CHANNEL CATFISH	388	260	79	50	76	75	37	74	61	40
ROCK BASS	0	0	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	4	2	6	3	1	4	4	1	3	2
WALLEYE	68	42	36	42	20	30	18	30	39	45
NOTHERN HOG SUCKER	0	0	0	0	0	0	0	0	0	0
TIGER MUSKELLUNGE	0	0	1	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**4,344**	**5,817**	**8,626**	**4,914**	**3,245**	**3,654**	**4,808**	**4,313**	**3,914**	**3,619**

Table 1. Continued

Date	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
Observation Time (hrs.)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	16.0	24.0
Water Temperature (^oF)	59.0	62.5	61.0	62.0	64.0	64.5	67.5	70.5	73.0	75.0
AMERICAN SHAD	3	4	1	16	11	24	111	134	174	54
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	1,536	3,174	876	2,016	2,311	2,579	1,804	2,691	3,542	2,091
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	0	0	0	0	0	0	0	0	0
BROWN TROUT	1	0	1	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	1	0	0	0	0	1	0
CARP	1	5	0	11	12	14	66	26	33	30
QUILLBACK	8	20	9	36	33	81	162	98	464	383
WHITE SUCKER	0	0	0	0	0	0	0	0	0	2
SHORTHEAD REDHORSE	0	4	0	0	1	0	0	1	8	5
CHANNEL CATFISH	28	21	26	127	51	87	173	246	389	399
ROCK BASS	0	0	0	0	0	0	0	0	2	13
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	0	4	3	7	1	5	12	12	12	13
WALLEYE	35	17	41	110	76	78	118	202	237	345
NOTHERN HOG SUCKER	0	0	0	0	0	0	0	0	0	0
TIGER MUSKELLUNGE	1	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	4	0	0	0	0	0	2	7
Total	**1,613**	**3,249**	**961**	**2,324**	**2,496**	**2,868**	**2,446**	**3,410**	**4,864**	**3,342**

Table 1. Continued

Date	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun
Observation Time (hrs.)	16.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Water Temperature (^oF)	78.0	78.0	73.0	69.0	70.0	68.0	66.0	66.0	67.0	64.5
AMERICAN SHAD	50	70	82	20	50	11	7	66	69	13
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	1,694	1,980	2,912	2,504	1,950	3,090	4,307	4,633	3,595	2,357
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	1	1	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	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	13	9	14	4	7	7	8	6	11	3
QUILLBACK	236	91	142	58	57	32	14	31	56	19
WHITE SUCKER	0	0	2	0	0	0	0	3	13	0
SHORTHEAD REDHORSE	0	1	0	8	13	0	0	51	41	0
CHANNEL CATFISH	208	107	411	269	511	896	292	256	191	202
ROCK BASS	0	0	0	0	0	4	2	0	0	0
PUMKINSEED	0	1	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	6	7	2	5	1	0	0	0	2	2
WALLEYE	92	121	63	44	3	22	12	28	48	22
NOTHERN HOG SUCKER	0	0	0	0	0	0	0	0	0	0
TIGER MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	16	0	0	0	4	0	0	0	3	0
Total	**2,315**	**2,387**	**3,628**	**2,912**	**2,596**	**4,062**	**4,642**	**5,075**	**4,030**	**2,618**

Table 1. Continued

Date	11-Jun	12-Jun	Total
Observation Time (hrs.)	8.0	8.0	**440**
Water Temperature (°F)	62.5	63.5	
AMERICAN SHAD	14	4	**1,913**
ALEWIFE	0	0	**0**
BLUEBACK HERRING	0	0	**0**
GIZZARD SHAD	1,773	1,188	**164,869**
HICKORY SHAD	0	0	**0**
STRIPED BASS	0	0	**5**
WHITE PERCH	0	0	**0**
AMERICAN EEL	0	0	**0**
RAINBOW TROUT	0	0	**1**
BROWN TROUT	0	0	**20**
MUSKELLUNGE	0	0	**7**
CARP	5	11	**968**
QUILLBACK	36	48	**7,448**
WHITE SUCKER	0	0	**169**
SHORTHEAD REDHORSE	17	34	**1,991**
CHANNEL CATFISH	105	85	**9,097**
ROCK BASS	0	0	**35**
PUMKINSEED	0	0	**2**
SMALLMOUTH BASS	1	13	**1,032**
WALLEYE	7	28	**7,810**
NOTHERN HOG SUCKER	0	0	**3**
TIGER MUSKELLUNGE	0	0	**4**
FLATHEAD CATFISH	0	0	**36**
Total	**1958**	**1411**	**195,410**

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East channel, sum of average flow from power station and main dam, water temperature, secchi, stop log gate position, and East channel and fishway water elevations during operation of the York Haven fishway complex in 2006.

	River	East	Main Dam	Water				Stop	Elevation (ft)					
	Flow	Channel	Flow	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	(cfs)	(^{o}F)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
22-Apr	20,400	2,100	18,300	57.5	>24	>24	>24	Closed	278.9	278.8	279.0	273.8	273.4	273.5
23-Apr	29,400	3,400	26,000	58.0	22	20	23	Closed	279.4	279.1	279.6	274.3	274.2	274.4
24-Apr	47,300	6,000	41,300	58.5	18	12	20	Closed	279.9	279.8	280.0	275.2	275.1	275.3
25-Apr	56,300	8,300	48,000	59.5	20	19	20	Closed	280.8	280.7	280.8	275.8	275.6	276.0
26-Apr	64,100	9,500	54,600	58.5	19	18	19	Closed	280.4	280.3	280.5	276.3	276.2	276.4
27-Apr	66,500	10,300	56,200	57.0	20	19	20	Closed	280.6	280.6	280.6	276.4	276.3	276.5
28-Apr	57,900	6,500	51,400	56.5	20	18	24	Closed	280.3	280.3	280.3	275.9	275.9	276.0
29-Apr	50,500	6,400	44,100	57.0	20	20	20	Closed	280.2	280.2	280.2	275.3	275.3	275.4
30-Apr	42,700	4,900	37,800	58.0	24	24	24	Closed	279.8	279.8	279.8	274.9	274.9	275.0
1-May	37,200	4,700	32,500	60.0	23	23	23	Closed	280.0	280.0	280.0	274.5	274.5	274.6
2-May	33,400	4,500	28,900	60.5	23	23	23	Closed	279.7	279.6	279.7	274.3	274.2	274.3
3-May	30,400	3,400	27,000	64.0	22	22	22	Closed	279.4	279.3	279.4	274.3	274.3	274.3
4-May	28,000	3,400	24,600	65.0	22	20	24	Closed	279.2	279.1	279.2	274.0	273.9	274.0
5-May	25,600	2,100	23,500	67.5	22	22	22	Closed	279.0	278.9	279.0	273.7	273.6	273.7
6-May	21,500	2,100	19,400	68.0	20	20	20	Closed	279.0	279.0	279.0	273.5	273.5	273.6
7-May	21,000	2,100	18,900	65.0	20	20	20	Closed	278.8	278.7	278.9	273.5	273.5	273.6
8-May	19,100	2,100	17,000	64.0	22	20	24	Closed	278.7	278.7	278.7	273.5	273.5	273.5
9-May	18,100	2,100	16,000	63.0	21	21	21	Closed	278.8	278.8	278.8	273.6	273.5	273.7
10-May	16,900	2,100	14,800	66.0	21	21	21	Closed	278.7	278.7	278.7	273.7	273.7	273.7
11-May	16,000	2,100	13,900	65.5	23	23	23	Closed	278.7	278.6	278.7	273.6	273.6	273.6
12-May	17,100	2,100	15,000	64.0	13	10	15	Closed	278.7	278.7	278.8	273.5	273.4	273.5
13-May	21,400	2,100	19,300	65.5	19	19	19	Closed	279.0	279.0	279.0	273.8	273.8	273.9
14-May	24,200	2,100	22,100	64.5	20	20	20	Closed	279.1	279.0	279.2	273.9	273.7	274.0
15-May	26,000	2,100	23,900	62.5	19	19	19	Closed	279.2	279.1	279.2	274.0	273.9	274.0
16-May	30,200	3,400	26,800	62.0	17	15	18	Closed	279.2	279.2	279.3	274.2	274.0	274.3
17-May	28,200	3,400	24,800	62.5	18	18	18	Closed	279.0	278.9	279.3	273.8	273.8	273.8
18-May	29,600	3,400	26,200	65.5	19	19	19	Closed	279.1	279.1	279.1	273.0	273.0	273.0
19-May	29,400	3,400	26,000	63.0	21	21	21	Closed	279.2	279.2	279.2	274.0	274.0	274.0
20-May	27,800	3,400	24,400	62.0	17	15	18	Closed	279.1	279.1	279.1	273.9	273.9	274.0
21-May	28,200	3,400	24,800	61.5	18	18	18	Closed	279.2	279.2	279.2	274.0	274.0	274.0
22-May	27,000	3,300	23,700	59.0	18	18	18	Closed	279.1	279.1	279.1	273.9	273.9	273.9
23-May	26,000	2,100	23,900	62.5	19	19	19	Closed	279.1	279.1	279.1	273.7	273.7	273.7
24-May	24,600	2,100	22,500	61.0	20	20	20	Closed	278.9	278.9	278.9	273.6	273.6	273.7
25-May	22,000	2,100	19,900	62.0	20	20	20	Closed	279.0	279.0	279.0	273.6	273.6	273.7

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East channel, sum of average flow from power station and main dam, water temperature, secchi, stop log gate position, and East channel and fishway water elevations during operation of the York Haven fishway complex in 2006.

	River	East	Main Dam	Water				Stop	Elevation (ft)					
	Flow	Channel	Flow	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	(cfs)	(°F)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
26-May	21,000	2,100	18,900	64.0	18	18	18	Closed	278.9	278.9	279.0	273.6	273.6	273.7
27-May	20,800	2,100	18,700	64.5	19	19	19	Closed	278.9	278.9	278.9	273.6	273.5	273.6
28-May	20,200	2,100	18,100	67.5	21	20	24	Closed	278.6	278.6	278.7	273.5	273.5	273.5
29-May	18,800	2,100	16,700	70.5	19	19	19	Closed	278.7	278.7	278.7	273.5	273.4	273.5
30-May	16,700	2,100	14,600	73.0	19	19	20	Closed	278.7	278.4	278.8	273.5	273.4	273.5
31-May	16,300	2,100	14,200	75.0	15	5	20	Closed	278.7	278.5	278.7	273.5	273.4	273.5
1-Jun	24,000	2,100	21,900	78.0	18	18	18	Closed	279.0	278.7	279.1	273.8	273.4	273.9
2-Jun	23,400	2,100	21,300	78.0	19	18	20	Closed	278.8	278.8	278.8	273.6	273.6	273.6
3-Jun	19,700	2,100	17,600	73.0	18	18	18	Closed	278.9	278.9	278.9	273.7	273.6	273.7
4-Jun	29,600	3,400	26,200	69.0	18	18	18	Closed	279.2	279.0	279.3	274.1	274.0	274.2
5-Jun	39,000	3,950	35,050	70.0	14	10	15	Closed	279.6	279.5	279.7	274.8	274.6	279.7
6-Jun	71,400	13,500	57,900	68.0	17	17	17	Closed	279.4	279.3	279.4	276.8	276.7	276.8
7-Jun	63,400	9,300	54,100	66.0	18	18	18	Closed	279.2	279.2	279.3	276.2	276.2	276.3
8-Jun	49,240	6,750	42,490	66.0	18	18	18	Closed	279.1	279.1	279.2	275.5	275.4	275.6
9-Jun	42,200	4,800	37,400	67.0	18	15	20	Closed	279.7	279.6	279.7	274.8	274.7	275.0
10-Jun	35,000	3,500	31,500	64.5	19	19	19	Closed	279.3	279.3	279.3	274.5	274.5	274.5
11-Jun	30,200	3,500	26,700	62.5	20	20	20	Closed	279.2	279.2	279.2	274.2	274.2	274.2
12-Jun	27,800	3,000	24,800	63.5	20	20	20	Closed	278.9	278.9	278.9	274.1	274.1	274.1

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2006.

		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.
22-Apr	20,400	278.9	278.8	279.0	273.8	273.4	273.5	274.6	274.5	274.9	277.3	277.2	277.4	278.9	278.9	278.9	277.2	277.2	277.2	278.7	278.7	278.8
23-Apr	29,400	279.4	279.1	279.6	274.3	274.2	274.4	274.9	274.8	275.0	277.7	277.6	277.9	279.3	279.1	279.6	277.5	277.3	277.6	279.2	279.1	279.3
24-Apr	47,300	279.9	279.8	280.0	275.2	275.1	275.3	275.8	275.7	275.8	278.1	278.1	278.2	280.0	279.9	280.0	278.0	278.0	278.0	279.8	279.7	279.8
25-Apr	56,300	280.8	280.7	280.8	275.8	275.6	276.0	276.1	275.9	276.3	278.7	278.2	278.9	280.2	280.1	280.3	278.2	278.2	278.2	280.0	279.8	280.1
26-Apr	64,100	280.4	280.3	280.5	276.3	276.2	276.4	276.5	276.4	276.5	278.7	278.6	278.7	280.5	280.4	280.5	278.3	278.3	278.3	280.2	280.1	280.3
27-Apr	66,500	280.6	280.6	280.6	276.4	276.3	276.5	276.7	276.7	276.7	278.6	278.5	278.6	280.5	280.5	280.6	278.3	278.3	278.4	280.2	280.1	280.5
28-Apr	57,900	280.3	280.3	280.3	275.9	275.9	276.0	276.2	276.1	276.2	278.4	278.4	278.4	280.1	280.0	280.1	278.1	278.0	278.2	279.9	279.9	280.0
29-Apr	50,500	280.2	280.2	280.2	275.3	275.3	275.4	275.6	275.6	275.6	278.6	278.6	278.7	280.0	280.0	280.0	277.9	277.9	278.0	279.6	279.6	279.7
30-Apr	42,700	279.8	279.8	279.8	274.9	274.9	275.0	275.2	275.2	275.3	278.1	278.1	278.2	279.8	279.8	279.8	277.9	277.8	278.0	279.3	279.3	279.4
1-May	37,200	280.0	280.0	280.0	274.5	274.5	274.6	275.0	275.0	275.0	278.3	278.3	278.3	279.5	279.5	279.6	277.8	277.8	277.8	279.3	279.2	279.5
2-May	33,400	279.7	279.6	279.7	274.3	274.2	274.3	274.8	274.7	274.8	277.8	278.8	278.9	279.4	279.4	279.5	277.5	277.4	277.5	279.1	279.1	279.3
3-May	30,400	279.4	279.3	279.4	274.3	274.3	274.3	274.7	274.6	274.7	277.8	277.7	277.8	279.3	279.2	279.3	277.5	277.5	277.5	279.1	279.0	279.2
4-May	28,000	279.2	279.1	279.2	274.0	273.9	274.0	274.7	274.7	274.8	277.6	277.5	277.7	279.1	279.0	279.1	277.4	277.3	277.4	278.8	277.7	277.8
5-May	25,600	279.0	278.9	279.0	273.7	273.6	273.7	274.5	274.4	274.5	277.5	277.5	277.5	279.0	279.0	279.0	277.3	277.3	277.3	278.7	278.7	279.0
6-May	21,500	279.0	279.0	279.0	273.5	273.5	273.6	274.5	274.5	274.5	277.2	277.2	277.3	278.9	278.9	278.9	277.2	277.2	277.3	278.6	278.4	278.8
7-May	21,000	278.8	278.7	278.9	273.5	273.5	273.6	274.3	274.3	274.3	277.2	277.2	277.2	279.6	279.6	279.7	277.1	277.1	277.1	278.4	278.4	278.6
8-May	19,100	278.7	278.7	278.7	273.5	273.5	273.5	274.3	274.3	274.3	277.3	277.3	277.3	278.6	278.6	278.6	277.1	277.1	277.1	278.3	278.3	278.3
9-May	18,100	278.8	278.8	278.8	273.6	273.5	273.7	274.4	274.2	274.5	277.1	277.1	277.2	278.6	278.6	278.7	277.2	277.2	277.2	278.4	278.4	278.5

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2006.

		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.
10-May	16,900	278.7	278.7	278.7	273.7	273.7	273.7	274.4	274.4	274.5	277.0	277.0	277.0	278.6	278.6	278.6	277.0	277.0	277.0	278.5	278.5	278.6
11-May	16,000	278.7	278.6	278.7	273.6	273.6	273.6	274.4	274.4	274.4	277.0	277.0	277.0	278.5	278.5	278.6	277.0	277.0	277.0	278.5	278.5	278.5
12-May	17,100	278.7	278.7	278.8	273.5	273.4	273.5	274.4	274.4	274.5	277.1	277.1	277.1	278.8	278.7	278.8	277.0	276.9	277.0	278.5	278.4	278.6
13-May	21,400	279.0	279.0	279.0	273.8	273.8	273.9	274.4	274.4	274.5	277.0	277.0	277.0	278.8	278.8	278.9	277.0	277.0	277.0	278.6	278.6	278.6
14-May	24,200	279.1	279.0	279.2	273.9	273.7	274.0	274.7	274.6	274.8	277.3	277.2	277.4	279.1	279.0	279.2	277.3	277.3	277.4	278.7	278.7	278.8
15-May	26,000	279.2	279.1	279.2	274.0	273.9	274.0	274.8	274.7	274.9	277.4	277.3	277.4	279.1	279.0	279.1	277.4	277.3	277.4	278.8	278.8	278.9
16-May	30,200	279.2	279.2	279.3	274.2	274.0	274.3	274.9	274.9	275.0	277.3	277.0	277.3	279.3	279.2	279.3	277.3	277.3	277.4	278.9	278.8	279.0
17-May	28,200	279.0	278.9	279.3	273.8	273.8	273.8	274.7	274.7	274.8	277.4	277.4	277.4	279.1	279.1	279.2	277.4	277.4	277.4	278.8	278.8	278.9
18-May	29,600	279.1	279.1	279.1	273.0	273.0	273.0	274.9	274.9	274.9	277.6	277.5	277.6	279.1	279.0	279.1	277.6	277.5	277.6	278.8	278.8	278.8
19-May	29,400	279.2	279.2	279.2	274.0	274.0	274.0	274.9	274.9	275.0	277.7	277.6	277.7	279.1	279.0	279.2	277.7	277.6	277.7	278.8	278.8	278.8
20-May	27,800	279.1	279.1	279.1	273.9	273.9	274.0	274.8	274.8	274.8	277.5	277.5	277.5	279.1	279.1	279.1	277.4	277.4	277.4	278.8	278.7	278.8
21-May	28,200	279.2	279.2	279.2	274.0	274.0	274.0	274.9	274.9	274.9	277.7	277.7	277.7	279.1	279.1	279.2	277.6	277.6	277.7	278.8	278.8	278.8
22-May	27,000	279.1	279.1	279.1	273.9	273.9	273.9	274.8	274.7	274.8	277.6	277.6	277.6	279.0	279.0	279.0	277.6	277.6	277.6	278.8	278.8	278.8
23-May	26,000	279.1	279.1	279.1	273.7	273.7	273.7	274.6	274.6	274.6	277.5	277.5	277.6	279.0	279.0	279.0	277.5	277.5	277.6	278.9	278.9	279.0
24-May	24,600	278.9	278.9	278.9	273.6	273.6	273.7	274.6	274.6	274.6	277.6	277.5	277.6	279.0	279.0	279.0	277.4	277.3	277.4	278.8	278.8	278.8
25-May	22,000	279.0	279.0	279.0	273.6	273.6	273.7	274.5	274.5	274.6	277.4	277.4	277.4	278.9	278.9	278.9	277.4	277.4	277.4	278.7	278.7	278.7
26-May	21,000	278.9	278.9	279.0	273.6	273.6	273.7	274..5	274.5	274.5	277.4	277.4	277.4	278.8	278.8	278.8	277.4	277.4	277.4	278.7	278.7	278.7
27-May	20,800	278.9	278.9	278.9	273.6	273.5	273.6	274.5	274.5	274.5	277.4	277.4	277.4	278.8	278.8	278.8	277.4	277.4	277.4	278.7	278.7	278.7

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2006.

Date	River Flow (cfs)	Elevation (ft) Head Pond Avg.	Min.	Max.	Tailwater Avg	Min.	Max.	Inside Fishway Avg	Min.	Max.	Inside Weir Avg	Min.	Max.	Above Counting Room Avg	Min.	Max.	Below Fixed Wheel Gate Avg	Min.	Max.	Counting Room Avg	Min.	Max.
28-May	20,200	278.6	278.6	278.7	273.5	273.5	273.5	274.4	274.4	274.4	277.4	277.4	277.4	278.7	278.6	278.7	277.3	277.3	277.3	278.5	278.5	278.5
29-May	18,800	278.7	278.7	278.7	273.5	273.4	273.5	274.4	274.4	274.4	277.3	277.3	277.3	278.6	278.6	278.6	277.3	277.3	277.3	278.4	278.4	278.4
30-May	16,700	278.7	278.4	278.8	273.5	273.4	273.5	274.4	274.4	274.4	277.3	277.3	277.4	278.6	278.6	278.6	277.3	277.3	277.4	278.4	278.3	278.4
31-May	16,300	278.7	278.5	278.7	273.5	273.4	273.5	274.4	274.4	274.5	277.2	277.2	277.3	278.5	278.4	278.5	277.2	277.2	277.3	278.3	278.3	278.3
1-Jun	24,000	279.0	278.7	279.1	273.8	273.4	273.9	274.6	274.4	274.7	277.5	277.2	277.6	278.8	278.4	279.0	277.6	277.2	277.7	278.7	278.3	278.8
2-Jun	23,400	278.8	278.8	278.8	273.6	273.6	273.6	274.4	274.4	274.4	277.5	277.4	277.5	278.7	278.7	278.7	277.3	277.3	277.3	278.5	278.5	278.5
3-Jun	19,700	278.9	278.9	278.9	273.7	273.6	273.7	274.5	274.4	274.5	277.5	277.5	277.5	278.7	278.7	278.7	277.3	277.3	277.3	278.5	278.5	278.5
4-Jun	29,600	279.2	279.0	279.3	274.1	274.0	274.2	274.7	274.7	274.8	277.6	277.6	277.7	279.0	278.9	279.1	277.6	277.5	277.7	278.6	278.6	278.6
5-Jun	39,000	279.6	279.5	279.7	274.8	274.6	279.7	275.5	275.4	275.5	278.0	278.0	278.1	279.6	279.5	279.7	277.7	277.6	277.9	279.4	279.3	279.5
6-Jun	71,400	279.4	279.3	279.4	276.8	276.7	276.8	277.1	277.1	277.1	278.8	278.7	278.8	280.5	280.5	280.5	278.8	278.8	278.8	280.3	280.3	280.4
7-Jun	63,400	279.2	279.2	279.3	276.2	276.2	276.3	276.5	276.5	276.6	278.5	278.5	278.6	280.2	280.2	280.3	278.4	278.4	278.5	280.2	280.2	280.2
8-Jun	49,240	279.1	279.1	279.2	275.5	275.4	275.6	275.9	275.9	276.0	278.1	278.1	278.2	279.8	279.8	279.9	278.1	278.1	278.2	279.6	279.6	279.7
9-Jun	42,200	279.7	279.6	279.7	274.8	274.7	275.0	275.5	275.4	275.5	278.0	277.9	278.0	279.6	279.5	279.6	277.8	277.8	277.8	279.3	279.2	279.3
10-Jun	35,000	279.3	279.3	279.3	274.5	274.5	274.5	278.1	278.1	278.1	277.9	277.9	277.9	279.4	279.4	279.4	277.9	277.9	277.9	279.1	279.1	279.2
11-Jun	30,200	279.2	279.2	279.2	274.2	274.2	274.2	274.7	274.7	274.7	2777.0	277.7	277.7	279.1	279.1	279.1	277.7	277.7	277.7	279.0	279.0	279.0
12-Jun	27,800	278.9	278.9	278.9	274.1	274.1	274.1	274.6	274.6	274.6	277.1	277.1	277.1	279.0	279.0	279.0	277.1	277.1	277.1	279.0	279.0	279.0

Table 4. Hourly summary of American shad passage through the sepentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2006.

Date	**22-Apr**	**23-Apr**	**24-Apr**	**25-Apr**	**26-Apr**	**27-Apr**	**28-Apr**	**29-Apr**	**30-Apr**
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)									
0801 - 0900	0	0	1	2	3	0	27	6	0
0901 - 1000	0	3	1	2	0	2	4	1	0
1001 - 1100	0	0	0	6	0	0	6	4	0
1101 - 1200	0	3	1	1	0	5	0	0	4
1201 - 1300	1	2	1	2	1	5	3	0	5
1301 - 1400	0	0	1	0	0	1	3	0	2
1401 - 1500	0	2	0	0	0	10	1	1	0
1501 - 1600	0	0	0	2	0	2	2	1	0
Total Catch	**1**	**10**	**5**	**15**	**4**	**25**	**46**	**13**	**11**

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

Date	**1-May**	**2-May**	**3-May**	**4-May**	**5-May**	**6-May**	**7-May**	**8-May**	**9-May**
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1700	1600	1600
Military Time (Hours)									
0801 - 0900	19	7	1	20	6	28	27	25	27
0901 - 1000	0	5	8	8	7	10	10	4	5
1001 - 1100	0	2	3	6	7	4	3	2	3
1101 - 1200	1	6	2	7	3	27	4	0	7
1201 - 1300	2	3	4	5	3	21	6	2	5
1301 - 1400	1	3	0	2	0	11	8	2	0
1401 - 1500	0	0	1	1	0	5	1	4	3
1501 - 1600	0	0	4	4	2	3	0	2	2
Total Catch	**23**	**26**	**23**	**53**	**28**	**109**	**59**	**41**	**52**

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

Date	**10-May**	**11-May**	**12-May**	**13-May**	**14-May**	**15-May**	**16-May**	**17-May**	**18-May**
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1700
Military Time (Hours)									
0801 - 0900	2	24	10	22	8	4	0	0	1
0901 - 1000	3	20	3	4	27	1	2	3	0
1001 - 1100	5	14	8	20	19	0	1	0	2
1101 - 1200	8	4	11	24	10	0	1	0	0
1201 - 1300	7	4	7	7	8	1	3	0	0
1301 - 1400	3	1	5	7	9	1	0	0	1
1401 - 1500	5	4	0	6	3	1	2	1	0
1501 - 1600	4	2	1	4	2	1	2	0	2
Total Catch	**37**	**73**	**45**	**94**	**86**	**9**	**11**	**4**	**6**

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

Date	**19-May**	**20-May**	**21-May**	**22-May**	**23-May**	**24-May**	**25-May**	**26-May**	**27-May**
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)									
0801 - 0900	0	2	0	0	0	0	7	2	2
0901 - 1000	0	1	2	2	2	0	0	1	9
1001 - 1100	0	0	1	0	0	1	4	4	1
1101 - 1200	0	2	0	0	1	0	0	2	2
1201 - 1300	1	1	0	0	0	0	0	0	5
1301 - 1400	0	1	1	0	0	0	2	2	2
1401 - 1500	0	0	2	1	0	0	1	0	2
1501 - 1600	0	1	1	0	1	0	2	0	1
Total Catch	**1**	**8**	**7**	**3**	**4**	**1**	**16**	**11**	**24**

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

Date **Observation Time (Start)** **Observation Time (End)**	**28-May**	**29-May**	**30-May**	**31-May**	**1-Jun**	**2-Jun**	**3-Jun**	**4-Jun**	**5-Jun**
Military Time (Hours)									
0001 - 0100	-	-	-	0	0	-	-	-	-
0101 - 0200	-	-	-	0	0	-	-	-	-
0201 - 0300	-	-	-	0	0	-	-	-	-
0301 - 0400	-	-	-	0	0	-	-	-	-
0401 - 0500	-	-	-	0	1	-	-	-	-
0501 - 0600	-	-	-	2	0	-	-	-	-
0601 - 0700	-	-	-	2	1	-	-	-	-
0701 - 0800	-	-	-	1	3	-	-	-	-
0801 - 0900	40	27	38	1	5	7	6	5	2
0901 - 1000	22	25	47	11	11	8	5	2	3
1001 - 1100	11	21	37	8	22	5	4	1	1
1101 - 1200	8	17	13	0	1	18	20	2	13
1201 - 1300	4	20	8	6	2	3	15	5	13
1301 - 1400	15	16	10	0	2	13	16	2	10
1401 - 1500	7	6	10	5	1	13	12	2	4
1501 - 1600	4	2	3	2	1	3	4	1	4
1601 - 1700	-	-	3	3	-	-	-	-	-
1701 - 1800	-	-	1	2	-	-	-	-	-
1801 - 1901	-	-	2	1	-	-	-	-	-
1901 - 2000	-	-	0	2	-	-	-	-	-
2001 - 2100	-	-	0	8	-	-	-	-	-
2101 - 2200	-	-	0	0	-	-	-	-	-
2201 - 2300	-	-	2	0	-	-	-	-	-
2301 - 2400	-	-	0	0	-	-	-	-	-
Total Catch	**111**	**134**	**174**	**54**	**50**	**70**	**82**	**20**	**50**

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

Date **Observation Time (Start)** **Observation Time (End)**	**6-Jun**	**7-Jun**	**8-Jun**	**9-Jun**	**10-Jun**	**11-Jun**	**12-Jun**	**Total**	%
Military Time (Hours)									
0001 - 0100	-	-	-	-	-	-	-	**0**	**0.2**
0101 - 0200	-	-	-	-	-	-	-	**0**	**22.4**
0201 - 0300	-	-	-	-	-	-	-	**0**	**0.0**
0301 - 0400	-	-	-	-	-	-	-	**0**	**0.0**
0401 - 0500	-	-	-	-	-	-	-	**1**	**0.1**
0501 - 0600	-	-	-	-	-	-	-	**2**	**0.1**
0601 - 0700	-	-	-	-	-	-	-	**3**	**0.2**
0701 - 0800	-	-	-	-	-	-	-	**4**	**0.2**
0801 - 0900	0	0	0	13	0	1	0	**428**	**22.4**
0901 - 1000	1	0	6	11	2	1	0	**305**	**15.9**
1001 - 1100	4	1	12	9	3	3	4	**272**	**14.2**
1101 - 1200	2	2	3	9	1	5	0	**250**	**13.1**
1201 - 1300	1	1	17	13	3	0	0	**226**	**11.8**
1301 - 1400	0	0	15	9	2	2	0	**181**	**9.5**
1401 - 1500	0	1	10	4	2	1	0	**135**	**7.1**
1501 - 1600	3	2	3	1	0	1	0	**82**	**4.3**
1601 - 1700	-	-	-	-	-	-	-	**6**	**0.3**
1701 - 1800	-	-	-	-	-	-	-	**3**	**0.2**
1801 - 1901	-	-	-	-	-	-	-	**3**	**0.2**
1901 - 2000	-	-	-	-	-	-	-	**2**	**0.1**
2001 - 2100	-	-	-	-	-	-	-	**8**	**0.4**
2101 - 2200	-	-	-	-	-	-	-	**0**	**0.0**
2201 - 2300	-	-	-	-	-	-	-	**2**	**0.1**
2301 - 2400	-	-	-	-	-	-	-	**0**	**0.0**
Total Catch	**11**	**7**	**66**	**69**	**13**	**14**	**4**	**1913**	**99.5**

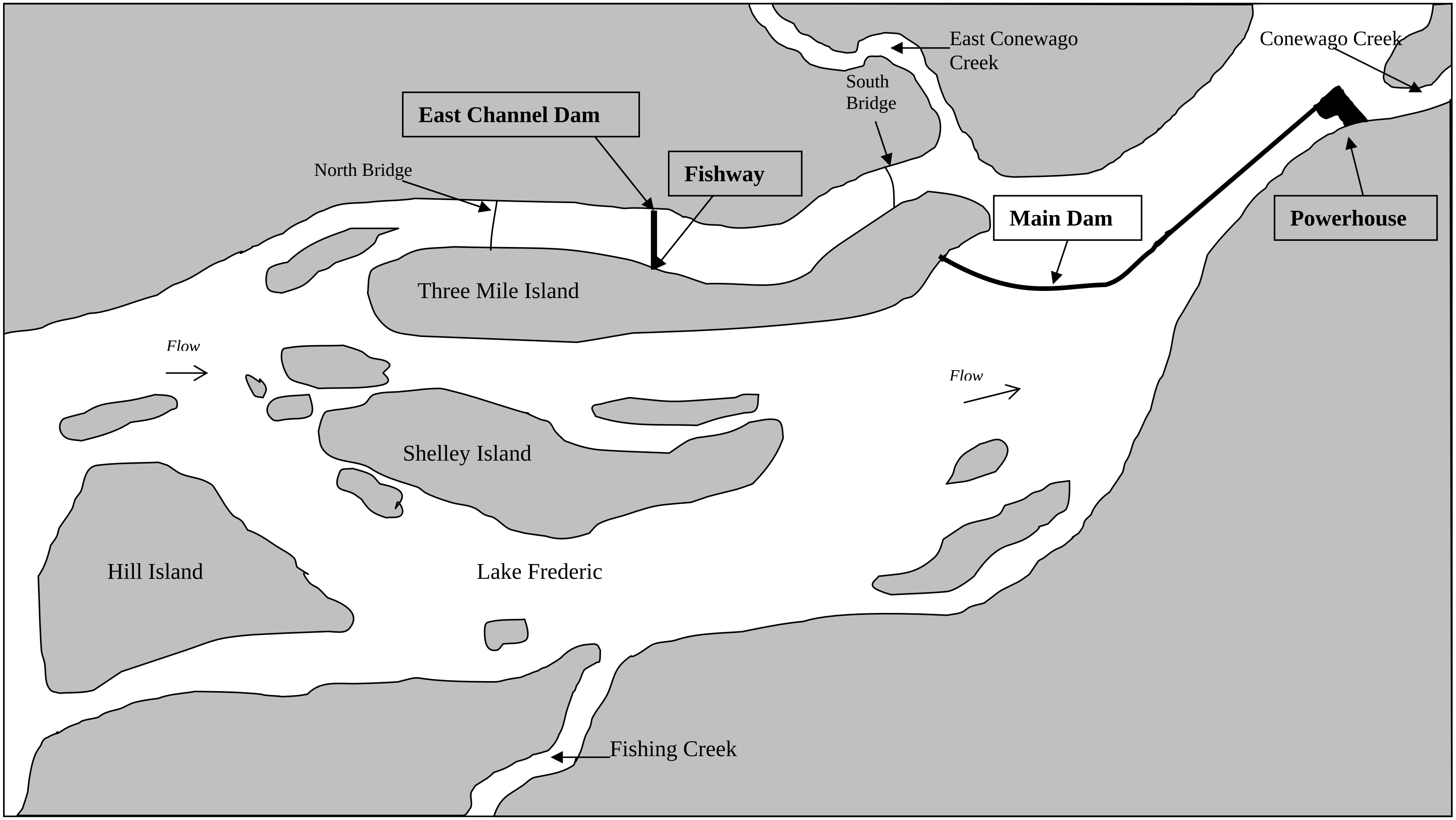
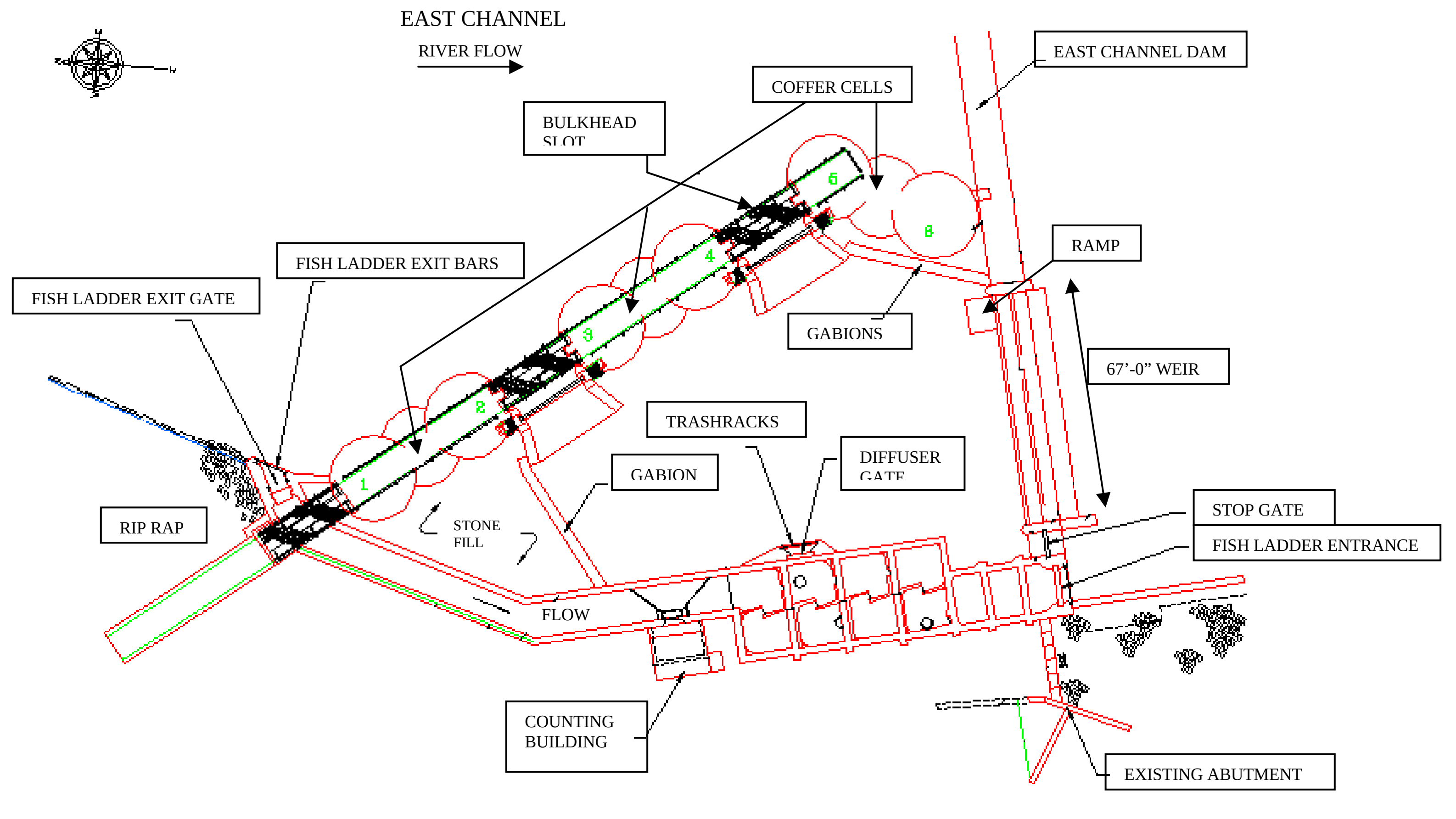


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



GENERAL ARRANGEMENT
YORK HAVEN FISHWAY

FIGURE 2

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 2006

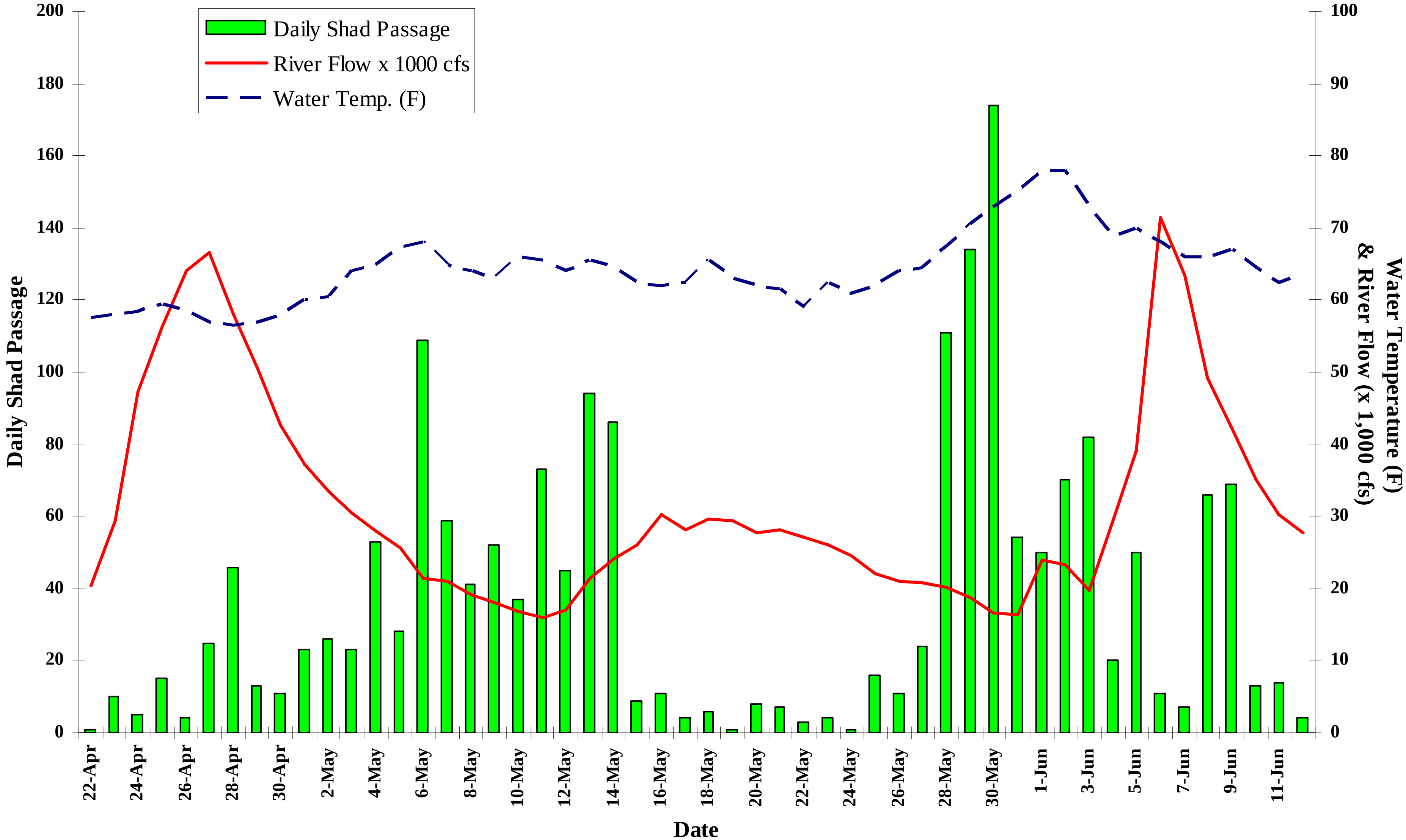


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2006

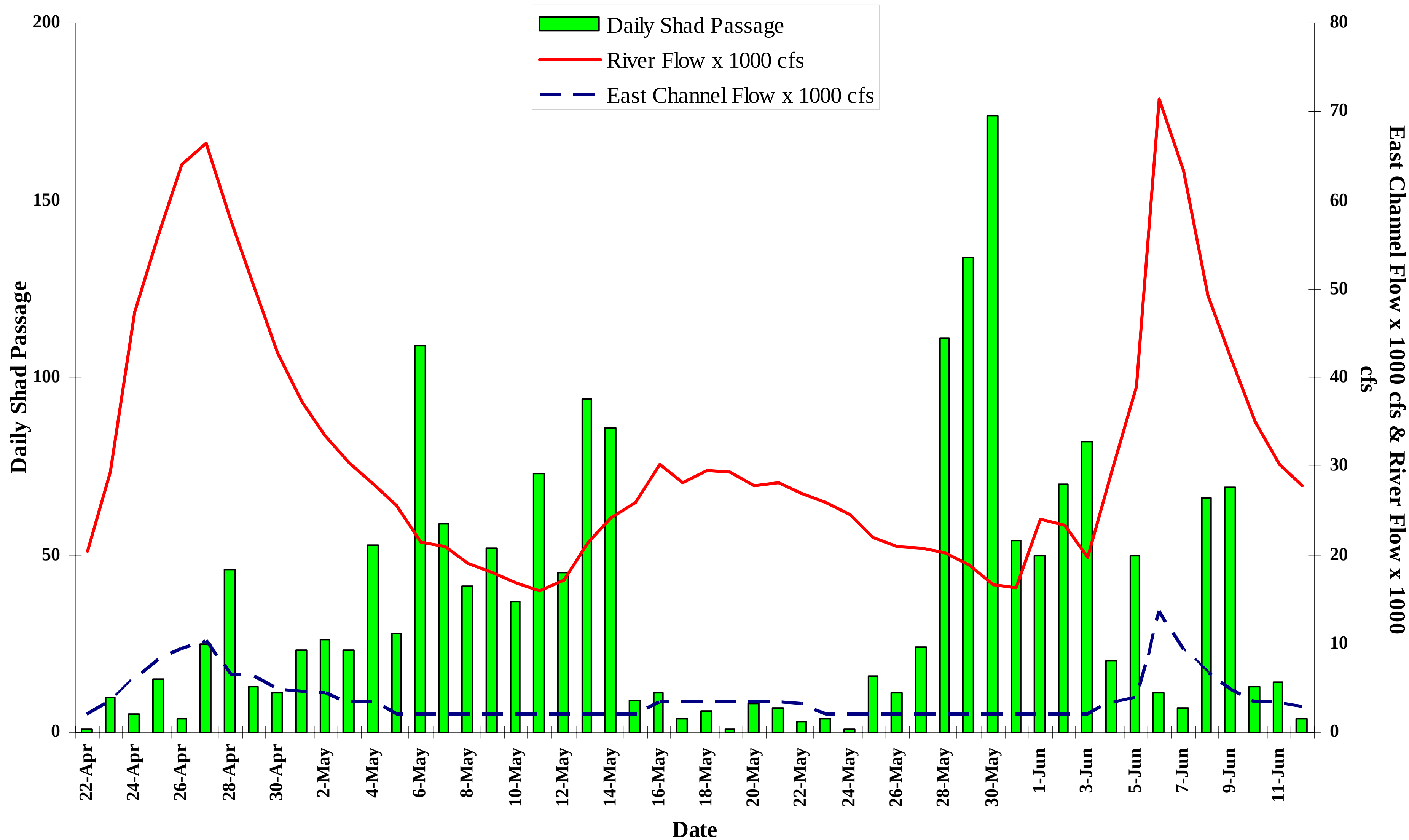
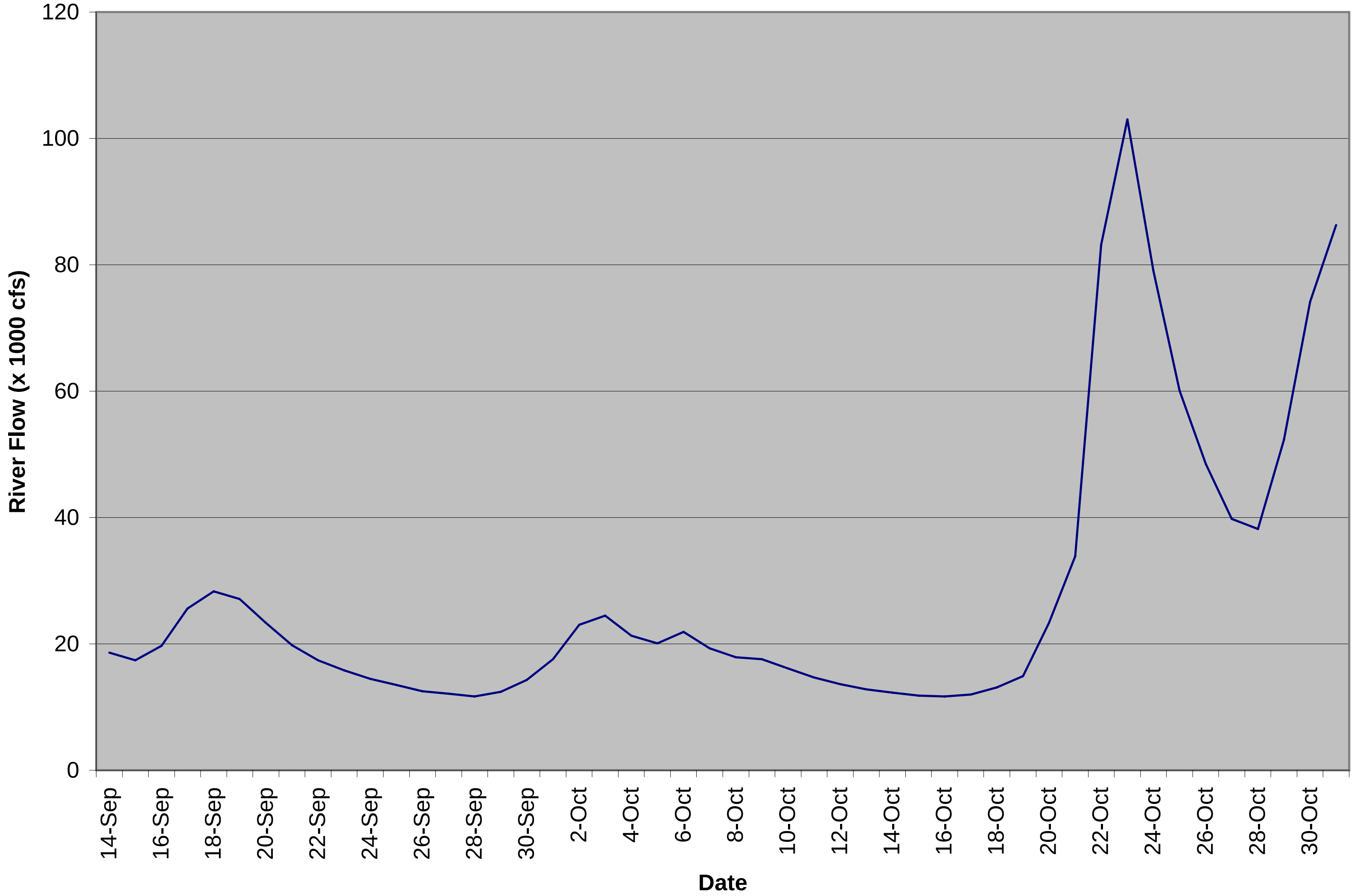


Figure 5. Plot of River Flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River, 14 September to 31 October, 2006



Job II – Part 1

SUSQUEHANNA RIVER AMERICAN SHAD (*ALOSA SAPIDISSIMA*) RESTORATION: POTOMAC AND HUDSON RIVER EGG COLLECTION, 2006

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

ABSTRACT

During April and May, 2006 we used monofilament gill nets to collect 1194 American shad from the Potomac (rkm 150) and Hudson (rkm 203) Rivers. The purpose of sampling was to supply viable eggs to the Van Dyke American Shad Hatchery in support of ongoing Susquehanna River American shad restoration efforts. Over 29 sampling days, 99.3 L (44% viable) and 60.0 L (69% viable) of eggs were delivered from the Potomac and Hudson Rivers, respectively, with a potential yield of ≈ 3.2 million individuals. The Potomac River catch was dominated by gizzard shad (39%), American shad (29%) and striped bass (27%). Green female, ripe female, and male shad represented 13%, 12% and 5% of the catch, respectively. The Hudson River catch was dominated by American shad (64%) and brown bullhead (17%). Male, ripe female, and green female shad represented 34%, 18% and 12% of the catch, respectively. On average, the Potomac River yielded more ripe/running male and female American shad per unit effort ($\bar{x}$ = 0.021/h/ft^2) than did the Hudson River ($\bar{x}$ = 0.007/h/ft^2), which was offset by the Hudson's increased egg viability. The U.S. Fish and Wildlife Service's first attempt to deliver Potomac and Hudson River eggs for Susquehanna River American shad restoration was a success. Results from the Potomac and Hudson Rivers nearly equaled the combined effort from the Delaware and Susquehanna Rivers, which is the basis for our recommendation to continue the project in 2007.

Job II – Part 1

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 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, followed by May in the Hudson River.

Shad have been economically important to Americans since European colonization of North America and 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 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 and Hudson 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, American shad eggs are incubated until hatching then the young are grown out to a suitable size for stocking into the Susquehanna River drainage.

STUDY AREA

The Potomac River is approximately 1.5 km wide at Marshall Hall, MD (rkm 150), where American shad gill netting occurs. The collection site is bounded by Dogue Creek (North) and Gunston Cove (South) and has long been linked to shad harvest and culture. Bottom habitat is characterized by an abrupt transition from the deep channel (≈ 18.3 m) area to relatively shallow depths (≤ 3.5 m). Channel substrate consists of firm sandy mud with intermittent shell. Sand is more prevalent in the shoal area forming a comparatively harder substrate.

The Hudson River sample site (rkm 203) is approximately 32 kilometers South of Albany and adjacent to the town of Stuyvesant, NY on the River's Eastern shore. Here the mid–Hudson is narrow (≈ 0.50 km) compared to the Potomac River. The site is a shoal area that gradually slopes to a depth of approximately 2.0 m before dropping off to a maximum depth of approximately 6.0 m. The feature is much shallower and the transition from shoal to channel is more gradual compared to the Potomac collection site. Bottom substrate at the Hudson River sample site is softer, compared to the Potomac, consisting of mud over sandy clay.

MATERIALS AND METHODS

On the Potomac River, 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 12.2 to 18.3 m. Two small (6.7 m) boats consisting of four to five crew members set as many as five interconnected nets each. Gill nets were set shortly before the evening's slack tide and fished between 40-60 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.

On the Hudson River, we initially anchored 2.4 m deep by 91.4 m long sinking monofilament gill nets with 14.0 cm stretch mesh panels. These nets were outfitted with float lines during the second week of sampling in order to sample the top 2.4 m of the water column. After conversion, the nets remained anchored in place while fishing. Up to four gill nets per boat were fished perpendicular to shore in less than 4.5 m of water. Stationary nets afforded consistent start times for Hudson sampling because the nets could be set and fished repeatedly in one location. As on the Potomac, set times ranged from 40 to 60 minutes. Because Hudson River nets were anchored on a shoal, we were able to set nets in advance of the evening slack tide and continue to fish well into tide reversal. Tidal condition (transitioning high or low) was noted and surface temperature (C^o), dissolved oxygen (mg/L), and salinity (ppt) were recorded (Yellow Springs Instruments Model 85) each night gill nets were set (Figures 1and 2). We recorded the number of ripe, green, or spent female American shad, running male American shad, and bycatch (Table 1, Figures 3 and 4). Effort was recorded but not regimented, as the goal was to maximize effort 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. All CPUE values were multiplied by 1000 as a scalar for display (Figures 1 and 2). American shad otolith samples were taken along with total length (nearest mm) and weight (nearest 0.1 gram) from 5% (39) of American shad used for egg or sperm harvest from the Potomac River. Scale samples were also taken from 300 American shad sampled from the Hudson River. The samples were permit requirements of the Potomac River Fisheries Commission and the New York Department of Environmental Conservation, respectively.

Job II – Part 1

RESULTS

During spring 2006 we sampled the Potomac and Hudson Rivers 16 and 13 days, respectively. Over 29 days of fishing we collected ≥ 5.0 L of eggs 16 times (55%). We shipped a total of 99.3 L (Range = 3.9 - 15.3 L, $\bar{x}$ = 9.0 L/shipment) of eggs from the Potomac River and an average of 10.0 L/shipment (Range = 5.1 – 13.3 L) of eggs from the Hudson River (Mike Hendricks, personal communication). Egg viability averaged 44.0 (Range = 16.5 – 62.8%) and 68.6% (Range = 48.5 – 93.2%) respectively from the Potomac and Hudson Rivers (Mike Hendricks, personal communication).

Gill net sampling produced 2571 and 620 fish from the Potomac and Hudson Rivers, respectively. Together, thirteen fish species from seven families were represented (Table 1). The Potomac River catch was dominated by gizzard shad (39%), American shad (29%) and striped bass (27%). Green female, ripe female, and male shad represented 13%, 12% and 5% of the catch, respectively. (Figure 3). By contrast, the target species dominated the Hudson River catch (64%) with brown bullhead contributing 17 percent. Male, ripe female, and green female shad represented 34%, 18% and 12% of the catch, respectively. (Figure 4).

From mid-April to early July, surface temperature increased and dissolved oxygen decreased gradually on the Potomac River. There, surface temperatures ranged from 15.5 to 20.6 C^o ($\bar{x}$ = 18.2 C^o) while dissolved oxygen behaved inversely (Range 6.2 – 8.6, $\bar{x}$ = 7.4 mg/L) (Figure 1). Weather on the Hudson River, from early May to June, was erratic by comparison, resulting in periods of unseasonably cool water temperatures. There the lowest recorded surface temperature (12.9 C^o) occurred midway (5/23) through sampling and gradually increased to a high of 20.6 C^o, when sampling ceased (Figure 2). Fluctuation in Hudson River surface temperature was reflected in dissolved oxygen values (7.64 – 10.0, $\bar{x}$ = 8.0 mg/L) (Figure 2). As time progressed CPUE was variable and apparently unrelated to tide on both rivers. CPUE was highest on the first day of sampling ($0.118/h/ft^2$, $0.033/h/ft^2$) for the Potomac and Hudson rivers, respectively (Figure 1). The lowest CPUE values were recorded on the final day of sampling on the Potomac ($0.001/h/ft^2$) and Hudson ($< 0.001/h/ft^2$) Rivers (Figures 1 and 2), which is expected given ambient surface temperatures (Figures 1 and 2). On average, the Potomac River yielded more ripe/running male and female American shad per unit effort ($\bar{x} = 0.021/h/ft^2$) than did the Hudson River ($\bar{x} = 0.007/h/ft^2$) (Figures 1 and 2). Total egg shipments and liters were also higher for the Potomac (N = 11, 99.30 L) compared to the Hudson (N = 6, 60.00 L) (Table 2). However, egg viability was higher from the Hudson River (68.65%) than from the Potomac River (44.40%).

DISCUSSION

The amount of nightly effort (gill net linear feet) increased on both rivers as American shad sampling progressed. Net design and the method of fishing were different than anticipated for the Hudson River and provided unique challenges, initially. Crew members with local knowledge eased the transition to Hudson River sampling.

Wet weather in the Northeast curtailed Hudson River sampling during May 2006. Cool cloudy weather and heavy rainfall combined to reduce surface water temperatures and increase flows, which led to some localized flooding. Of the six egg shipments made from the Hudson River, two were collected when surface water temperatures were ≤ 15 C^o. Also, New York permitting requires that gill netting be suspended from Friday 6:00 pm to Saturday 6:00 pm (local) to allow recreational anglers unfettered access to the river. The mandatory stand down and inclement weather combined to reduce sampling effort below that which may be expected during a typical Hudson River American shad spawning season. For instance, the net lift and a three day foul weather allowance would leave 24 days for shad egg harvest/season on the Hudson River. Actual conditions permitted 13 fishing days. Of 13 attempts, 6 yielded an egg volume ≥ 5 L. We supplied an estimated 1.3 million viable American shad eggs from the Hudson River during spring, 2006 (Table 2). Given our average viability (≈ 69%) and harvest volume (10.0 L), 5.1 million viable American shad eggs were possible, given 24 days of effort. Therefore, the 3.8 million viable egg difference (expected – observed) may be considered the cost of spring 2006 weather. Fortunately, weather - induced losses on the Hudson were offset by Potomac River gill netting during April 2006 (Table 2). However, lower egg viability in the Potomac River (≈ 44%) compared to the Hudson River (≈ 69%) reduced the 4.5 million potential eggs to 2.0 million viable eggs (Table 2).

Overall, American shad from the Hudson River seemed larger than those observed from the Potomac River. Greater fecundity and higher fitness is expected from larger individuals. Although anecdotal, the Hudson's larger spawning female American shad may explain the higher observed mean egg viability (Table 2). This assumption is supported, albeit circumstantially, by the nearly two - fold increase (0.32 : 0.54 L/ripe female) in observed egg yield from Hudson vs. Potomac River females.

American shad and bycatch recruited to the gear variably and in pulses during spring, 2006. This was especially evident on the Potomac River during the evening of April, 28. During this sampling event 328 striped bass were caught in 1.48 hours with a combined 549 m of net. Net length was equally divided between two Service boats fishing in a North/South line parallel and in close proximity to the steep drop, from shoal to channel. Service nets were joined directly to the south by identical nets of similar length, belonging to MDDNR. Fishing in this manner resulted in an almost uninterrupted blockade of the underwater feature. The large aggregation of striped bass encountered a small area of net over a relatively short time period. Most (n = 287) of the school was caught in 275 m of Northernmost boat's net. The remaining striped bass were caught by the boat to the South. Further South, MDDNR nets captured approximately 75 striped bass in approximately the same amount of time. Short staggered gill net set/retrieval times and assistance from MDDNR combined to prevent large–scale loss of striped bass.

American shad harvest in numbers sufficient to yield egg shipments was also variable on the Potomac River. Often, most of the shad were encountered by one boat. Males were rare from the Potomac (5%) compared to the Hudson River (34%) and were outnumbered by ripe females by nearly 2 to 1 (Figures 3 and 4). Restoration efforts would have benefited from this ratio, had it been maintained throughout sampling. On the Potomac River, male American shad were often shared between Service boats and MDDNR and occasionally re-used. By contrast male American shad dominated the Hudson River catch (Figure 4) and were never a limiting factor, as on the Potomac River.

CONCLUSION

The Service's first attempt to harvest eggs from the Potomac and Hudson Rivers for delivery to the Van Dyke American shad hatchery, in support of Susquehanna River restoration, was a success. Taken together, harvest, from Service gill netting, equaled results from the Delaware and Susquehanna Rivers, with respect to viable eggs, which is the basis for our recommendation to continue the project. A key to success was the decision to gill net the Potomac River for American shad prior to the Hudson River season. Spreading effort over two months at locations separated by nearly 640 km circumvented the unforeseen effects of inclement weather in the Northeast.

ACKNOWLEDGEMENTS

The Maryland Fishery Resources Office thanks those who volunteered time and energy to further Susquehanna River American shad restoration efforts. They are Art Coppola, Dr. Fred Pinkney, and Dan Murphy from the U.S. Fish and Wildlife Service; Matthew Baldwin from the Maryland

Department of Natural Resources; Kathy Hattala, Kris McShane and Jen Temple from the New York Department of Environmental Conservation; Kale Kaposhilin from Kingston, New York. We also appreciate Richard St. Pierre's expertise and guidance during the early stages of this project.

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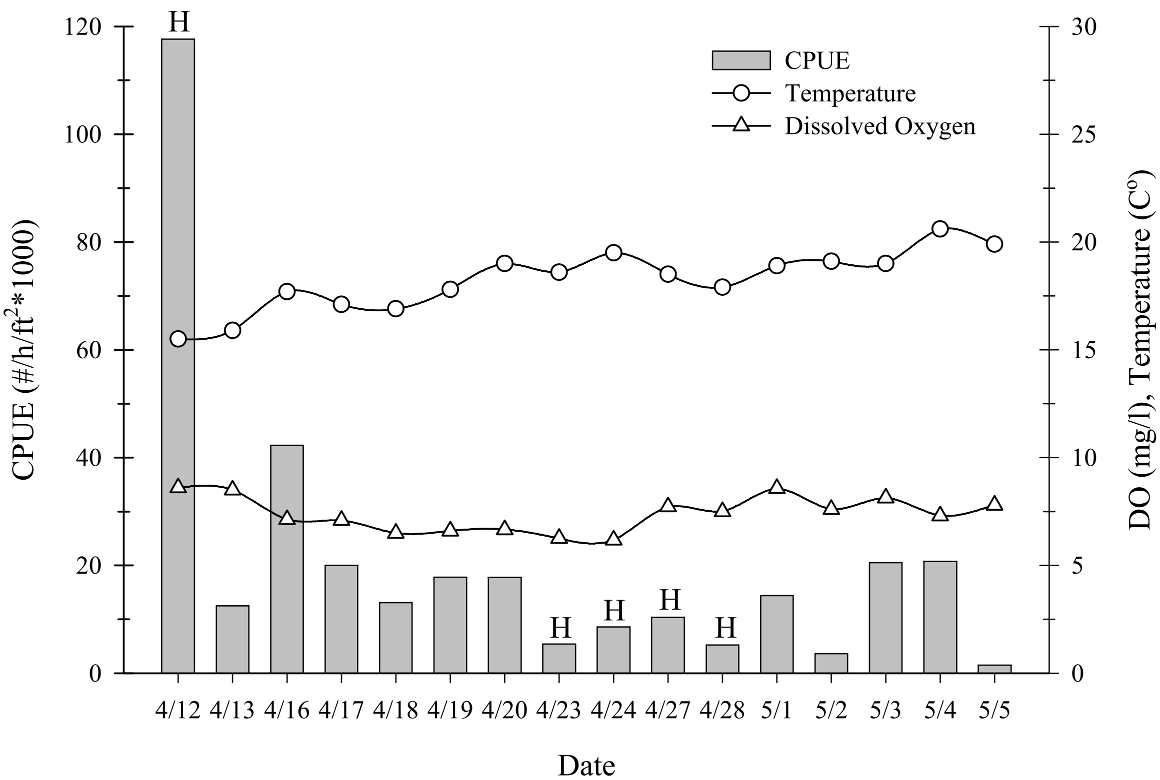

Figure 1. Spring 2006 American shad catch per unit effort, surface dissolved oxygen, and surface temperature, by sample date, for the Potomac River at Marshall Hall, MD. Surface salinity (not depicted) was always ≤ 0.20 ppt. H = tide transition from low to high.

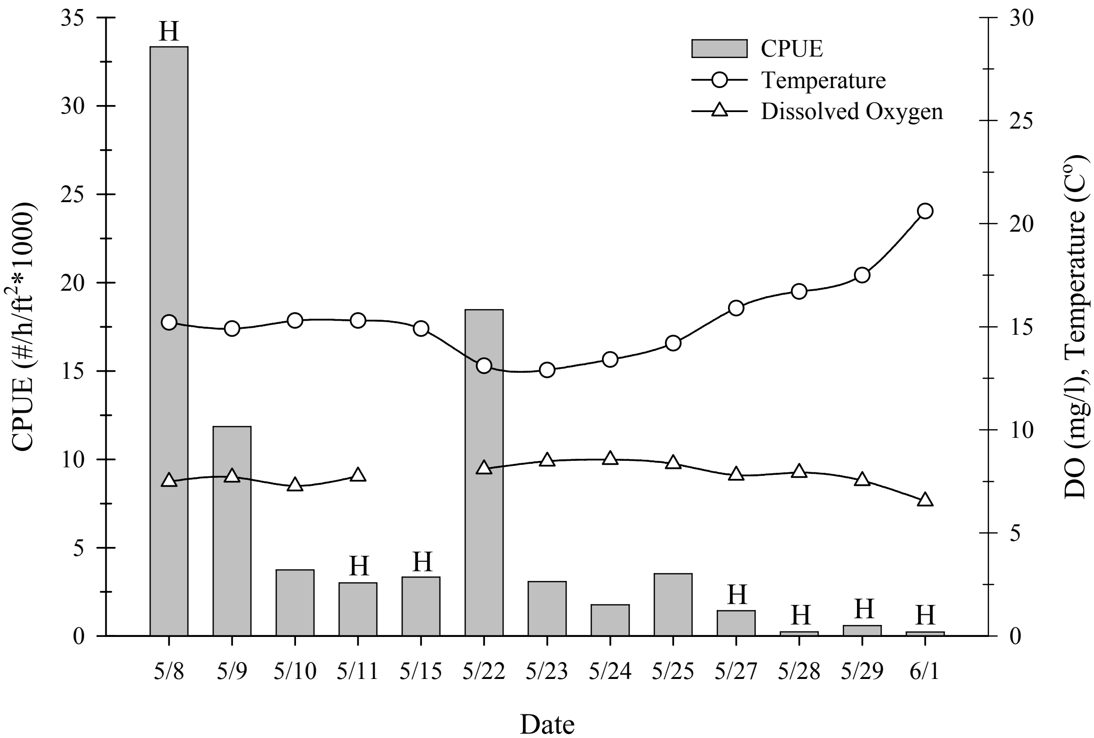

Figure 2. Spring 2006 American shad catch per unit effort, surface dissolved oxygen, and surface temperature, by sample date, for the Hudson River at Stuyvesant, NY. Surface salinity (not depicted) was always ≤ 0.20 ppt. H = tide transition from low to high.

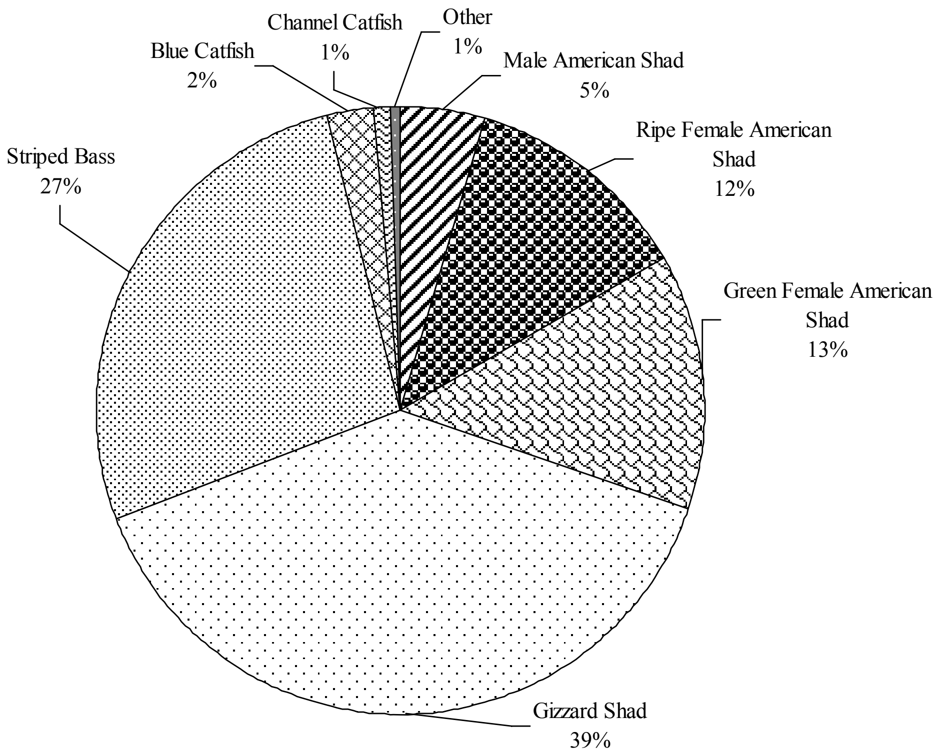

Figure 3. Spring 2006 species composition from Potomac River gill net sampling at Marshall Hall, MD. Other species were longnose gar, Alosids, and common carp.

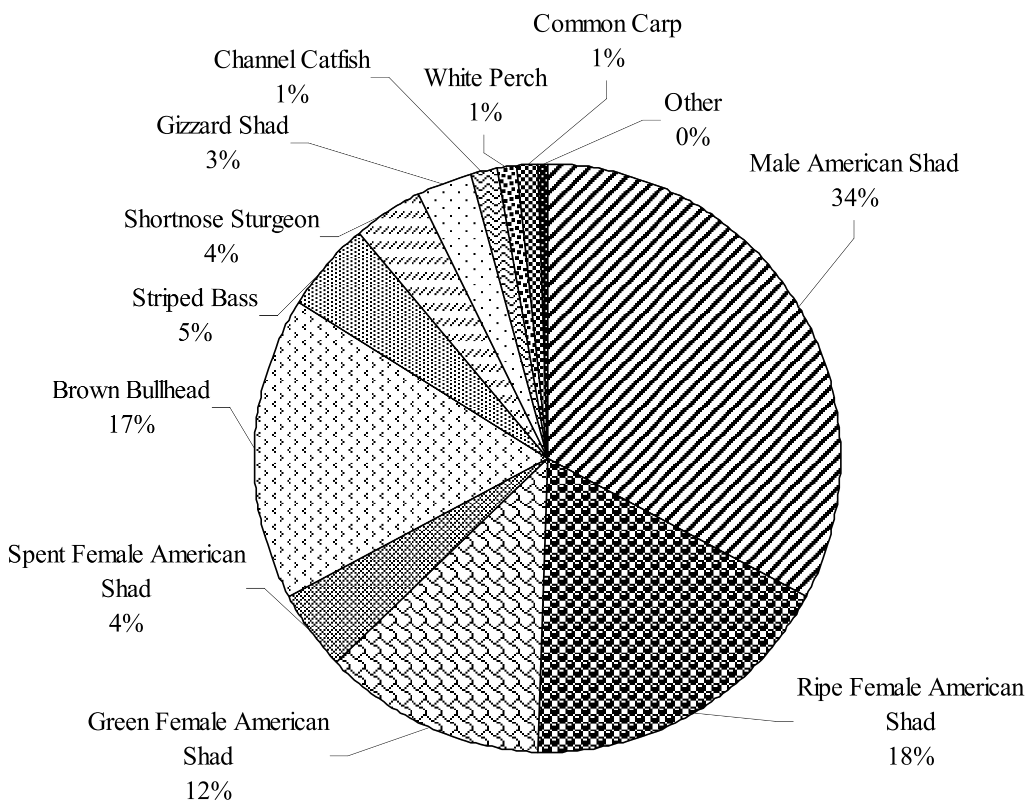

Figure 4. Spring 2006 species composition from Hudson River gill net sampling at Stuyvesant, NY. Other species were walleye and goldfish.

Table 1. List of species and number collected in gill nets from the Potomac and Hudson Rivers during spring, 2006.

Family	Scientific Name	Common Name	Number	
			Potomac R.	Hudson R.
Acipenseridae	*Acipenser brevirostrum*	shortnose sturgeon		25
Clupeidae	*Alosa sapidissima*	American shad	777	417
	Alosa sp.	river herring	3	
	Dorosoma cepedianum	gizzard shad	1002	18
Cyprinidae	*Carassius auratus ssp.*	goldfish		1
	Cyprinus carpio	common carp	2	8
Lepisosteidae	*Lepisosteus osseus*	longnose gar	12	
Moronidae	*Morone americana*	white perch		7
	Morone saxatilis	striped bass	693	31
Ictaluridae	*Ameiurus nebulosus*	brown bullhead		103
	Ictalurus furcatus	blue catfish	63	
	Ictalurus punctatus	channel catfish	19	8
Percidae	*Stizostedion vitreum*	walleye		2

Table 2. 2006 American shad egg shipment and viability summary from sites delivering to the Van Dyke American Shad Hatchery near Thompsontown, PA (Hendricks 2006, unpublished).

Site	Shipments (N)	Volume (L)	Eggs (N)	Viable Eggs (N)	Viability (%)
Potomac R.	11	99.3	4,511,426	2,003,222	44.40
Hudson R.	6	60.0	1,859,518	1,276,500	68.65
Delaware R.	12	64.9	2,328,165	1,164,868	50.03
Susquehanna R.	17	169.25	10,281,444	2,232,459	21.71
Total	46	393.45	18,980,553	6,677,049	35.18

Job II - Part 2

COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2006

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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 dependant upon reliable sources of good quality eggs. Cost-effective collection of eggs requires intensive sampling efforts in well- documented spawning areas where ripe brood fish are abundant.

The Delaware River was first used as a source of American shad eggs in 1973. Between 1973 and 1975, 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 2006, as in past years, was to collect and ship up to 15 million American shad eggs.

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 2006, 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 2006, fourteen 200-foot gill nets were set per night with the exception of the first and second nights, when nine and ten 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.

Job II - Part 2

RESULTS AND DISCUSSION

Table 1 summarizes daily Delaware River shad egg collections during May and June 2006. American shad spawning operations commenced on May 3, when river flow was 5,120 cfs (USGS gauge at Montague, NJ), and river temperature was 14.7˚ C (58.5˚ F). Egg take ended on June 1, when river flow was 7,150 cfs and temperature was 23.9˚ C (75˚ F). The 2006 egg-take operation was initiated during a period of decreasing flow, interrupted by a freshet from May 12 to May 23 during which time few eggs were collected (Figure 1, Table 1). The majority of the successful egg collections occurred when flow was below 62-year median flows and declining (Figure 1). Egg collections were negatively impacted by successive coldfronts, increased flows during May 12 to May 23, and by apparently lower than normal stock size (Lambertville hydro-acoustics estimate of 114,000 shad).

Nets were set on 15 nights with 9-14 nets set on each night. The usual number of nets set per mesh size (stretch, inch) each night was: 4.50- 2-3 each; 4.75- 1 each; 5.00- 3-4 each; 5.25- 0-1 each; 5.50- 1-2 each; 5.75- 1 each; and 6.00- 1-2 each.

A total of 358 adult American shad were caught (Table 1), which was only one-third of the number caught in 2005. Nightly catches ranged from 2 to 48 shad. Sex ratio (male to female) was 0.62:1. Some 64.9 L (2.3 million) fertilized eggs were collected and shipped to the Van Dyke Hatchery in 2006, compared to 146L (6.2 million eggs) in 2005. A total of 293 thousand American shad larvae were stocked in the Lehigh River, 254 thousand were stocked in the Schuylkill River, and 53 thousand were stocked in the Delaware River at Smithfield Beach to replenish the Delaware for the adults used for egg-take. From 1983 to 2006, 154 million American shad eggs were collected from the Delaware River. From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 15.5 million in the Lehigh River, 5.3 million in the Schuylkill River, and 0.2 million in the Delaware River.

Job II - Part 2

The decreased numbers of adult shad collected in 2006, and a sharp decrease in catch/effort (Figure 3) are thought to be reflective of a decrease in the abundance of adult shad in 2006, but may also reflect the negative effects of the environmental conditions experienced.

SUMMARY

Fishing occurred from 3 May through 1 June 2005. Eggs were collected and shipped on 12 of the 15 nights of fishing. A total of 358 adult shad were captured and 64.9 liters of eggs were shipped for a hatchery count of 2.3 million eggs. Overall, the viability for Delaware River American shad eggs was 50%.

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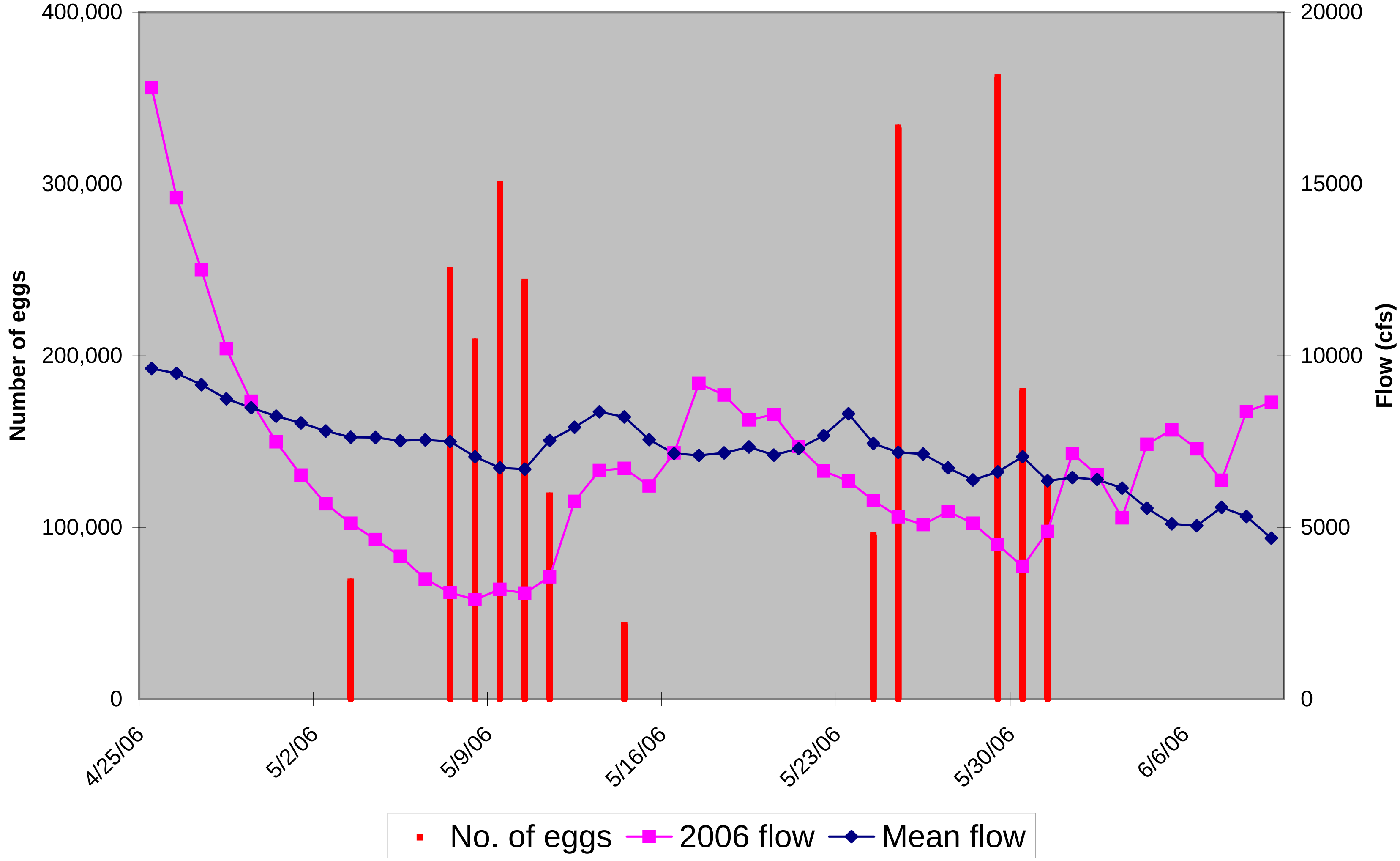
Figure 1. American shad egg collections and flow, Delaware River, 2006.



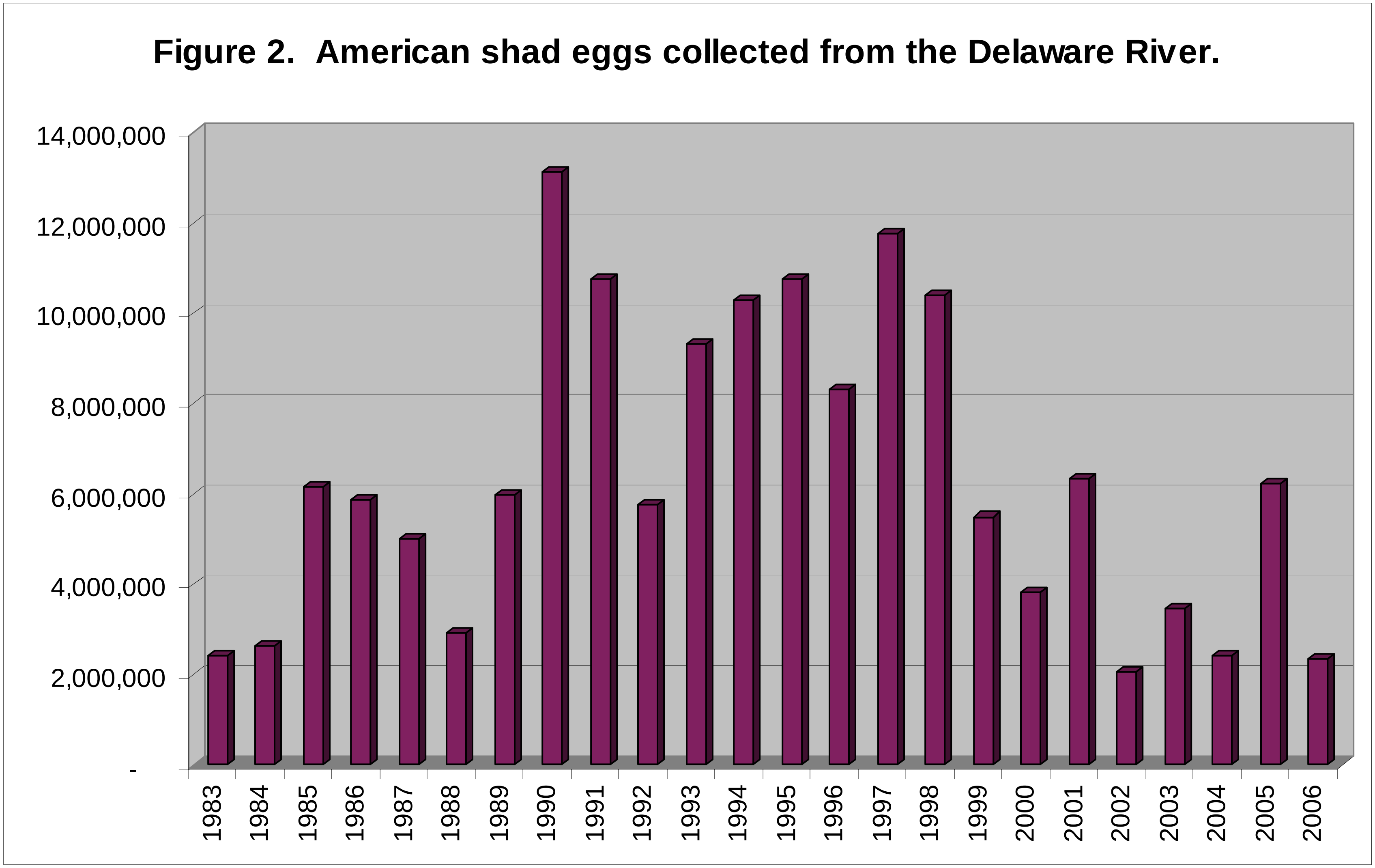


Figure 2. American shad eggs collected from the Delaware River.
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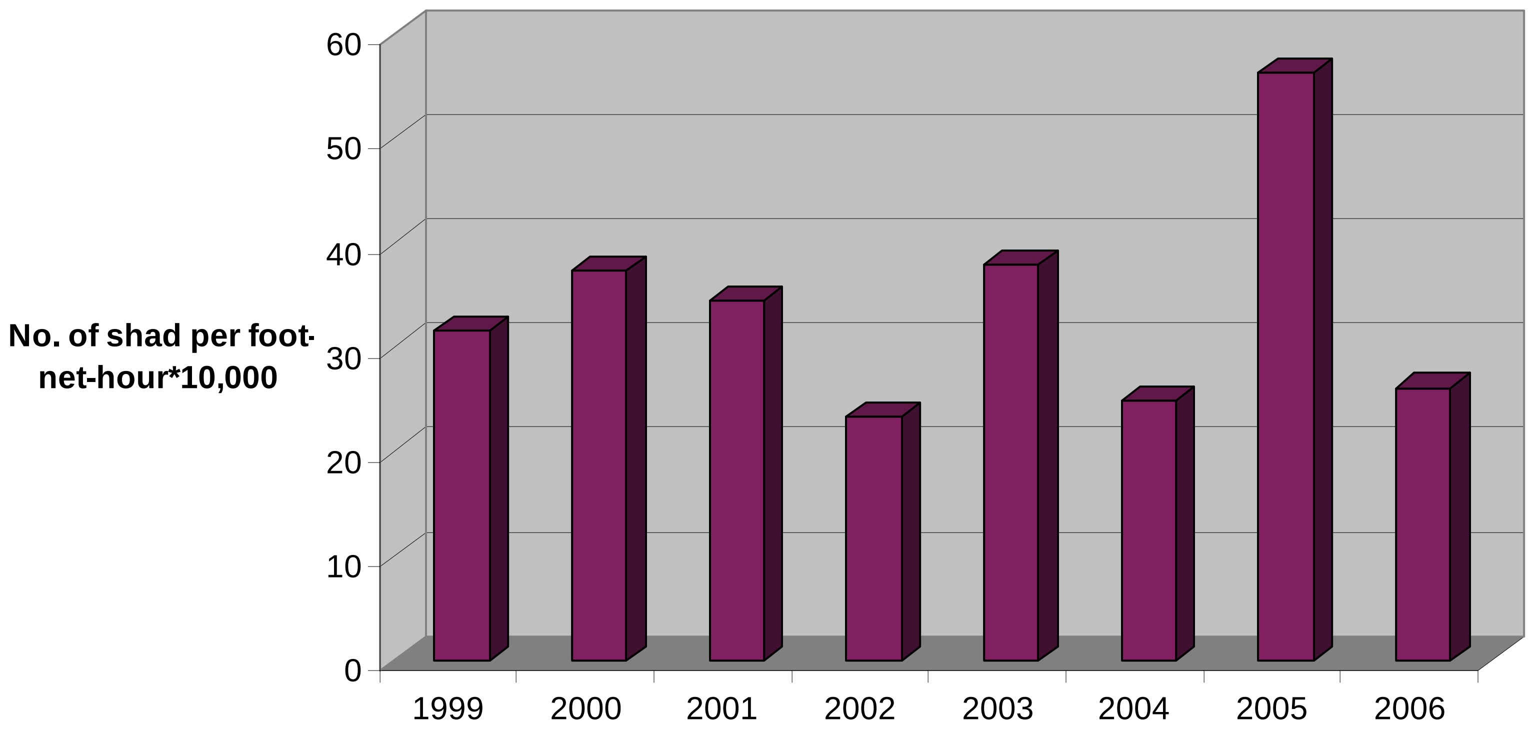
Figure 3. CPUE for adult American shad collected by gill net at Smithfield Beach, Delaware River.



Job II - Part 2

Table 1. Delaware River American shad egg collection, 2006.

Month	Day	Year	Location	Water Temp C	No. of nets	No. of shad captured	Volume (L)	Eggs	Viable Eggs	Percent Viable
5	3	2006	Smithfield Beach	14.7	9	16	2.4	68,483	58,186	85.0%
5	4	2006	Smithfield Beach	16.5	10	11	0.0	Collected < 1L of eggs		
5	7	2006	Smithfield Beach	17	14	43	7.5	249,753	173,848	69.6%
5	8	2006	Smithfield Beach	16.7	14	40	6.6	208,177	140,111	67.3%
5	9	2006	Smithfield Beach	16.3	14	48	9.5	299,648	144,288	48.2%
5	10	2006	Smithfield Beach	17.2	14	21	7.7	242,873	160,107	65.9%
5	11	2006	Smithfield Beach	16.6	14	10	3.2	118,435	-	0.0%
5	14	2006	Smithfield Beach	16.6	14	12	1.4	43,199	32,060	74.2%
5	15	2006	Smithfield Beach	14.7	Did not fish					
5	16	2006	Smithfield Beach	14.3	Did not fish					
5	21	2006	Smithfield Beach	13.6	14	2	0.0	Pulled nets after first run due to low catch		
5	24	2006	Smithfield Beach	14.8	14	16	3.2	95,509	67,978	71.2%
5	25	2006	Smithfield Beach	15.1	14	26	8.2	332,736	254,282	76.4%
5	29	2006	Smithfield Beach	21.6	14	38	8.0	361,911	57,006	15.8%
5	30	2006	Smithfield Beach	23.2	14	40	4.6	179,241	76,739	42.8%
5	31	2006	Smithfield Beach	23.8	14	20	2.6	128,201	264	0.2%
6	1	2006	Smithfield Beach	23.9	14	15	0.0	Caught all females, no eggs shipped		
					Total	**358**	**64.9**	**2,328,165**	**1,164,868**	**50.0%**

Job II – Part 3

REPORT ON HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN AND HICKORY SHAD AT CONOWINGO DAM, SPRING 2006

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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 has become controversial or questioned by state agencies. In an effort to reduce the costs and controversy of out of basin egg shipments, three options were proposed for the Annual Work Plan in 2001. Option 1 was the strip spawning of adult broodfish collected from known spawning areas in the Lower Susquehanna River. Option 2 was the hormone-induced spawning of shad broodfish on site at the Conowingo Dam West Fish Lift and Option 3 was the combination of Options 1 and 2. Option 2 was selected for the Annual Work Plan in 2001 and with modifications, this plan was continued in 2002. Option 3 was selected for the Annual Work Plan in 2003 and continued in 2004 and 2005. The 2006 Annual Work Plan returned to Option 2 with the elimination of strip spawning of adult broodstock from known spawning areas and focused on hormone induced spawning of shad on site at the Conowingo West Fish Lift. Beginning in 2004, and continuing in

2006, hormone induced spawning of hickory shad collected from Susquehanna River anglers was included in the Plan.

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 USFWS 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.

Job II – Part 3

METHODS AND MATERIALS

Cooperating anglers at the mouth of Deer Creek plus the elecrofishing efforts by DNR personnel at Lapidum provided the source for the pre spawn hickory shad for the 2006 trials at Conowingo Dam. Hickory shad spawning trials began on April 11 as river temperature reached 11 °C and hickory shad appeared in the angler catch at the mouth of Deer Creek. The fourth and last hickory shad trial was completed on the 19th of April when American shad numbers in the Conowingo tailrace were sufficient to warrant operation of the West Fish Lift and begin spawning trials with American shad. Hickory shad caught at the mouth of Deer Creek and at Lapidum 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. The Conowingo West Fish Lift was the source of all pre-spawned American shad broodstock for the 20 spawning trials conducted at Conowingo Dam in 2006.

The 2006 American shad trials were patterned after similar trials conducted by USFWS at Lamar in previous years and on the trials conducted at Conowingo Dam from 2001 to 2005. The 10 ft and 12 ft diameter fiberglass tanks used for spawning trials in 2006 were the same tanks that were used from 2002 to 2005. 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 four hickory shad trials were single tank trials. The stocking rate for the three hickory shad trials held in the 10 ft diameter tank ranged from 86 (1 fish per 74 liters) to 98 (1 fish per 65 liters) fish. The single hickory shad trial held in the 12 ft tank was stocked with 128 (1 fish per 72 liters) fish. A 3:2 (M/F) sex ratio was used if available. 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 same 3:2 sex ratio in favor of males was used for the American shad trials. Five of the 20 American shad trials were double tank (10 and 12 ft tank) trials and the remaining 15 were single tank trials. Two factors; availability of broodstock and noticeable differences in egg quality between the two tanks determined whether a trial was a single or double tank trial. All on-site spawning trials in 2006 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 was converted to 50 and 150 ug cholesterol based pellets by PFBC personnel. The remaining powder was used to make an injectable saline solution that contained 50 ug/ml for hickory shad trials or 150 ug/ml for American shad trials. The injectable solution was prepared just before use due to its short shelf life. Both sexes within each species received equal dosages of LHRH. Each fish was injected with a pelletized implant or liquid 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 only provided in the spawning tanks during the last trial (June 1-3) when ambient dissolved oxygen levels in the river fell below 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. While in the 10 gal bucket, the eggs were sieved multiple times through a colander with 0.25 in holes to remove scales and other debris. The final sieving releases the eggs in a framed nylon net suspended in the egg tank. A No. 20 standard testing sieve was used to transfer the washed eggs from the nylon net into a graduated 2 liter measuring cup. Volume measurements in the field were approximations. The final volume and viability determinations for all shipments were made at the PFBC Van Dyke Hatchery. The packaging of eggs for shipment followed well-established techniques. Up to five liters of water hardened eggs were mixed with 5 liters of river water in double plastic bags. Pure oxygen was introduced into the inner bag before being sealed with tape or rubber band. The bags were placed into marked insulated shipping containers and driven to the Van Dyke Hatchery by PFBC or Normandeau personnel. Eggs were generally driven to the hatchery on the same day they were collected. On one occasion (Trial 12) American shad eggs collected late in the day were held overnight in a shipping box and transported on the following day. When less than 5.0 liters of American shad eggs are collected in a day they were generally released in the river below the dam. 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.

RESULTS

Hormone induced spawning trials with hickory shad at Conowingo Dam began on April 11 and concluded on April 19, 2006. During this interval, 4 spawning trials, (3 pellet, 1 liquid), were conducted with 398 adult hickory shad (Appendix Table A-1). One of the trials was conducted in the 12 ft tank and three in the 10 ft tank. Each trial ran from two to three days but the largest pulse of eggs was produced on the second day. A total of 26.8 liters of eggs was collected from the hickory shad trials and shipped to the Van Dyke Hatchery (Table 1). Another 0.2 liters was released into the tailrace below the dam. The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 60.6% (Mike Hendricks, personal communication). Water temperature in the spawning tanks ranged from 11.5 to 17.2°C and dissolved oxygen levels ranged from 9.0 to 11.7 ppm. Adult mortality rate for hickory shad during the spawning trials was 22%.

A total of 20 on-site spawning trials with 1557 American shad from April 20 to 3 June produced 169.3 liters of eggs (Table 2 and Appendix Table A-2). All eggs were shipped to the Van Dyke Hatchery and none were released into the river below Conowingo Dam. Fourteen of the trials were conducted with pelletized implants and six with liquid injections. 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. Both sexes received an identical dosage of $LHRH_a$ (150 ug). The total volume of eggs produced per female in individual 2006 trials (0.27 liters) was below the average of 0.43 liter observed for the previous four years, (Figure 2). When adjusted for viability, the volume of viable eggs produced per female in the 2006 trials ranged from 0.01 to 0.14 liter in all trials (Figure 3). Water temperatures and oxygen levels in the spawning tanks were monitored daily and ranged from 14 to 22.3°C and 4.2 to 10.5 ppm. The overall estimated viability of the eggs shipped to VanDyke was 22% (Mike Hendricks, personal communication). Mortality rate for adult American shad during the 2006 trials was 3.3%. Mortality ranged from 2 to 6% in previous years.

SUMMARY

The results of the hickory shad hormone-induced spawning trials at Conowingo Dam in 2006 showed a continuation of the high quality levels achieved in 2005. (Table 3).. The estimated overall egg viability of 60.6% is similar to the 61.4% experienced in 2005. Both years were higher than the 44 and 46% viability estimates for on-site spawning trials with hickory shad in 2003 and 2004 respectively. The reduced volume of hickory shad eggs collected in 2006 (26.8 liters in 2006 vs. 73.8 liters in 2005) was primarily due to the reduced number of trials (4 vs. 8) conducted in 2006. This was the sixth year of hormone induced American shad spawning trials at the Conowingo West Fish. The results of the 2006 spawning trials were similar to last year's results (Table 4) and were within the range of results of previous years. Steady river flows and slowly climbing river temperatures in mid May probably helped this year's trials surpass those trials conducted in 2004.

Table 1:

Summary of egg production data for hormone-induced spawning trials conducted with hickory shad in a 10 ft diameter (S-2) and 12 ft diameter (S-1) tank at Conowingo Dam, Spring, 2006.

Trial #	Liquid/ Pellet	Start/Stop Date	S-1 M/F	S-2 M/F	S-1 Liters	S-2 Liters	No. Liters Shipped	Date Shipped	Eggs	No. Viable Eggs	Percent Viable
1	Pellet	4-11/4-13		70/28		3.2	3.2	4/13	1,609,888	1,335,075	82.9%
2	Liquid	4-12/4-15	77/51		1.3		1.3	4/14	654,017	198,178	30.3%
3	Pellet	4-13/4-15		50/36		9.2	9.2	4/14	4,414,294	3,313,627	75.1%
3	Pellet	4-13/4-15				2.6	2.6	4/15	1,308,034	920,983	70.4%
4	Pellet	4-17/4-19		50/36		10.5	10.5	4/18	7,179,694	3,426,711	47.7%
Totals			**77/51**	**170/100**	**1.3**	**25.5**	**26.8**		**15,165,928**	**9,194,583**	**60.6%**

Total Males =247
Total Females =151
Total Fish =398
Mean liters/trial. = 6.7 liters

Mean No. of Eggs/ Liter = 565,893
Mean No. of Eggs/Female (All Trials) = 100,437
Mean No, of Viable Eggs/ Female (All Trials) = 60,891
Mean Egg Viability (All Trials) = 60.6%

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Table 2:

Summary of egg production data for hormone-induced (LHRHa) spawning trials conducted with American shad in a 10 ft diameter (S-2) and 12 ft diameter (S-1) tank at Conowingo Dam, Spring, 2006.

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	4-20/4-23		30/20		6.9	6.7	22-Apr	432,961	118,593	27.4%
2	Pellet	4-21/4-23	45/30		5.4		5.4	23-Apr	289,517	45,324	15.7%
3	Pellet	5-3/5-5		30/20		8.0	8	5-May	390,755	70,947	18.2%
4	Pellet	5-4/5-7	45/30		12.2		11.7	6-May	692,744	159,096	23.0%
5	Pellet	5-5/5-7		30/20		8.3	8.3	7-May	413,130	132,180	32.0%
6&7	Pellet	5-8/5-10	45/30	30/20	8.7	4.9	13.6	10-May	729,153	194,012	26.6%
8&9	Pellet	5-10/5-12	45/30	30/20	3.8	5.0	8.8	12-Apr	521,038	79,991	15.4%
10&11	Liquid	5-12/5-14	45/30	30/20	4.0	1.5	5.5	14-May	396,754	69,221	17.4%
12	Pellet	5-15/5/17	45/30		6.0	4.5	10.5	17-May	627,227	161,874	25.8%
12	Pellet	5-15/5-17		30/20	4.9	4.0	8.9	17 May*	536,369	2,972	0.6%
13	Pellet	5-17/5-19	45/30	30/20	10.25	4.5	14.75	19-May	944,968	212,355	22.5%
14&15	Pellet	5-19/5-21	45/30	30/20	12.9	4.0	16.9	21-May	1,027,511	225,627	22.0%
16	Pellet	5-22/5-24		28/20		6.3	6.3	24-May	428,535	187,995	43.9%
17	Liquid	5-23/5-25	47/30		10.7		10.7	25-May	568,425	178,597	31.4%
18	Liquid	5-25/5-27	45/32	30/20	10.6	7.2	17.8	27-May	1,016,942	175,562	17.3%
19	Liquid	5-29/5-31	45/32	28/23	5.9	4.2	10.1	31-May	753,072	184,860	24.5%
20	Liquid	6-1/6-3	45/30	31/21	2.5	2.8	5.3	3-Jun	512,344	33,251	6.5%
Totals			**542/364**	**387/264**	**97.9**	**72.1**	**169.25**		**10,281,444**	**2,232,459**	**21.7%**

*Eggs boxed up and held overnight befor shipment.

Mean vol. / trial = 8.5 liters

Total Males = 929

Total Females = 628

Total Fish = 1557

Mean No. of Eggs / Liter (20 Trials) = 60,747

Mean No. of Eggs/Female (20 Trials) = 16,372

Mean No, of Viable Eggs/ Female (20 Trials) = 3,555

Table 3:

Summary of hormone induced spawning trials with hickory shad at Conowingo Dam, 2003-06

Year	**2003**	**2004**	**2005**	**2006**
Start/Finish date	4-15/4-27	4-19/4-26	4-15/4-27	4-11/4-19
Tank diam.	10+12 ft	10+12 ft	10+12 ft	10+12 ft
Tank volume (liters)	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200	6,400 - 9,200
No. of trials	5	4	8	4
Total fish	381	349	721	398
Males/Females per trial	40/36	48/39	55/34	62/38
Stocking density (fish/liters)	1/99	1/89	1/78	1/71
Male:Female ratio	1.1:1	1.2:1	1.6:1	1.6:1
Hormone injected	$LHRH_a$	$LHRH_a$	$LHRH_a$	$LHRH_a$
Liquid, Pellet	L+P	L+P	L+P	L+P
Dose(ug) Male/Female	50/50	50/50	50/50	50/50
Eggs collected (liters)	30.2	33.4	73.8	26.8
Liters of eggs /Female	0.167	0.215	0.271	0.177
No. eggs/liter	477,607	405,853	388,208	565,893
Total number of eggs	14,423,730	13,555,505	28,727,411	15,165,928
Viability (%)	44.1	46.1	61.4	60.6
Total number of viable eggs	6,360,865	6,245,259	17,645,251	9,194,583
Total liters of viable eggs	13.32	15.39	45.45	16.25
Adult mortality rate (%)	14.0	3.7	2.2	22.1

Table 4:

Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-2006.

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
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
Tank diameter	12 ft	10,12 ft	10,12 ft	10,12 ft	10,12 ft	10,12 ft
Tank volume (liters)	9,200	15,600	15,600	15,600	15,600	15,600
Number of trials	10	10	12	10	11	20
Total fish	599	1000	1504	1055	1135	1557
Males/Females per trial	36/24	66/34	75/50	75/50	75/50	47/31
Stocking density (fish/liter)	1/153	1/156	1/125	1/125	1/125	1/124
Male:Female ratio	3:2	2:1	3:2	3:2	3:2	3:2
Hormone injected	LHRHa	SGnRHa	LHRHa	LHRHa	LHRHa	LHRHa
Liquid, Pellet	P	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
Eggs collected (liters)	103	146.8	234	90.4	160.5	169.25
Liters of eggs /Female	0.429	0.432	0.387	0.244	0.418	0.270
No. eggs/liter	63,140	51,235	51,187	59,775	53,828	60,747
Total number of eggs	6,503,420	7,521,346	11,970,764	5,403,660	7,998,778	10,281,444
Viability (%)	33.2	10.1	17.7	20	23.9	21.7
Total number of viable eggs	2,159,135	760,935	2,118,852	1,080,732	1,913,801	2,232,459
Total liters of viable eggs	34.20	14.85	41.42	18.1	35.6	36.75
Adult mortality rate (%)	6.0	3.6	2.0	11.5*	3.3	3.5

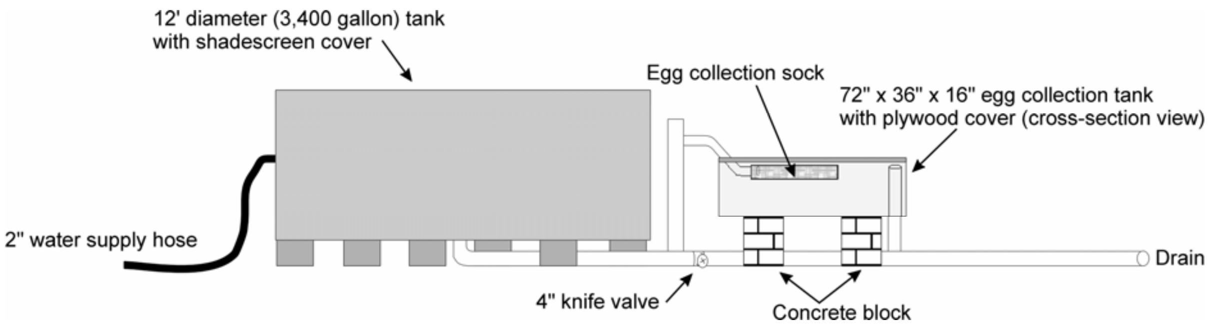

Figure 1

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

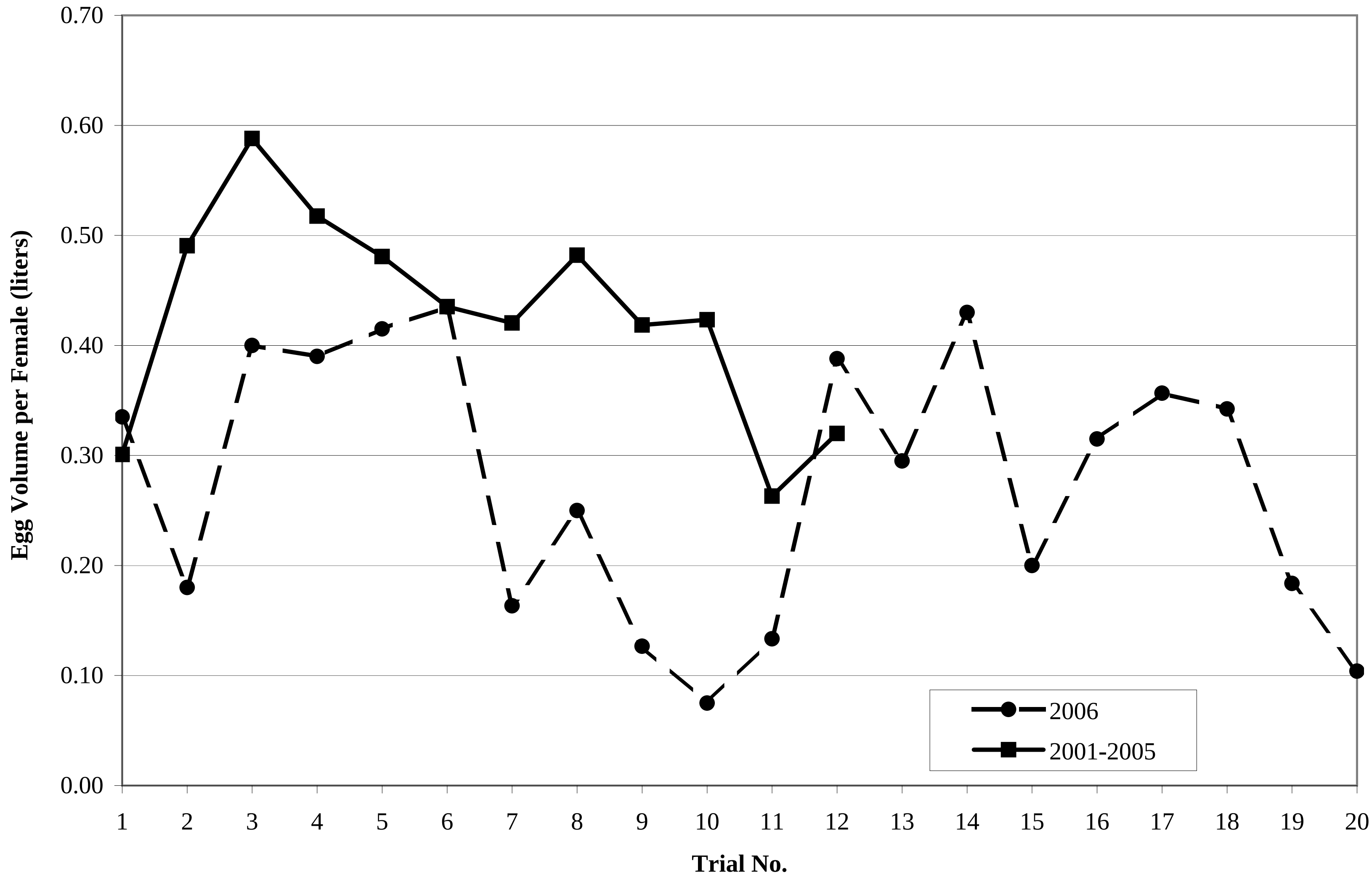

Figure 2. Comparison of American shad egg production per female by trial number at Conowingo Dam, 2001-2006

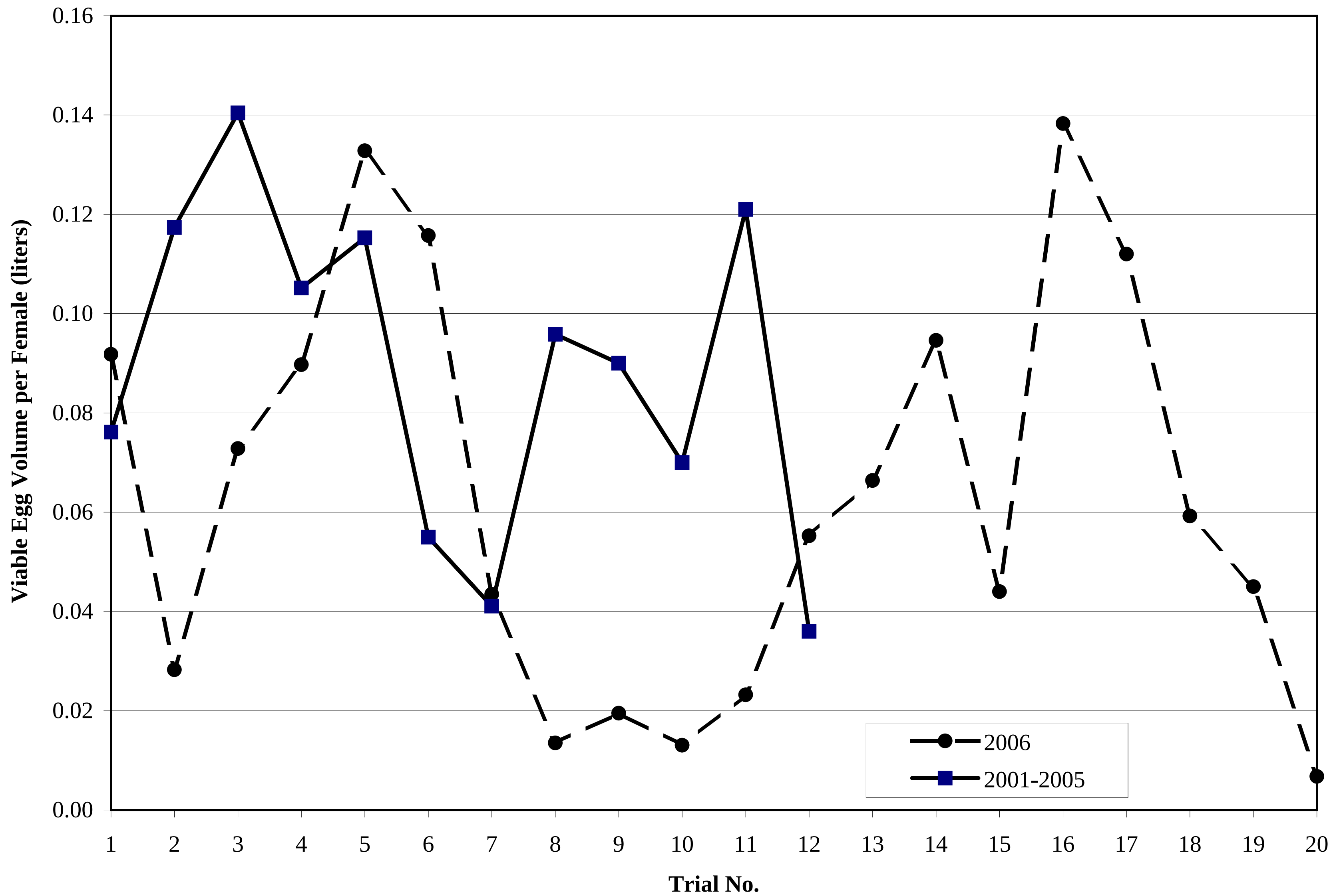

Figure 3. Comparison of viable American shad eggs produced per female by trial number at Conowingo Dam, 2001-2006.

Appendix Table A-1:

Individual trial data for hormone induced hickory shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2006.

Trial No. 1

M/F Ratio	70/28				10 ft tank		
Start Date	4/11/2006	0830			Dose/fish 50 ug LHRH pellet		
End Date	4/13/2006	1300					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/11/2006	1705	11.5	11.7				
4/12/2006	0744	13.1	10.9				
4/12/2006	1419	13.8	10.4				
4/13/2006	0735	13.5	10.4				
4/13/2006	1300			3.2	3.2		7

Trial No. 2

M/F Ratio	77/51				12 ft tank		
Start Date	4/12/2006	0930			Dose/fish 50 ug LHRH liquid		
End Date	4/15/2006	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/12/2006	0930	13.5	11				
4/12/2006	1417	13.8	10				
4/13/2006	0737	13.5	10.1				
4/13/2006	1515	14.7	9.8				
4/14/2006	1055	14.1	10.3				
4/14/2006	1200			1.3	1.3		
4/15/2006	0830	14	10.2				53

Trial No. 3

M/F Ratio	50/36				10 ft tank		
Start Date	4/13/2006	1415			Dose/fish 50 ug LHRH pellet		
End Date	4/15/2006	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/13/2006	1435	14.7	9.8				
4/14/2006	1058	14.1	10.4				
4/14/2006	1145			9.2	9.2		
4/15/2006	0900	14	10.3	2.6	2.6		14

Trial No. 4

M/F Ratio	50/36				10 ft tank		
Start Date	4/17/2006	1455			Dose/fish 50 ug LHRH pellet		
End Date	4/19/2006	1300					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/17/2006	1520	16.7	9.0				
4/18/2006	1137	17.2	9.2	10.5	10.5		
4/19/2006	0751	16.8	9.2			0.2	14

Appendix Table A-2.

Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, Spring 2006.

			Trial No. 1				
M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	4/20/2006	1115					
End Date	4/23/2006	0930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/20/2006	1330	18	8.1				
4/21/2006	0813	17.6	8.3				
4/22/2006	1025	17.6	8.1	6.7	6.7		
4/23/2006	0922	17.3	7.9	0.2		0.2	1m,4f
			Trial No. 2				
M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	4/21/2006	1045					
End Date	4/23/2006	1100					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/21/2006	1145	18	6.4				
4/22/2006	1111	17.9	7.6				
4/23/2006	0920	17.3	7.9	5.4	5.4		6f
			Trial No. 3				
M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/3/2006	1115					
End Date	5/5/2006	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/2006	1645	18.5	9.1				
5/5/2006	0910	18.2	9.1	8.0	8.0		1f
			Trial No. 4				
M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/4/2006	1030					
End Date	5/7/2006	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/2006	1645	18.5	9.2				
5/5/2006	1600	19.1	8.2				
5/6/2006	0948	18.9	8.4	11.7	11.7		
5/7/2006	0855	19.2	8.3	0.5		0.5	

Appendix Table A-2.

Continued.

Trial No. 5

M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/5/2006	1100					
End Date	5/7/2006	1030					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/5/2006	1600	19.1	8.9				
5/6/2006	0950	18.9	8.5				
5/7/2006	0855	19.2	8.6	8.3	8.3		

Trial No. 6

M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/8/2006	1005					
End Date	5/10/2006	1000					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/2006	1720	19.1	8.4				
5/10/2006	0915	20.0	7.2	8.7	8.7		1f

Trial No. 7

M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/8/2006	1055					
End Date	5/10/2006	1000					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/2006	1721	19.1	8.7				
5/10/2006	0916	20.0	7	4.9	4.9		

Trial No. 8

M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/10/2006	1200					
End Date	5/12/2006	1000					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2006	1715	20.5	6.4				
5/11/2006	0900	20	6.2				
5/11/2006	1540	2	5.3				
5/12/2006	0915	20.7	6.4	5	5		2f

Trial No. 9

M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/10/2006	1200					
End Date	5/12/2006	1000					

Appendix Table A-2.

Continued.

			Trial No. 9 Continued				
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2006	1715	20.5	6.5				
5/11/2006	0900	20	6.8				
5/11/2006	1540	20	5.7				
5/12/2006	0915	20.5	6				
5/12/2006	1000			3.8	3.8		1f

			Trial No. 10				
M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH liquid		
Start Date	5/12/2006	1100					
End Date	5/14/2006	1100					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/12/2006	1600	21.2	6.2				
5/13/2006	1034	20.8	6.2				
5/14/2006	0900	20	7.5				
5/14/2006	0930			1.5	1.5		1m, 2f

			Trial No. 11				
M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH liquid		
Start Date	5/12/2006	1145					
End Date	5/14/2006	1230					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/12/2006	1600	21.2	6.0				
5/13/2006	1035	20.8	6.0				
5/14/2006	0900	20	7				
5/14/2006	1000			4.0	4.0		1f

			Trial No. 12				
M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/15/2006	1030					
End Date	5/17/2006	0930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/15/2006	1710	21.2	5.4				
5/16/2006	0922	20.1	5.6				
5/16/2006	1600			4.7			
5/17/2006	0900	20.2	6.3	5.8	10.5		2f
M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		

Appendix Table A-2.

Continued.

Trial No. 12 Continued

Start Date	5/15/2006	0940					
End Date	5/17/2006	0930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/15/2006	1711	21.2	5.7				
5/16/2006	0920	20	5.8				
5/16/2006	1600			4.2			
5/17/2006	0830	20.2	6.5	4.7	8.9		

Trial No. 13

M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/17/2006	1200					
End Date	5/19/2006	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/17/2006	1550	20.1	5.6				
5/18/2006	0915	20	5.1				
5/18/2006	1645	19.8	5.4				
5/19/2006	1000	19.8	6	10.25	10.25		1m, 3f

M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/17/2006	1300					
End Date	5/19/2006	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/17/2006	1550	20.1	5.7				
5/18/2006	0915	20	5.5				
5/18/2006	1645	19.8	5.4				
5/19/2006	1030	19.8	5.9	4.5	4.5		1m, 2f

Trial No. 14

M/F	45/30	12 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/19/2006	1230					
End Date	5/21/2006	1130					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/19/2006	1430	19.8	5.9				
5/20/2006	1254	19.4	6.5				
5/21/2006	0912	19.1	7.3				
5/21/2006	1030			12.9	12.9		2f

Trial No. 15

M/F	30/20	10 ft tank			Dose/fish 150 ug LHRH pellet		
Start Date	5/19/2006	1300					
End Date	5/21/2006	1200					

Appendix Table A-2.

Continued.

Trial No. 15 Continued

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/19/2006	1430	19.8	5.8				
5/20/2006	1255	19.4	7.1				
5/21/2006	0912	19.1	7.3				
5/21/2006	1100			4	4		1f

Trial No. 16

M/F	30/20	10 ft tank	Dose/fish 150 ug LHRH pellet
Start Date	5/22/2006	12:30	
End Date	5/24/2006	1000	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/22/2006	1652	19.2	7.1				
5/23/2006	1540	19.3	5.8				
5/24/2006	0842	18.4	7.5	6.3	6.3		1f

Trial No. 17

M/F	47/30	12 ft tank	Dose/fish 150 ug LHRH liquid
Start Date	5/23/2006	1145	
End Date	5/25/2006	0900	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/23/2006	1540	19.2	7.2				
5/24/2006	0842	18.5	7.3				
5/25/2006	0900	18.3	7.9	10.7	10.7		1f

Trial No. 18

M/F	30/20	10 ft tank	Dose/fish 150 ug LHRH liquid
Start Date	5/25/2006	1200	
End Date	5/27/2006	700	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/25/2006	1618	19	6.9				
5/26/2006	0850	18.5	7.2				
5/27/2006	0700	18.4	7.5	7.2	7.2		

M/F	45/32	12 ft tank	Dose/fish 150 ug LHRH liquid
Start Date	5/25/2006	1240	
End Date	5/27/2006		

Appendix Table A-2.

Continued.

			Trial No. 18 Continued				
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/25/2006	1618	19	7				
5/26/2006	0850	18.5	6.8				
5/27/2006	0620	18.4	7.4	10.6	10.6		
			Trial No. 19				
M/F	45/32	12 ft tank			Dose/fish 150 ug LHRH liquid		
Start Date	5/29/2006	1200					
End Date	5/31/2006	0730					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/29/2006	1550	20.2	6.6				
5/30/2006	1610	22.4	5.9				
5/31/2006	0730	20.3	6	5.9	5.9		2F
M/F	28/23	10 ft tank			Dose/fish 150 ug LHRH liquid		
Start Date	5/29/2006	1550					
End Date	5/31/2006	745					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/59/2006	1550	20.2	7				
5/30/2006	1610	22.4	5.4				
5/31/2006	0745	20.2	6	4.2	4.2		6F
			Trial No. 20				
M/F	45/30	12 ft tank aerated with oxygen			Dose/fish 150 ug LHRH liquid		
Start Date	6/1/2006	1445					
End Date	6/3/2006	0730					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/1/2006	1610	22.8	6.6				
6/2/2006	0800	22.2	5.8				
6/2/2006	1600	23.5	6.9				
6/3/2006	0730	23.7	6.6	2.6	2.6		7f
M/F	31/21	10 ft tank aerated with oxygen			Dose/fish 150 ug LHRH liquid		
Start Date	6/1/2006	1510					
End Date	6/3/2006	0745					

Appendix Table A-2.

Continued.

			Trial No. 20 Continued				
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/1/2006	1610	22.8	9.8				
6/2/2006	0800	22.2	9.2				
6/2/2006	1600	23.5	8.8				
6/3/2006	0745	23.7	10.5	3	3		4m, 1f

Job III

AMERICAN SHAD HATCHERY OPERATIONS, 2006

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INTRODUCTION

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

In 2003, a new effort in migratory fish restoration was undertaken. Adult hickory shad (*Alosa mediocris*) were collected and tank-spawned as part of the initial efforts to culture, release and restore runs of hickory shad to the Susquehanna and Delaware River basins.

As in previous years, production goals for American shad for 2006 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.

Job III

EGG SHIPMENTS

Hickory shad

A total of 15.1 million hickory shad eggs (26.8 L) were received in five shipments from tank-spawning operations at Conowingo Dam (Table 1). Some 9.2 million (60.6%) of the hickory shad eggs were viable.

American shad

A total of 19.0 million American shad eggs (394 L) were received in 46 shipments in 2006 (Table 1). This was the fourth lowest quantity of eggs received since 1982 (Tables 2 and 3, Figure 1). Egg collections were reduced, in part, due to cold, wet weather on the Hudson River. Overall American shad egg viability (which we define as the percentage which ultimately hatches) was 35.2%.

Eleven Potomac River egg shipments (4.5 million eggs) were received from April 13 to May 5, 2006. Overall viability was 44.4%. These collections marked the first use of Potomac River eggs for the Susquehanna River restoration since 1974.

Six Hudson River egg shipments (1.9 million eggs) were received from May 9 to May 30, 2006. Overall viability was 68.6%. By comparison, in 2005, 13 shipments were received from the Hudson River for a total of 2.9 million eggs. Hudson River egg shipments have varied without trend from 3 million to over 17 million during 1989 to 2006 (Table 3, Figure 1).

Delaware River egg shipments were received from May 8 to June 1. A total of 12 shipments were received (2.3 million eggs) with a viability of 50.0%. By comparison, in 2005, the Delaware River produced 6.2 million eggs. Delaware River egg shipments have declined from approximately 10 million annually, during 1990 to 1998, to 5 million or less during 1999 to 2006 (Table 3, Figure 6).

Job III

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 10.3 million eggs, in 17 shipments, were delivered to the Van Dyke Hatchery, with a viability of 21.7%. By comparison, 8.0 million eggs, in 11 shipments, were received from this source in 2005. This has become a consistent source of eggs for the restoration program, but viability has been low, ranging from 10% to 33%.

SURVIVAL

Overall survival of American shad larvae was 74% compared to a range of 19% to 94% for the period 1984 through 2005. The 13% decrease in survival from 2005 (87%) was due, in part, to mortality in 12 tanks from various egg sources (Figure 2).

Survival of individual tanks followed patterns similar to those observed in the past. Eighteen tanks, reared from 16 to 27 days of age, exhibited 26-d survival of 87% (Figure 2). High mortality episodes occurred in 12 tanks after nine days of age. One tank, Potomac River egg source, exhibited 23-d survival of 67%. Two tanks, Susquehanna River source, exhibited 18-d survival of 60%. Five tanks, Delaware River source, exhibited 22-d survival of 58%. Four tanks, Hudson River source, exhibited 20-d survival of 44%. These mortality episodes occurred across egg sources and egg jar types. Higher mortality tanks were reared later in the rearing season: all tanks exhibiting less than 60% survival were hatched on or after May 17. The cause of these mortalities is unknown, although pH or physical damage may have played a role. Van Dyke influent pH ranged from 5.7 to 6.2 with a mean of 6.0 and no trend over time. By comparison, in 2005, pH ranged from 5.7 to 6.5 with a mean of 6.2 and a clearly increasing trend over time from 5.7 early in the season to 6.2 in mid-season and 6.4 by the end of the season. 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.

Job III

Sometime prior to 1985, a load of crushed limestone was deposited in the influent end of the warming pond. We will add additional limestone in 2007 to attempt to further buffer the influent water.

Specimens from a high mortality tank were supplied to the PFBC pathologist who filed the following report: "Other than the abnormal eye condition that I showed you (apparent physical damage to the eye), I did not observe any other abnormalities in the shad fry from tank H4 that you delivered on 6/19/06. The portions of the gills that I could see were normal in structure. One fish had several protozoans, presumptively identified as *Costia*, on and around the skin surface; however, I did not observe the organism on any of the other specimens that I examined. All digestive tracts were empty. The pathologist speculated that the observed eye damage on several specimens may have been due to strike trauma from over-aggressive tank spinning during tank cleaning. We will take care to be gentler in working with the fish during 2007.

LARVAL PRODUCTION

Hickory shad larvae (2.6 million) were stocked in the lower Susquehanna River at Muddy Creek Access in the Conowingo Reservoir. Some 6.5 million hickory shad were also stocked in the Delaware River (750 thousand) and its tributaries Pennypack Creek (5.4 million) and Ridley Creek (350 thousand).

Production and stocking of American shad larvae, summarized in Tables 2, 4 and 5, totaled 4.9 million. A total of 2.7 million was released in the Juniata River, 28 thousand in the Susquehanna River near Montgomery Ferry, 315 thousand in the West Branch Susquehanna River, 274 thousand in the North Branch Susquehanna River in Pennsylvania, 164 thousand in Conodoguinet Creek, 160 thousand in the Conestoga River, 135 thousand in Swatara Creek, and 135 thousand in West Conewago Creek. Some 230 thousand and 172 thousand were provided to New York for stocking in the North Branch Susquehanna River and the Chemung River, respectively. Due to the poor egg production, no larvae were provided to New Jersey for stocking in the Raritan River. Delaware River egg collections were not sufficient to meet the goals for the Delaware River Basin. Larvae were stocked in the Lehigh River (293 thousand), the Schuylkill River (254 thousand), and the Delaware River (53 thousand). Larvae stocked in the Delaware River were allocated to replenish the Delaware for the brood stock taken there.

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. American shad larvae from the Susquehanna River egg source, and stocked in the Juniata River or Susquehanna River near Montgomery Ferry were given a triple mark at 3, 6, and 9 days of age. Larvae from the Hudson River egg source and stocked in the Juniata River or Susquehanna River near Montgomery Ferry were marked at 18 days of age. Larvae stocked in the West Branch Susquehanna River were given a quintuple mark at 3, 6, 9, 12, and 15 days of age. Larvae stocked in the North Branch Susquehanna River in Pennsylvania were given a quadruple mark at 3, 6, 9 and 15 days of age. Larvae stocked in Conodoguinet Creek were given a quadruple mark on 3, 6, 12 and 15 days of age. Larvae stocked in the Conestoga River were given a quadruple mark on 3, 9, 12 and 15 days of age. Larvae stocked in Swatara Creek were given a quintuple mark on 3, 6, 9, 15 and 18 days of age. Larvae stocked in West Conewago Creek were given a quintuple mark on 3, 6, 12, 15 and 18 days of age. Larvae stocked in the North Branch Susquehanna River in New York were given a quintuple mark on 3, 6, 9, 12 and 18 days of age. Larvae stocked in the Chemung River in New York were given a triple mark on 3, 15 and 18 days of age. Larvae stocked in the Lehigh River were given a triple mark at 9, 12, and 15 days of age. Larvae stocked in the Schuylkill River were given a quadruple mark at 3, 6, 9, and 12 days of age.   Larvae stocked in the Delaware River were given a quintuple mark at 3, 6, 12, 15, and 18 days of age.

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.

Retention of tetracycline marks for American shad was 100% for most groups analyzed (Table 6). In order to provide enough raceways, raceway sections were divided and screened to segregate groups. Several of the raceway samples contained fish which had escaped through the screens from an adjacent raceway section and exhibited the mark from the adjacent raceway. These included one fish from the West Branch Susquehanna River raceway, one fish from the Schuylkill River raceway, and five fish from the Swatara Creek raceway. Nineteen of the 20 mark retention fish from the North Branch Susquehanna River in New York exhibited the 3, 6, 9, 12, 18 mark, but one fish exhibited a mark which appeared as a 3, 6, 9, 12, 15 mark. This was most likely due to poor otolith growth between days 12 and 18. Only five of the 20 mark retention fish from the Delaware River exhibited the 3, 6, 12, 15, 18 mark. The remaining fifteen exhibited marks which appeared as a 3, 6, 12, 15 mark (missing the day 18 mark).   On the five specimens which did exhibit a day 18 mark, the mark was faint. The cause of the poor mark retention for this one mark is unknown, but may be related to immersion mark timing. This was the last mark produced in 2006, on the last tank in the hatchery. In order to complete marking and move on to other tasks, marking was begun at 8:30AM, two hours earlier than normal, which may have impacted mark retention and quality. Mark retention for fish stocked in the Lehigh River was assessed on only one fish since it was the only survivor in the raceway. Mark retention could not be evaluated for the day 3, 15, 18 mark (larvae stocked in the Chemung River) because none were stocked in a raceway. Mark retention was 95% for hickory shad (19 of 20 marked).

Job III

Marking protocols for 2006 to 2010 are given in Table 7. The primary production mark for Hudson and 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.

SUMMARY

Five shipments of hickory shad eggs (15 million eggs) were received at Van Dyke in 2006. Egg viability was 61% and 9.2 million hickory shad larvae were stocked in Conowingo Reservoir and in the Delaware River and its tributaries, Pennypack Creek and Ridley Creek.

A total of 46 shipments of American shad eggs (19 million eggs) was received at Van Dyke in 2006. Total egg viability was 35% and survival of viable eggs to stocking was 74%, resulting in production of 4.9 million larvae. Larvae were stocked in the Juniata River, the Susquehanna River near Montgomery Ferry, the West Branch Susquehanna River, the North Branch Susquehanna River in Pennsylvania, Conodoguinet Creek, the Conestoga River, Swatara Creek, West Conewago Creek, the North Branch Susquehanna River in New York and the Chemung River in New York. Delaware River source larvae were stocked in the Lehigh River, the Schuylkill River and the Delaware River.

Overall survival of larvae was 74%. No episodes of major mortality occurred as a result of larvae lying on the bottom of the tank but unexplained mortalities occurred in 12 tanks late in the season. Van Dyke jars with foam bottom screens were used seven times with no mortality problems.

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. Mark retention for American shad was 100% for most groups analyzed, however two groups exhibited less than 100% retention. Hickory shad were marked at 512 ppm on day three. Mark retention for hickory shad was 95%.

Job III

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 larvae from the Hudson and Potomac River egg sources, stocked in the Juniata or Susquehanna Rivers, and uniquely marked on a three year rotating schedule.

12. Mark hickory shad at 512ppm OTC.

13. Continue using Pfizer Terramycin 343 (now FDA approved) for marking alosines.

14. Attempt to buffer Van Dyke influent water by adding crushed limestone to the influent end of the warming pond.

15. Be gentler when spinning the tank for cleaning.

16. Mark all tanks of larvae beginning at 11:00AM, regardless of other considerations.

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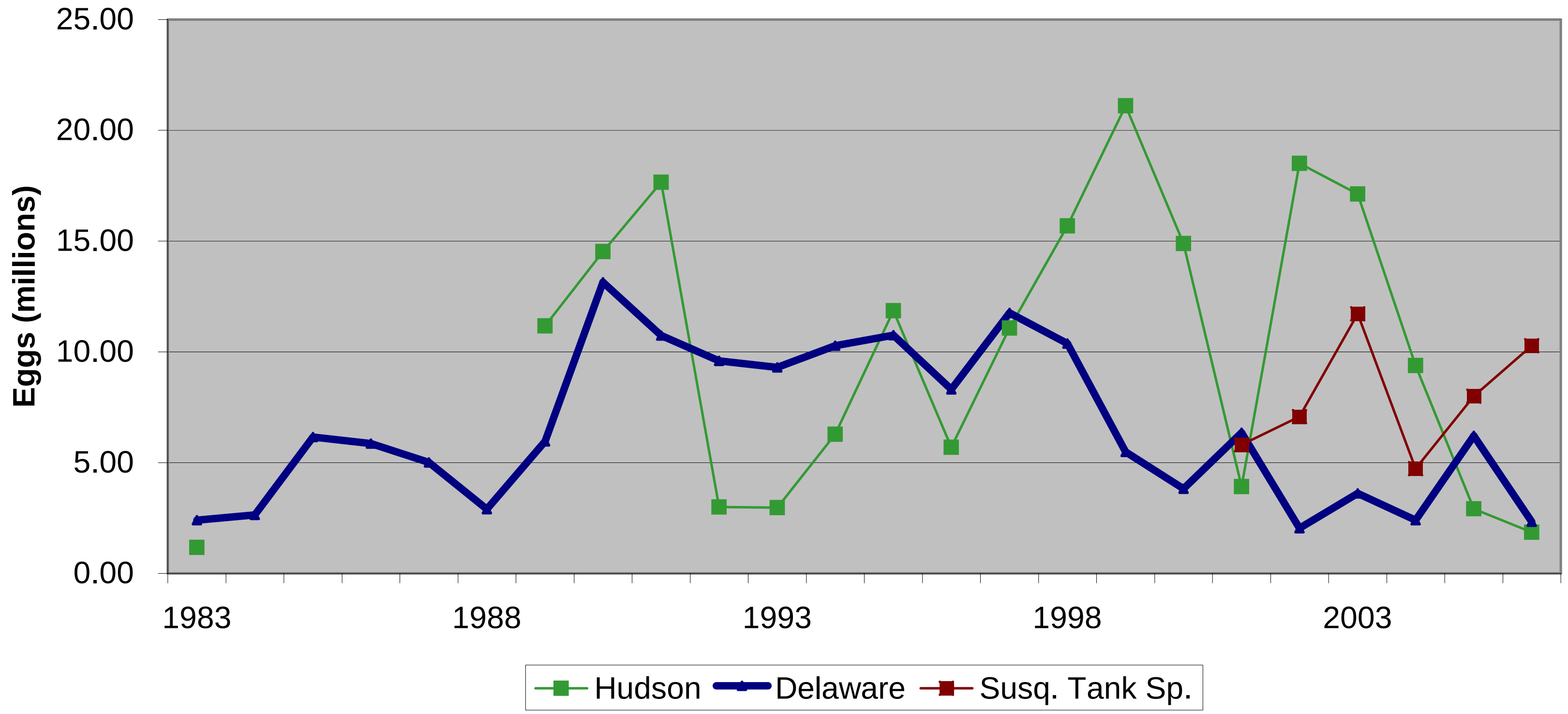
Figure 1: American shad eggs collected by source for the Susquehanna River restoration.



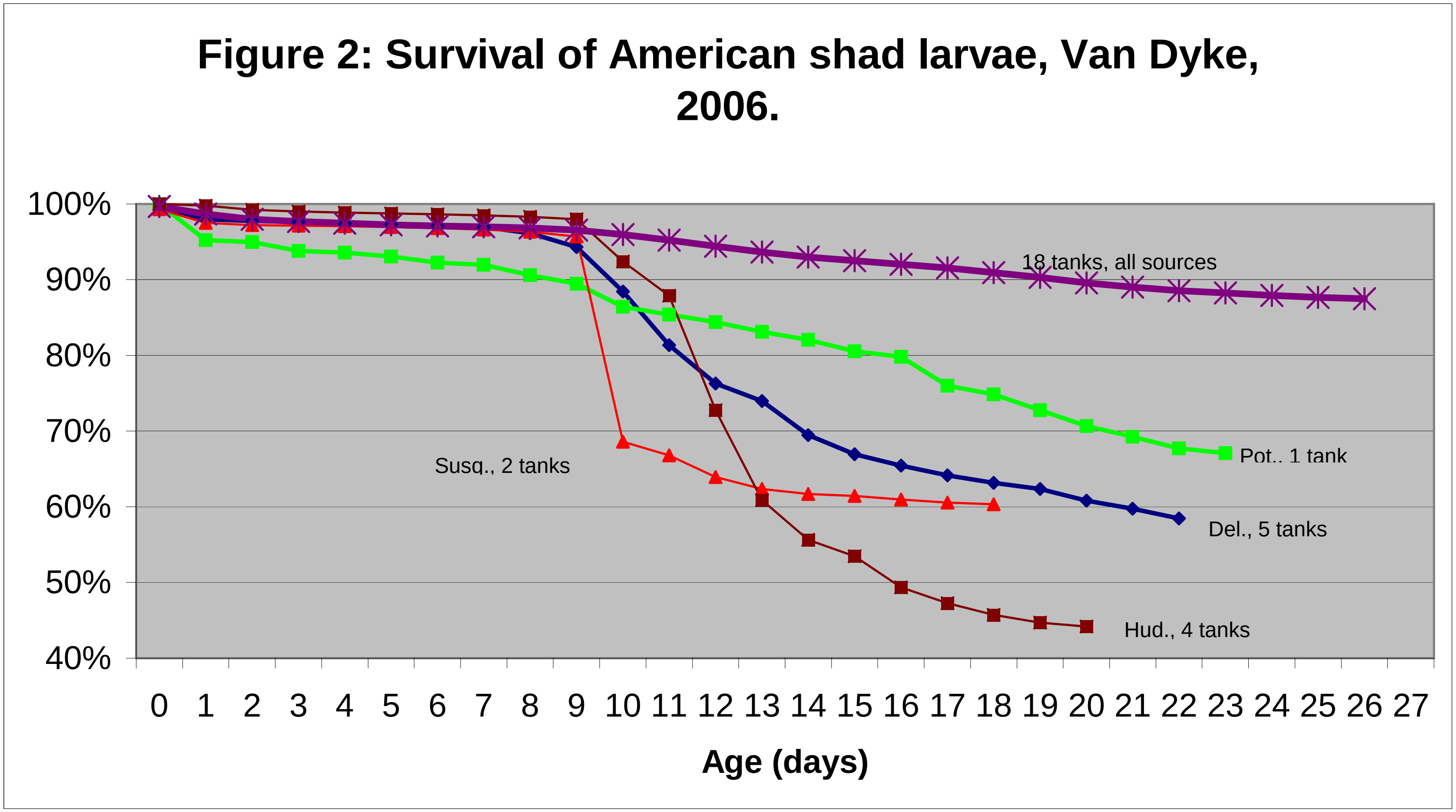


Figure 2: Survival of American shad larvae, Van Dyke, 2006.
100%
90%
80%
70%
60%
50%
40%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Age (days)
18 tanks, all sources
Pot., 1 tank
Susq., 2 tanks
Del., 5 tanks
Hud., 4 tanks

Job III

Table 1. Egg shipments received at Van Dyke, 2006.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	American shad	Potomac	4/12/06	4/13/06	5.8	328,396	176,391	53.7%
2	Hickory shad	Susq.- Conowingo	4/13/06	4/13/06	3.2	1,609,888	1,335,075	82.9%
3	Hickory shad	Susq.- Conowingo	4/14/06	4/14/06	1.3	654,017	198,187	30.3%
4	Hickory shad	Susq.- Conowingo	4/14/06	4/14/06	9.2	4,414,294	3,313,627	75.1%
5	Hickory shad	Susq.- Conowingo	4/15/06	4/15/06	2.6	1,308,034	920,983	70.4%
6	American shad	Potomac	4/16/06	4/17/06	3.9	211,020	39,695	18.8%
7	American shad	Potomac	4/17/06	4/18/06	4.7	173,951	73,896	42.5%
8	Hickory shad	Susq.- Conowingo	4/18/06	4/18/06	10.5	7,179,694	3,426,711	47.7%
9	American shad	Potomac	4/18/06	4/19/06	11.1	468,792	273,683	58.4%
10	American shad	Potomac	4/19/06	4/20/06	15.3	639,775	329,135	51.4%
11	American shad	Potomac	4/20/06	4/21/06	12.5	599,071	343,680	57.4%
12	American shad	Susq.- Conowingo	4/22/06	4/22/06	6.7	432,961	118,593	27.4%
13	American shad	Susq.- Conowingo	4/23/06	4/23/06	5.4	289,517	45,324	15.7%
14	American shad	Potomac	4/24/06	4/25/06	6.4	375,583	61,819	16.5%
15	American shad	Potomac	4/27/06	4/28/06	7.1	285,210	178,974	62.8%
16	American Shad	Potomac	5/1/06	5/2/06	13.8	680,451	152,059	22.3%
17	American Shad	Delaware	5/3/06	5/4/06	2.4	68,483	58,186	85.0%
18	American shad	Potomac	5/3/06	5/4/06	10.3	350,423	188,892	53.9%
19	American shad	Potomac	5/4/06	5/5/06	8.4	398,754	184,997	46.4%
20	American shad	Susq.- Conowingo	5/5/06	5/5/06	8.0	390,755	70,947	18.2%
21	American shad	Susq.- Conowingo	5/6/06	5/6/06	11.7	692,744	159,096	23.0%
22	American shad	Susq.- Conowingo	5/7/06	5/7/06	8.3	413,130	132,180	32.0%
23	American shad	Delaware	5/7/06	5/8/06	7.5	249,753	173,848	69.6%
24	American shad	Delaware	5/8/06	5/9/06	6.6	208,177	140,111	67.3%
25	American shad	Hudson	5/8/06	5/9/06	13.3	366,769	258,655	70.5%
26	American shad	Delaware	5/9/06	5/10/06	9.5	299,648	144,288	48.2%
27	American shad	Hudson	5/9/06	5/10/06	6.7	211,331	102,512	48.5%
28	American shad	Susq.-Conowingo	5/10/06	5/10/06	13.6	729,153	194,012	26.6%
29	American shad	Delaware	5/10/06	5/11/06	7.7	242,873	160,107	65.9%
30	American shad	Delaware	5/11/06	5/12/06	3.2	118,435	0	0.0%
31	American shad	Susq.- Conowingo	5/12/06	5/12/06	8.8	521,038	79,991	15.4%
32	American shad	Susq.-Conowingo	5/14/06	5/14/06	5.5	396,754	69,221	17.4%
33	American shad	Delaware	5/14/06	5/14/06	1.4	43,199	32,060	74.2%
34	American shad	Susq.- Conowingo	5/17/06	5/17/06	10.5	627,227	161,874	25.8%
35	American shad	Susq.- Conowingo	5/16/06	5/17/06	8.9	536,369	2,972	0.6%
36	American shad	Susq.- Conowingo	5/19/06	5/19/06	14.8	944,968	212,355	22.5%
37	American shad	Susq.- Conowingo	5/21/06	5/21/06	16.9	1,027,511	225,627	22.0%
38	American shad	Susq.-Conowingo	5/24/06	5/24/06	6.3	428,536	187,995	43.9%
39	American shad	Delaware	5/24/06	5/25/06	3.2	95,509	67,978	71.2%
40	American shad	Hudson	5/24/06	5/25/06	12.2	340,301	282,542	83.0%
41	American shad	Susq.-Conowingo	5/25/06	5/25/06	10.7	568,425	178,597	31.4%
42	American shad	Delaware	5/25/06	5/26/06	8.2	332,736	254,282	76.4%
43	American shad	Hudson	5/25/06	5/26/06	10.8	318,761	297,189	93.2%
44	American shad	Susq.-Conowingo	5/27/06	5/27/06	17.8	1,016,942	175,562	17.3%
45	American shad	Hudson	5/28/06	5/29/06	5.1	153,921	102,534	66.6%
46	American shad	Delaware	5/29/06	5/30/06	8.0	361,911	57,006	15.8%
47	American shad	Hudson	5/29/06	5/30/06	11.9	468,435	233,070	49.8%
48	American shad	Delaware	5/30/06	5/31/06	4.6	179,241	76,739	42.8%
49	American shad	Susq.-Conowingo	5/31/06	5/31/06	10.1	753,072	184,860	24.5%
50	American shad	Delaware	5/31/06	6/1/06	2.6	128,201	264	0
51	American shad	Susq-Conowingo	6/3/06	6/3/06	5.3	512,344	33,251	6.5%

Totals			No. of shipments	Volume (L)	Eggs	Viable Eggs	Percent Viable
	American shad	Potomac	11	99.3	4,511,426	2,003,222	44.4%
		Hudson	6	60.0	1,859,518	1,276,500	68.6%
		Delaware	12	64.9	2,328,165	1,164,868	50.0%
		Susq.- Conowingo	17	169.3	10,281,444	2,232,459	21.7%
		Grand total	46	393.5	18,980,553	6,677,049	35.2%
	Hickory shad	Susq.- Conowingo	5	26.8	15,165,928	9,194,583	60.6%

Table 2. Annual summary of American shad production, 1976-2006.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of Fry stocked (exp.3)	No. of Finglerling stocked (exp.3)	Total stocked (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969	35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629	34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526	5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048	98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996	30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876	61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274	81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267	60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034	253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963	233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870	79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720 *	140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930 *	-	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466 *	-	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757	2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412	-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535	-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524	7	6,531	0.31	0.88
2002	943	35.6	38.8	13.8	2,589	-	2,589	0.07	0.19
2003	1005	33.0	49.4	16.3	12,742	-	12,742	0.39	0.78
2004	462	17.3	54.0	9.3	5,637	-	5,637	0.33	0.60
2005	372	17.1	36.6	6.0	5,208	1	5,209	0.30	0.87
2006	394	19.0	35.2	6.7	4,945	-	4,945	0.26	0.74
						Total	245,366		
						Total since 1985 (OTC marked)	213,969		

*Includes fry reared at Manning Hatchery.

Job III

Table 3. American shad eggs (millions) used in the Susquehanna River shad restoration program, by egg source.

Year	Hudson Gill Net	Delaware Gill Net	Susq. Conowingo Tank Spawn	Susq. Lapidum Gill Net	Susq. Muddy Run Gill Net	Susq. Lamar Tank Spawn	Connecticut Gill Net	Pamunkey Gill Net	Mattaponi Gill Net	James Gill Net	Savannah Gill Net	Columbia Gill Net	Potomac Gill Net	Total
1971				8.42										8.42
1972				7.10										7.10
1973				4.74			4.30	8.45	6.48				34.64	58.61
1974							0.53	9.75	6.80	19.20		8.18	5.56	50.02
1975								1.88		7.15		18.42	5.70	33.15
1976		4.10										54.80		58.90
1977							0.35	4.40	0.57	3.42		8.90		17.64
1978								6.90		10.11		0.00		17.01
1979								3.17		4.99		0.00		8.16
1980								6.73		6.83		0.00		13.56
1981								4.58		1.26		5.78		11.62
1982								2.03		1.25		22.57		25.85
1983	1.17	2.40						5.49		5.91		19.51		34.48
1984		2.64						9.83		0.74		27.88		41.09
1985		6.16						5.28		2.05		12.06		25.55
1986		5.86						5.62		1.07		39.97		52.52
1987		5.01						4.35		0.11		23.53		33.00
1988		2.91						1.92		0.05		26.92		31.79
1989	11.18	5.96						1.91		0.53		23.10		42.68
1990	14.53	13.15				0.33		0.48			0.12			28.61
1991	17.66	10.75				0.30	1.10							29.80
1992	3.00	9.60					5.71			0.17				18.49
1993	2.97	9.30					7.45	1.78						21.50
1994	6.29	10.27					4.09	0.53	0.03					21.22
1995	11.85	10.75												22.61
1996	5.69	8.31				0.41								14.41
1997	11.08	11.76												22.84
1998	15.68	10.38				1.66								27.72
1999	21.10	5.49												26.59
2000	14.88	3.83												18.71
2001	3.92	6.35	5.81			5.05								21.13
2002	18.51	2.04	7.08			7.99								35.62
2003	17.12	3.61	11.72	0.56	0.02									33.04
2004	9.39	2.41	4.74	0.75										17.29
2005	2.92	6.21	8.00											17.14
2006	1.86	2.33	10.28										4.51	18.98
Total	190.81	161.59	47.63	21.57	0.02	15.74	23.53	85.08	13.88	64.84	0.12	291.62	50.41	966.84

Job III

Table 4. American shad stocking and fish transfer activities, 2006.

Date	Tank		Species	Number	Location	OTC mark (days)	Origin	Age	Size
5/8/06	A1	1	American shad	164,235	Conodoguinet Creek	3,6,12,15	Potomac	16	Fry
4/24/06	A2	1	Hickory shad	1,318,578	Pennypack Cr.	3	Susq.- Conowingo	4	Fry
4/27/06	A3	1	Hickory shad	1,690,821	Muddy Creek	3	Susq.- Conowingo	6	Fry
4/26/06	A4	1	Hickory shad	1,759,370	Pennypack Cr., Del. R. (Yardley), Ridley Cr.	3	Susq.- Conowingo	5	Fry
4/27/06	B1	1	Hickory shad	902,343	Muddy Creek	3	Susq.- Conowingo	5	Fry
5/25/06	B2	1	American shad	329,842	Millerstown (Rt. 17 Bridge)	18	Potomac	27	Fry
4/30/06	B3	1	Hickory shad	3,381,020	Pennypack Cr., Del. R. (Yardley), Ridley Cr.	3	Susq.- Conowingo	4	Fry
5/23/06	B4	1	American shad	392,247	Millerstown (Rt. 17 Bridge)	18	Potomac	24	Fry
5/26/06	C1	1	American shad	279,478	Millerstown (Rt. 17 Bridge)	18	Potomac	27	Fry
5/22/06	C2	1	American shad	135,166	Swatara Creek	3,6,9,15,18	Susq.- Conowingo	22	Fry
5/27/06	C3	1	American shad	41,477	Millerstown (Rt. 17 Bridge)	18	Potomac	23	Fry
5/22/06	C4	1	American shad	159,920	Conestoga River	3,9,12,15	Potomac	16	Fry
5/30/06	D1	1	American shad	135,258	W. Conewago Cr.	3,9,12,15,18	Potomac	20	Fry
6/8/06	D2	1	American shad	36,484	Lehigh River	9,12,15	Delaware	27	Fry
6/8/06	D3	1	American shad	145,370	Huntingdon	18	Potomac	27	Fry
6/9/06	D4	1	American shad	148,105	Huntingdon	18	Potomac	27	Fry
5/28/06	E1	1	American shad	319,104	Millerstown (Rt. 17 Bridge)	3,6,9	Susq.- Conowingo	14	Fry
6/8/06	E2	1	American shad	234,540	Lehigh River	9,12,15	Delaware	22	Fry
6/4/06	E3	1	American shad	175,000	West Branch Susquehanna River	3,6,9,12,15	Hudson	18	Fry
6/13/06	E3	1	American shad	140,388	West Branch Susquehanna River	3,6,9,12,15	Hudson	27	Fry
5/29/06	E4	1	American shad	187,286	Millerstown (Rt. 17 Bridge)	3,6,9	Susq.- Conowingo	12	Fry
6/8/06	F1	1	American shad	22,058	Lehigh River	9,12,15	Delaware	16	Fry
6/12/06	F2	1	American shad	126,506	Huntingdon	3,6,9	Susq.- Conowingo	23	Fry
6/10/06	F3	1	American shad	158,681	Huntingdon	3,6,9	Susq.- Conowingo	17	Fry
6/7/06	F4	1	American shad	250,000	Huntingdon	3,6,9	Susq.- Conowingo	10	Fry
6/9/06	G1	1	American shad	353,109	Huntingdon	3,6,9	Susq.- Conowingo	10	Fry
6/23/06	G2	1	American shad	206,557	Schuylkill River	3,6,9,12	Delaware	22	Fry
6/20/06	G3	1	American shad	136,614	North Branch Susq. (NY)	3,6,9,12,18	Hudson	19	Fry
6/20/06	G4	1	American shad	93,748	North Branch Susq. (NY)	3,6,9,12,18	Hudson	19	Fry
6/21/06	H1	1	American shad	117,501	North Branch Susq. (PA)	3,6,9,15	Susq.- Conowingo	19	Fry
6/26/06	H2	1	American shad	55,408	Chemung River	3,15,18	Hudson	22	Fry
6/23/06	H3	1	American shad	47,171	Schuylkill River	3,6,9,12	Delaware	16	Fry
6/26/06	H4	1	American shad	116,418	Chemung River	3,15,18	Hudson	20	Fry
6/21/06	I1	1	American shad	156,093	North Branch Susq. (PA)	3,6,9,15	Susq.- Conowingo	16	Fry
6/26/06	I2	1	American shad	52,782	Delaware River (Smithfield Beach)	3,6,12,15,18	Delaware	19	Fry
6/22/06	I3	1	American shad	28,607	Clemson Island	3,6,9	Susq.- Conowingo	12	Fry

Job III

Table 5. Production and utilization of juvenile Alosines, Van Dyke, 2006.

	Site		Fry
American shad Releases	Millerstown (Greenwood)		
	Millerstown (Rt. 17 Bridge)		1,549,434
	Thompsontown		
	Muskrat Springs		
	Mexico		
	Mifflin		
	Treaster's Exxon		
	Huntingdon		1,181,771
	Warrior Ridge Dam		
	Tuscarora Creek		
		Juniata River Subtotal	2,731,205
	Clemson Island		28,607
	Montgomery Ferry		
	Millersburg Ferry		
	Liverpool		
	Mahantango		
	Conodoguinet Creek		164,235
	Conestoga River		159,920
	Swatara Creek		135,166
	West Conewago Creek		135,258
	North Branch Susquehanna River (PA)		273,594
	West Banch Susquehanna River		315,388
	Chemung River		171,826
	North Branch Susquehanna River (NY)		230,362
		Susquehanna River Basin Subtotal	4,345,561
	Delaware River		52,782
	Schuylkill River		253,729
	Lehigh River		293,083
	Raritan River		
		Total American shad	4,945,154
Hickory shad releases	Muddy Creek Access Area		2,593,163
		Susquehanna River Basin Subtotal	2,593,163
	Delaware River		750,000
	Pennypack Creek		5,358,968
	Ridley Creek		350,000
		Delaware River Basin Subtotal	6,458,968
		Total Hickory shad	9,052,132

Job III

Table 6. Summary of marked Alosines stocked in Pennsylvania, 2006.

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										
1,336,518	Fry	18	Juniata/Susq. R.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
1,423,294	Fry	3,6,9	Juniata/Susq. R.	Susquehanna	256ppm OTC	100%	-	-	Van Dyke	-
315,388	Fry	3,6,9,12,15	W. Br. Susq. R.	Hudson	256ppm OTC	100%*	-	-	Van Dyke	-
164,235	Fry	3,6,12,15	Conodoguinet Cr.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
159,920	Fry	3,9,12,15	Conestoga R.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
135,258	Fry	3,9,12,15,18	W. Conewago Cr.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
135,166	Fry	3,6,9,15,18	Swatara Cr.	Hudson	256ppm OTC	100%*	-	-	Van Dyke	-
273,594	Fry	3,6,9,15	N. Br. Susq. R.(PA)	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
230,362	Fry	3,6,9,12,18	N. Br. Susq. R.(NY)	Hudson	256ppm OTC	95%**	-	-	Van Dyke	-
171,826	Fry	3,15,18	Chemung R. (NY)	Hudson	256ppm OTC	N/A	-	-	Van Dyke	-
52,782	Fry	3,6,12,15,18	Delaware R.	Delaware	256ppm OTC	25%***	-	-	Van Dyke	-
293,083	Fry	9,12,15	Lehigh R.	Delaware	256ppm OTC	100%****	-	-	Van Dyke	-
253,729	Fry	3,6,9,12	Schuylkill R.	Delaware	256ppm OTC	100%*	-	-	Van Dyke	-
Hickory shad										
2,593,163	Fry	3	Conowingo Res.	Susquehanna	512ppm OTC	95%	-	-	Van Dyke	-
750,000	Fry	3	Delaware River	Susquehanna	512ppm OTC	95%	-	-	Van Dyke	-
5,358,968	Fry	3	Pennypack Cr.	Susquehanna	512ppm OTC	95%	-	-	Van Dyke	-
350,000	Fry	3	Ridley Cr.	Susquehanna	512ppm OTC	95%	-	-	Van Dyke	-

* Of 20 fish analyzed, one to five fish with different tags escaped into these raceways from an adjacent raceway.
** One fish exhibited marks which appeared as a 3,6,9,12,15 day mark.
*** 75% of the fish exhibited marks on days 3,6,12,15 but not the day 18 mark.
**** Only one fish survived in the raceway. It exhibited the proper mark.

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.	Hudson/Potomac	2006
Fry	15,18	256ppm OTC	Juniata/Susq. R.	Hudson/Potomac	2007
Fry	15,18,21	256ppm OTC	Juniata/Susq. R.	Hudson/Potomac	2008
Fry	3,9,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Hudson/Potomac	2009
Fry	3,6,12,15,18,21	256ppm OTC	Juniata/Susq. R.	Hudson/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.	Hudson/Potomac	2006-2010
Fry	3,6,12,15	256ppm OTC	Conodoguinet Cr.	Hudson/Potomac	2006-2010
Fry	3,9,12,15	256ppm OTC	Conestoga R.	Hudson/Potomac	2006-2010
Fry	3,9,12,15,18	256ppm OTC	W. Conewago Cr.	Hudson/Potomac	2006-2010
Fry	3,6,9,15,18	256ppm OTC	Swatara Cr.	Hudson/Potomac	2006-2010
Fry	3,6,9,15	256ppm OTC	N. Br. Susq. R.(PA)	Hudson/Potomac	2006-2010
Fry	3,6,9,12,18	256ppm OTC	N. Br. Susq. R.(NY)	Hudson/Potomac	2006-2010
Fry	3,15,18	256ppm OTC	Chemung R. (NY)	Hudson/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
Fry	3	256ppm OTC	Raritan R. (NJ)	Hudson	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

Job III - Appendix 1

SURVIVAL OF AMERICAN SHAD LARVAE RELEASED AT VARIOUS SITES IN THE SUSQUEHANNA RIVER DRAINAGE, 2006.

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INTRODUCTION

Development of tetracycline marking has permitted evaluation of the relative success of the hatchery component of the American shad restoration program (Hendricks et al., 1991). Larvae are marked by 4h immersion in 256 ppm oxytetracycline hydrochloride. Detectable fluorophore from these marks is visible in the one otolith increment produced on the day of marking. Multiple marks, 3 or 4d apart, have been used to evaluate the relative survival of groups uniquely marked according to release site, egg source river, release time of day, or release habitat (Hendricks et al., 1992, Hendricks et al., 1993).

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

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

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

As a result, production larvae stocked in 1995 and 1996 were released at 7 days of age. In order to imprint larvae to other areas in the drainage, smaller numbers of larvae were released in tributary streams or other main-stem areas (North Branch and West Branch Susquehanna River) within the Susquehanna River Basin. In order to mark these larvae with unique tetracycline marks, they had to be stocked at an older age. Recovery rates of these uniquely marked larvae stocked in 1995 and 1996 suggested that larvae released at 7 days of age may not survive any better than those released later. One explanation for this is that multiple releases at any one site may be attracting predators to that site, resulting in reduced survival. It was theorized that spreading larvae out by stocking at a number of sites may result in improved survival.

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

Job III - Appendix 1

In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. In 2006, we returned to multiple stockings of larvae at one site, based on cohort analysis (Hendricks 2006) which showed that cohorts produced before 1997 exhibited higher return rates than those produced in 1998 or after. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2006 and summarizes results from 1995 to 2006.

MATERIALS AND METHODS

Production larvae, stocked in 2006, included 1.34 million Potomac River source (strip-spawn) larvae marked at 18 days of age; and 1.42 million Susquehanna River source (tank-spawn) larvae marked at 3,6, and 9 days of age. These groups were stocked at Huntingdon or Millerstown in the Juniata River or in the Susquehanna River at Clemson Island. Uniquely marked larvae were also stocked in the West Branch Susquehanna River (315,388; day 3,6,9,12,15 mark), the North Branch Susquehanna River in PA (273,594; day 3,6,9,15 mark), the North Branch Susquehanna River in NY (230,362; day 3,6,9,12,18 mark), the Chemung River (171,826; day 3,15,18 mark), Swatara Creek (135,166; day 3,6,9,15,18 mark), Conodoguinet Creek (164,235; day 3,6,12,15 mark), West Conewago Creek (135,258; day 3,9,12,15,18 mark) and Conestoga River (159,920; day 3,9,12,15 mark).

Juvenile American shad were sampled during autumn by lift net (Holtwood Dam), in intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam. Other juvenile samples were collected, but were not used in this analysis because of the potential that they were not representative of the out-migrating population as a whole. A sub-sample of 30 fish per site per sampling date was retained for otolith analysis. Shad were frozen whole and delivered to Benner Spring Fish Research Station for otolith analysis. Otoliths were extracted, mounted, ground and analyzed according to standard procedures (Hendricks et al., 1991). The number of fish observed with each unique mark was expanded to the entire sample by multiplying the total number of fish collected in a sample and dividing by the number of fish sub-sampled for otolith analysis. Data for 1995 to 2005 was similarly corrected to account for the total number of shad collected, not just those sampled. Recovery rates were calculated for each group by dividing the expanded number of fish recovered by the number stocked and multiplying by 10,000 to remove the decimal point and convert the rate to a whole number. Relative survival was calculated by dividing the recovery rate for each group by the recovery rate for the group with the highest recovery rate.

RESULTS AND DISCUSSION

In many years, there are times when the Juniata River is high and muddy, but the Susquehanna remains clear. When this occurs (1995, 1996, 2000-2005; Table A1-2), shad larvae marked for stocking in the Juniata River are diverted to the Susquehanna River in the vicinity of Montgomery Ferry. In these cases, shad stocked in the Juniata River cannot be distinguished from those stocked in the Susquehanna River at Montgomery Ferry and the two sites must be combined for analysis. In 1998, 1998 and 2006, river conditions permitted stocking all production marked fish in the Juniata River, thus, there is no entry in Table A1-2 for the combined Juniata/Susq. site. In 1997, a mark was used for stocking in the Juniata/Susq. combined site and a separate, unique mark was used for fish stocked in the Juniata River only. This permitted separating the two sites in the 1997 entry in Table A1-2.

In 2006, Hudson River source larvae stocked in the West Branch Susquehanna River exhibited the best survival (relative survival set to 1.00, Table A1-1). Potomac River source larvae, stocked in Conodoguinet Cr. exhibited relative survival of 0.85. Susquehanna tank-spawn source larvae stocked in Swatara Cr. exhibited relative survival of 0.78. Potomac River source larvae, stocked in the Juniata River at Huntingdon or Millerstown exhibited relative survival of 0.71. Susquehanna tank-spawn source larvae stocked in the Juniata River or the Susquehanna River at Clemson Island exhibited relative survival of 0.42. Potomac River source larvae, stocked in the Conestoga River exhibited relative survival of 0.22. No fish were recovered from larval stockings in West Conewago Cr., or the North Branch Susquehanna River (PA or NY).

A summary of the results of eleven years of uniquely marking larvae according to stocking site is provided in Table A1-2. Recovery rates for 2006 varied from 0.00 to 0.29. The overall recovery rate for 2006 (0.14) was the third lowest for the ten year time period, reflecting the low number of larvae stocked and poor conditions for survival (high river flows). This result is also confirmed by low CPUE for haul seine and lift net collections (see Job IV).

Inter-annual relative survival was highly variable within stocking sites (Table A1-2). For example, relative survival ranged from 0.00 (the lowest possible) to 1 (the highest possible) for the Conestoga River, the North Branch Susquehanna River, and the Chemung River. Inter-annual variation exceeded 0.85 for the Juniata and Susquehanna River at Montgomery Ferry, West Conewago Creek, and Swatara Creek.

Mean relative survival rates for each stocking site, for the eleven-year period, are also presented in Table A1-2. Excluding sites with less than four data points, the highest mean relative survival was recorded for the Juniata River site (0.79). The Juniata R./Susq. R, @ Mont. Ferry site had a mean relative survival of 0.55 (third highest among those with more than three data points). Combining these Juniata River vicinity sites, mean relative survival was 0.63. Mean relative survival rates for other sites, in descending order, excluding sites with fewer than four data points, were: Swatara Creek (0.58), North Branch Susquehanna River (PA- 0.52), Juniata River (Susquehannna source eggs- 0.47), Conodoguinet Creek (0.41), West Branch Susquehanna River (0.39), Conewago Creek (0.37) and the Conestoga River (0.26). These data validate our strategy of stocking moderate numbers of larvae throughout the drainage to facilitate colonizing of the entire basin while concentrating a large portion of production larvae in the Juniata River to maximize survival.

Job III - Appendix 1

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Table A1-1. Relative survival of American shad fry stocked at various sites in the Susquehanna River Basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 2006.

Stocking Site	Egg Source	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Huntingdon or Millerstown	Potomac	23-27	5/25-6/9	1,336,518	31%	27	44	0.202	0.71
Juniata R./ middle Susq. R. at Clemson I.	Susq.-Con	12-23	5/28-6/22	1,423,294	33%	17	27	0.119	0.42
W. Br. Susq. R.	Hudson	18-27	6/4-6/13	315,388	7%	9	15	0.29	1.00
Conodoguinet Cr.	Potomac	16	5/8	164,235	4%	4	6	0.24	0.85
Conestoga R.	Potomac	16	5/22	159,920	4%	1	2	0.06	0.22
Swatara Cr.	Susq.-Con	22	5/22	135,166	3%	3	5	0.22	0.78
W. Conewago Cr.	Potomac	20	5/30	135,258	3%	0	0	0.00	0.00
N. Br. Susq. R.(PA)	Susq.-Con	16-19	6/21	273,594	6%	0	0	0.00	0.00
N. Br. Susq. R.(NY)	Hudson	19	6/20	230,362	5%	0	0	0.00	0.00
Chemung R.	Hudson	20-22	6/26	171,826	4%	1	2	0.06	0.20
			Total	4,345,561		62		0.14	

Job III - Appendix 1

Table A1-2. Annual summary of relative survival of American shad fry stocked at various sites in the Susquehanna River Basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995-2006.

Stocking Site	Recovery Rate 1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006
Juniata R./Susq. R. @ Mont. Ferry	2.12	0.10	1.85	-	-	0.72	2.07	0.15	0.05	0.26	-
Juniata R.(various sites)	-	-	2.09	0.15	0.63	-	-	-	-	-	0.20
Juniata R.(Susq. eggs)	-	-	-	0.10	-	-	1.32	0.37	0.14	0.31	0.12
Huntingdon	-	-	1.52	-	-	-	-	-	-	-	-
Standing Stone Cr.	-	0.00	-	0.00	-	-	-	-	-	-	-
Conodoguinet Cr.	2.52	0.12	0.29	0.05	0.51	0.54	0.07	0.00	0.06	-	0.24
mouth of Conodiguinet C	2.96	-	-	-	-	-	-	-	-	-	-
Conestoga R.	3.28	0.00	0.26	0.00	0.87	0.13	0.22	0.00	0.00	-	0.06
mouth of Conestoga Cr.	1.18	-	-	-	-	-	-	-	-	-	-
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-	-
Conewago Cr.	-	-	-	0.19	0.18	0.61	0.18	0.00	0.10	-	0.00
Swatara Cr.	-	-	-	0.20	0.69	0.00	1.15	0.00	0.19	-	0.22
W. Br. Susq. R.	-	0.09	0.86	0.00	0.00	0.17	0.09	0.54	0.07	1.62	0.29
N. Br. Susq. R.(PA)	-	0.34	2.02	0.21	0.19	0.40	1.06	0.00	0.09	-	0.00
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.64	0.04	-	0.00
Chemung R.	-	-	-	-	-	-	-	1.02	0.00	-	0.06
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.50	-
Overall	2.13	0.12	1.77	0.15	0.54	0.62	1.37	0.27	0.07	0.41	0.14

Stocking Site	Relative Survival 1995	1996	1997	1998	1999	2000	2001	2002	2003	2005	2006	Mean
Juniata R./Susq. R. @ Mont. Ferry	0.65	0.31	0.89	-	-	1.00	1.00	0.15	0.29	0.16	-	0.55
Juniata R.(various sites)	-	-	1.00	0.72	0.73	-	-	-		-	0.71	0.79
Juniata R.(Susq. eggs)	-	-	-	0.49	-	-	0.64	0.37	0.73	0.19	0.42	0.47
Huntingdon	-	-	0.72	-	-	-	-	-	-	-	-	0.72
Standing Stone Cr.	-	0.00	-	0.00	-	-	-	-	-	-	-	0.00
Conodoguinet Cr.	0.77	0.37	0.14	0.25	0.59	0.74	0.03	0.00	0.32	-	0.85	0.41
mouth of Conodiguinet C	0.90	-	-	-	-	-	-	-	-	-	-	0.90
Conestoga R.	1.00	0.00	0.12	0.00	1.00	0.18	0.11	0.00	0.00	-	0.22	0.26
mouth of Conestoga Cr.	0.36	-	-	-	-	-	-	-	-	-	-	0.36
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-	-	0.00
Conewago Cr.	-	-	-	0.89	0.20	0.84	0.09	0.00	0.55	-	0.00	0.37
Swatara Cr.	-	-	-	0.96	0.80	0.00	0.56	0.00	1.00	-	0.78	0.58
W. Br. Susq. R.	-	0.28	0.41	0.00	0.00	0.23	0.05	0.54	0.36	1.00	1.00	0.39
N. Br. Susq. R.(PA)	-	1.00	0.97	1.00	0.21	0.56	0.51	0.00	0.47	-	0.00	0.52
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.62	0.22	-	0.00	0.28
Chemung R.	-	-	-	-	-	-	-	1.00	0.00	-	0.20	0.40
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.31	-	0.31

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

Job IV

ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER, 2006

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INTRODUCTION

This report summarizes the results of bio-monitoring activities for juvenile alosines conducted in the Susquehanna River and its tributaries in 2006.

The Conowingo West Fish Lift continued to be used as a source of adult American shad and river herring to support monitoring activities and tank spawning. A total of 3,970 adult shad were collected at the Conowingo West Lift. The majority were released back into the Conowingo tailrace, with 1,516 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 2006 spring migration, Conowingo East Lift passed 56,899 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 35,968, 24,929 and 1,913 American shad, respectively. No river herring were passed at Conowingo, Holtwood, Safe Harbor or York Haven Dams. Four hickory shad were passed at Conowingo Dam, but none were passed at upstream dams.

Job IV

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 2006 production season, the PFBC Van Dyke Research Station for Anadromous Fish produced 4.3 million shad larvae which were released in the Susquehanna Basin in Pennsylvania. Most larval releases occurred from May 22 to May 29 and June 7 to June 12 to avoid an episode of high flow from May 31 to June 6 (Figure 1). Larvae were released in the following locations and numbers:

Juniata River (various sites)	2,731,205
North Branch Susquehanna River (NY)	230,362
Chemung River (NY)	171,826
North Branch Susquehanna River (PA)	273,594
West Branch Susquehanna River	315,388
Conodoguinet Creek	164,235
Swatara Creek	135,166
West Conewago Creek	135,258
Conestoga River	159,920

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

Job IV

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 (due to be released in 2007) recommends use of area-under-the-curve (AUC) methods in cases where sampling is targeted at migrants moving through an area (Andy Kahnle, NY Dept. of Conservation, personal communication). 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.

Haul Seining - Main Stem

Haul seining in the lower Susquehanna River was scheduled once each week beginning mid-July and continuing through October. High river flows in July postponed initial sampling until the first week of August. Fifteen weekly sampling events were planned for 2006, however, high river flows during September and in late October, coupled with the low number of juvenile shad being collected, resulted in postponement and eventually cancellation of sampling events. A total of 11 sampling events occurred.

Job IV

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.

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

Sampling at the Holtwood Dam inner fore-bay began on September 12 and continued every third day through November 2006. A total of 30 sampling events was planned for 2006, but by mid- November it was apparent from the low collection numbers that further sampling efforts were not warranted. Therefore, the program was terminated after completion of 23 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.

A comprehensive program to monitor intake screens for impinged alosines at Peach Bottom APS was conducted in 2006. Sampling was conducted on a 24-hour basis, once per week from September 5 to October 17. After the first shad was collected on October 23, the sampling regime changed to daily until Nov. 17. A total of 59 samples was collected during October through November. Conowingo Hydroelectric Station's cooling water intake strainers were also sampled for impinged alosines twice weekly from October 13 to November 20 for a total of 4 samples.

Susquehanna River Mouth and Flats

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

Job IV

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.

RESULTS

Haul Seining - Main Stem

One juvenile American shad of hatchery origin was captured by haul seine on October 18, resulting in a Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) of 0.01 (Tables 1 and 2). Table 3 lists weekly catches of American shad by haul seine from 1989 to 2006. Catches generally peaked in August and September, except in 1989 and 1992 when catches peaked in July, and in 2005 and 2006 when there was no peak.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner fore-bay resulted in 8 juvenile American shad captured in 300 lifts (Table 4). All shad were captured on October 24. Geometric Mean CPUE (individual lift) was 0.01 while GM CPUE (combined daily) was 0.03 (Table 5). Area under the curve (AUC) was 2. Historical weekly catches peaked in October, except in 1985, 1997, 2000, and 2001 when catches peaked in November (Table 5, Figure 1).

Peach Bottom intake screens produced 59 juvenile American shad and one blueback herring between

October 23 and November 10 (Table 7).

Cooling water intake strainers at Conowingo produced 4 American shad, collected between 26 October and 8 November, but only 2 specimens were suitable for analysis (Tables 8 and 9). Four alewifes were collected in strainer samples in 2006.

Susquehanna River Mouth and Flats

In 2006, 20 juvenile American shad were captured at seven permanent sites by Maryland DNR's juvenile finfish haul seine survey during 24 hauls, and 3 juvenile American shad were captured at the auxiliary sites during 36 hauls (Table 11).

Otolith Mark Analysis

Results of otolith analysis are presented in Table 12. A total of 70 juvenile American shad were collected in haul seines, lift nets, Peach Bottom intakes and Conowingo strainers. Of the 70 specimens evaluated for hatchery tags, 10% were wild and 90% were hatchery. Represented in the catch were YOY shad from releases in the Juniata River (Potomac River egg source), Juniata River (Susquehanna River egg source), Conodoguinet Creek, Swatara Creek, Conestoga River, Chemung River, and the West Branch Susquehanna River. No shad were recaptured from releases in West Conewago Creek, or the North Branch Susquehanna River (either PA or NY releases- see Job III, Appendix 1 for a discussion of relative survival).

DISCUSSION

River conditions for the Susquehanna River Basin during 2006 could be characterized by relatively stable flows in May, August and October, with a peak during the first week of June (Figure 2), a severe flood during the end of June and early July (Figure 3), and additional peaks during early September and late October through November (Figures 3 and 4). Water temperatures at Conowingo Dam increased gradually from 50F on April 5 to 77F on June 3. In response to the peak in Juniata River flow on May 31 (Figure 2), we postponed stocking until June 7. When stocking was resumed, we stocked the remainder of our production fish at Huntingdon, upstream from a severe storm which had a greater impact on the lower river (Figure 2).

The extremely high flows in the watershed during late June (403,000 cfs on June 29, 2006) probably had a negative impact on survival of both hatchery and wild juvenile shad and accounted for the low catches of juvenile shad by haul seine and lift net.

Fish passage at Holtwood (35,968) was better than average with 63% passage, based on counts at Conowingo and Holtwood (long-term mean = 33%). Fish passage at Safe Harbor (24,929) was 69%, close to the long-term mean of 74%, based on counts at Holtwood and Safe Harbor. Fish passage at York Haven (1,913) was 8%, lower than the long-term meanof 13%, based on counts at Safe Harbor and York Haven.

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 2006, 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 lowest value ever recorded for that gear type since 1990. GM CPUE for lift net collections (Table 5) in the Holtwood Dam forebay was also close to an all-time low. Juvenile shad abundance has been below normal for five consecutive years, a disturbing trend that may impact upstream fish passage counts during 2007 to 2011. 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 can be attributed to fewer larvae stocked (compared to the decade of the 1990's) and the late June flood which, undoubtedly, impacted survival.

Stock Composition and Mark Analysis

Hatchery contribution was 90% for all sites combined and exceeded wild contribution at nearly every collection site in 2006. Contribution of hatchery fish from Columbia, Holtwood, Peach Bottom and Conowingo was 100%, 100%, 90% and 50%, respectively.

SUMMARY

- Juvenile American shad were collected by haul seine at Columbia, in lift nets at Holtwood, in cooling water intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam.

- Haul seine GM CPUE (combined daily lifts) of 0.01 was the lowest recorded for that gear type since 1990.

- Lift-net GM CPUE (combined daily lifts) of 0.03 was among the lowest recorded for that gear type for the period of record. Lift net AUC was the second lowest recorded for the period of record.

- Otoliths from the four sites combined were 10% wild and 90% hatchery.

- Fewer eggs were delivered to the Van Dyke Hatchery, resulting in decreased production of hatchery larvae, and decreased production of juvenile American shad in the Susquehanna River basin.

Job IV

ACKNOWLEDGMENTS

Normandeau Associates (Drumore, PA) was contracted by the PFBC to perform juvenile collections.

Many individuals supplied information for this report. Ken Woomer processed shad otoliths.

Table 1. Number of fish collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2006.

Date	**2-Aug**	**9-Aug**	**16-Aug**	**23-Aug**	**30-Aug**	**13-Sep**	**20-Sep**	**26-Sep**	**4-Oct**	**11-Oct**	**18-Oct**	**Total**
Daily Mean River Flow (cfs)	25,400	14,200	9,600	7,690	21,600	22,300	25,600	12,700	22,900	16,300	15,000	
Water Temperature (°C)	31.0	27.8	26.8	26.0	23.5	18.0	18.0	18.5	18.0	16.5	18.0	
Secchi Disk (in)	27	40	70	60	35	24	25	60	58	80	80	
American shad	-	-	-	-	-	-	-	-	-	-	1	1
Gizzard shad	-	-	-	-	4	-	-	-	-	-	-	4
Comely shiner	-	-	-	-	-	-	-	-	1	1	-	2
Spottail shiner	9	5	1	-	4	7	-	-	3	-	1	30
Spotfin shiner	7	5	-	8	-	5	2	5	31	8	25	96
Mimic shiner	7	1	2	5	-	-	1	-	17	2	31	66
Fallfish	1	-	-	-	-	-	-	-	-	-	-	1
Quillback	-	-	-	1	2	-	-	-	-	-	-	3
Northern hog sucker	-	4	-	-	-	-	-	-	-	-	-	4
Channel catfish	2	2	6	-	-	1	1	18	3	2	-	35
Mosquitofish	-	-	-	2	-	-	-	2	-	-	-	4
Rock bass	-	-	-	-	-	-	-	1	-	1	-	2
Bluegill	-	-	-	-	-	-	-	-	-	1	-	1
Smallmouth bass	1	-	-	2	-	-	-	-	-	-	-	3
Tessellated darter	-	-	-	-	-	-	-	-	1	1	-	2
Banded Darter	-	-	-	-	-	-	-	1	-	-	-	1
Walleye	2	-	-	-	-	-	-	-	-	-	-	2
Total	**29**	**17**	**9**	**18**	**10**	**13**	**4**	**27**	**56**	**16**	**58**	**257**
No. of Species	**7**	**5**	**3**	**5**	**3**	**3**	**3**	**5**	**6**	**7**	**4**	**17**

Table 2. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990 - 2006.

		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

* Required by ASMFC

Table 3. Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River, 1989 through 2006.

Month	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	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	*	250
24-31 Jul	45	31	-	-	0	60	24	15	22	144	1	0	42	0	0	*	0	*	384
1-7 Aug	-	0	0	20	0	24	29	32	14	30	1	2	70	0	*	*	5	0	227
8-15 Aug	61	0	0	2	8	13	35	56	20	0	0	6	37	0	*	0	1	0	239
16-23 Aug	7	69	0	16	0	46	40	43	171	9	0	1	36	0	0	*	2	0	440
24-31 Aug	-	-	-	-	13	-	42	39	120	10	10	0	36	0	8	16	2	0	296
1-7 Sep	-	25	12	-	20	-	43	34	129	3	*	0	23	0	5	5	3	*	302
8-15 Sep	-	97	16	-	41	75	65	4	135	3	264	0	31	0	4	4	0	0	739
16-23 Sep	-	28	30	-	27	14	46	12	59	4	17	0	15	0	0	*	1	0	253
24-30 Sep	-	0	73	-	11	5	15	15	32	0	20	1	34	0	*	*	2	0	208
1-7 Oct	-	0	69	2	22	5	19	10	91	3	1	0	6	0	*	0	0	0	228
8-15 Oct	-	0	7	-	0	2	31	3	0	0	3	11	1	0	0	0	2	0	60
16-23 Oct	-	-	5	-	-	10	-	-	14	0	5	0	0	*	*	0	3	1	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**	**4,914**

* No sampling due to high river flow.

Table 4. Number and percent composition of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 2006.

Date:	12 Sep	15 Sep	18 Sep	21 Sep	24 Sep	27 Sep	30 Sep	03 Oct	06 Oct	09 Oct	12 Oct	15 Oct	18 Oct
Water Temp (°C):	21.0	19.5	20.0	20.5	19.5	19.8	18.5	18.9	18.0	17.0	17.0	16.0	15.0
Secchi (in):	25	24	25	35	36	48	12	32	34	30	34	40	38
River Flow (cfs):	24,650	20,800	30,700	22,000	16,200	12,900	14,900	25,650	24,000	19,200	15,100	12,400	15,000
Start Time (hr):	1847	1845	1845	1822	1819	1826	1816	1820	1806	1752	1751	1752	1745
End Time (hr):	1953	1956	1956	1930	1935	1936	1928	1926	1914	1911	1908	1912	1903
Alewife	-	-	-	-	-	-	-	-	-	-	-	-	-
American shad	-	-	-	-	-	-	-	-	-	-	-	-	-
Gizzard shad	-	1	1	67	1	-	-	-	1	-	1	-	1
Comely shiner	3	1	-	1	1	6	-	-	-	-	-	-	-
Spottail shiner	159	-	434	1	1	-	-	-	12	-	-	-	-
Spotfin shiner	30	375	26	169	163	188	36	-	35	17	34	13	5
Mimic shiner	1	-	-	1	1	-	-	-	-	-	-	-	-
Channel catfish	1	-	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	1	2	-	-	1	-	-	-	1	-	-
White crappie	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**194**	**377**	**462**	**241**	**167**	**194**	**37**	**0**	**48**	**17**	**36**	**13**	**6**
No. of Species	**5**	**3**	**4**	**6**	**5**	**2**	**2**	**0**	**3**	**1**	**3**	**1**	**2**

Table 4. Continued.

Date:	21 Oct	24 Oct	25 Oct	27 Oct	30 Oct	02 Nov	05 Nov	08 Nov	11 Nov	14 Nov	
Water Temp (°C):	14.0	10.0	9.5	8.5	9.0	9.8	8.1	8.5	9.5	10.8	
Secchi (in):	45	19	22	30	18	24	33	42	33	39	
River Flow (cfs):	32,500	78,900	60,800	40,700	77,400	70,700	47,500	43,500	37,800	59,200	
Start Time (hr):	1740	1750	1740	1731	1630	1636	1627	1625	1612	1609	
End Time (hr):	1900	1905	1856	1840	1741	1742	1732	1732	1738	1725	**TOTAL**
Alewife	-	1	-	-	-	-	-	-	-	-	1
American shad	-	8	-	-	-	-	-	-	-	-	8
Gizzard shad	-	-	-	-	-	-	-	-	-	-	73
Comely shiner	-	-	-	-	-	-	-	-	1	-	13
Spottail shiner	6	-	-	-	-	-	-	-	-	-	613
Spotfin shiner	4	-	-	-	-	-	-	1	6	-	1,102
Mimic shiner	-	-	-	-	-	-	-	-	-	-	3
Channel catfish	-	-	-	-	-	-	-	-	-	-	1
Bluegill	1	-	-	-	-	-	-	-	1	-	7
White crappie	-	-	-	-	1	1	1	-	-	-	3
Walleye	1	-	-	-	-	-	-	-	-	-	1
Total	**12**	**9**	**0**	**0**	**1**	**1**	**1**	**1**	**8**	**0**	**1,825**
No. of Species	**4**	**2**	**0**	**0**	**1**	**1**	**1**	**1**	**3**	**0**	**11**

Table 5. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2006.

		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	0.0	0.0	2	0	0.0	0.0	0	8	0.0	0.0	2

* 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**	**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	0.1
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	0.6
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	0.5
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	1.0
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	1.9
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	5.6
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	7.7
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	7.3
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	5.0
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	-	3.7
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	-	2.8
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	-	-	7.7
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	
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	300	300	260	300	240	270	230	
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	

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

Job IV

Table 7. Number of fish collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall, 2006.

Species	Unit 2	Unit 3	Total
Alewife	1	5	**6**
Blueback herring	0	1	**1**
American shad	22	37	**59**
Gizzard shad	377	636	**1,013**
Golden shiner	4	3	**7**
Comely shiner	3	0	**3**
Spottail shiner	0	6	**6**
Mimic shiner	0	2	**2**
Spotfin shiner	3	11	**14**
Quillback	1	0	**1**
Bluntnose minnow	0	1	**1**
Central stoneroller	0	1	**1**
Yellow bullhead	0	1	**1**
Channel catfish	76	101	**177**
Flathead catfish	26	45	**71**
Rock bass	2	11	**13**
Green sunfish	3	14	**17**
Pumpkinseed	0	3	**3**
Bluegill	250	409	**659**
Largemouth bass	0	9	**9**
White crappie	22	28	**50**
Yellow perch	0	2	**2**
Logperch	0	1	**1**
TOTAL	**790**	**1,327**	**2,117**

Job IV

Table 8. Number of juvenile American shad collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall, 2006.

Date	Unit 2	Unit 3	Total
23 Oct	3	3	**6**
24 Oct	11	17	**28**
25 Oct	6	9	**15**
26 Oct	2	4	**6**
27 Oct	0	1	**1**
31 Oct	0	1	**1**
01 Nov	0	1	**1**
10 Nov	0	1	**1**
TOTAL	**22**	**37**	**59**

Table 9. Species and number of fish collected during cooling water intake sampling at Conowingo Dam in Fall, 2006.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	2	2	**4**
Gizzard shad	95	417	**512**
Alewife	4	0	**4**
Comely shiner	7	8	**15**
Spotfin shiner	16	6	**22**
Channel catfish	11	10	**21**
Rock bass	0	1	**1**
Striped bass	1	1	**2**
Bluegill	4	23	**27**
Green sunfish	0	17	**17**
Tessellated darter	0	1	**1**
TOTAL	**140**	**486**	**626**

Job IV

Table 10. Number of juvenile American shad collected during cooling water intake strainer sampling at Conowingo Dam in fall, 2006.

Date	Francis Units (7)	Kaplan Units (4)	Total
26 Oct	0	2	**2**
29 Oct	1	0	**1**
08 Nov	1	0	**1**
TOTAL	**2**	**2**	**4**

Table 11. Catch of juvenile American shad by location from the upper Chesapeake Bay during the 2006 Maryland DNR juvenile finfish haul seine survey.

Permanent Sites

Location	**Round 1**	**Round 2**	**Round 3**	**Totals**
Howell Point	0	0	0	0
Tims Creek	0	0	0	0
Ordinary Point	0	0	0	0
Parlor Point	0	0	0	0
Elk Neck State Park	0	1	0	1
Welch Point	0	0	0	0
Hyland Point	0	9	0	9
Total	0	10	0	10
Mean Catch Per Haul	**0.00**	**2.50**	**0.00**	

Auxiliary Sites

Location	**Round 1**	**Round 2**	**Round 3**	**Totals**
Carpenter Point	0	0	0	0
Popular Point	0	0	0	0
Plum Point	0	1	0	1
Spoil Island	0	0	2	2
Tydings Estate	0	0	0	0
Tolchester	0	0	0	0
Total	0	1	2	3
Mean	**0.00**	**0.17**	**0.33**	

Table 12. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2006

Collection Site	Coll. Date	Immersion marks: Day 18 Jun. R. 0	Days 3,6,9 Jun. R./ Susq. R.*	Days 3,6,9, 12,15 W. Br. Susq. R.	Days 3,9, 12,15 Conestoga R.	Days 3,6,12,15 Conodoguinet Cr.	Days 3,6,9, 15,18 Swatara Cr.	Days 3,15,18 Chemung R.	Total Hatchery		Total Wild		Total Processed	Total Collected
Columbia	10/18/06	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0		0.0		1	1
Holtwood	10/24/06	4.0	1.0	3.0	0.0	0.0	0.0	0.0	8.0		0.0		8	8
Peach Bottom	10/23/06	0.0	1.0	2.0	0.0	1.0	0.0	0.0	4.0		2.0		6	6
Impingement	10/24/06	11.0	10.0	3.0	0.0	1.0	1.0	0.0	26.0		2.0		28	28
	10/25/06	9.0	3.0	1.0	0.0	0.0	2.0	0.0	15.0		0.0		15	15
	10/26/06	3.0	2.0	0.0	0.0	0.0	0.0	0.0	5.0		1.0		6	6
	10/27/06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		1	1
	10/31/06	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0		0.0		1	1
	11/01/06	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0		0.0		1	1
	11/10/06	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0		0.0		1	1
Conowingo Strainers	10/27/06	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0		1.0		2	2
Holt./P. Bot./Con.		27.0	17.0	9.0	1.0	4.0	3.0	1.0	62.0	**	7.0	**	69.0	69.0
Percent		39.1%	24.6%	13.0%	1.4%	5.8%	4.3%	1.4%	89.9%		10.1%			
Grand Total		27.0	17.0	9.0	1.0	5.0	3.0	1.0	63.0	**	7.0	**	70.0	70.0
Percent		38.6%	24.3%	12.9%	1.4%	7.1%	4.3%	1.4%	90.0%		10.0%			

*Susquehanna River source eggs.

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

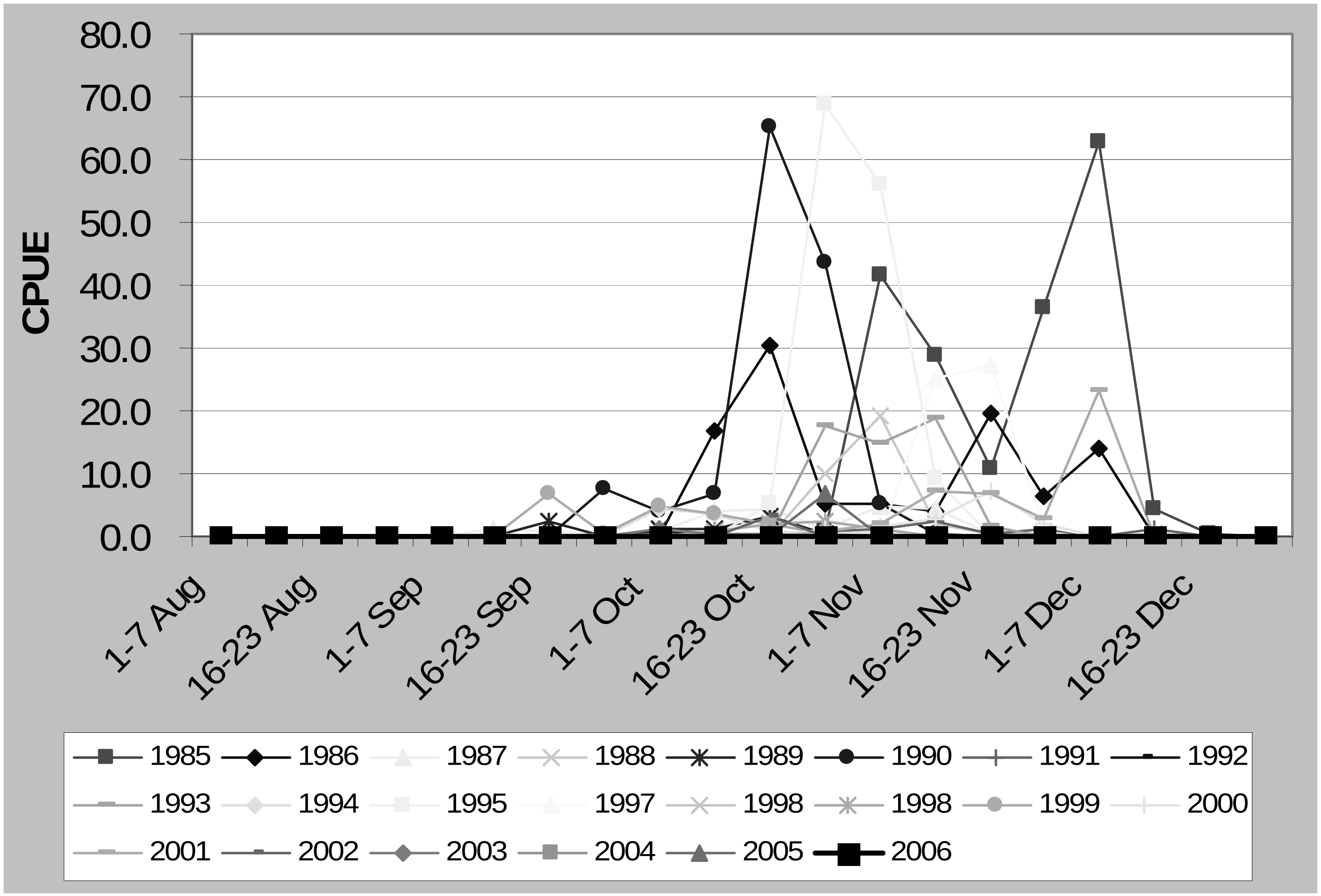


Figure 2. Number of larval American shad stocked and flow at two sites in the Juniata River, 2006.

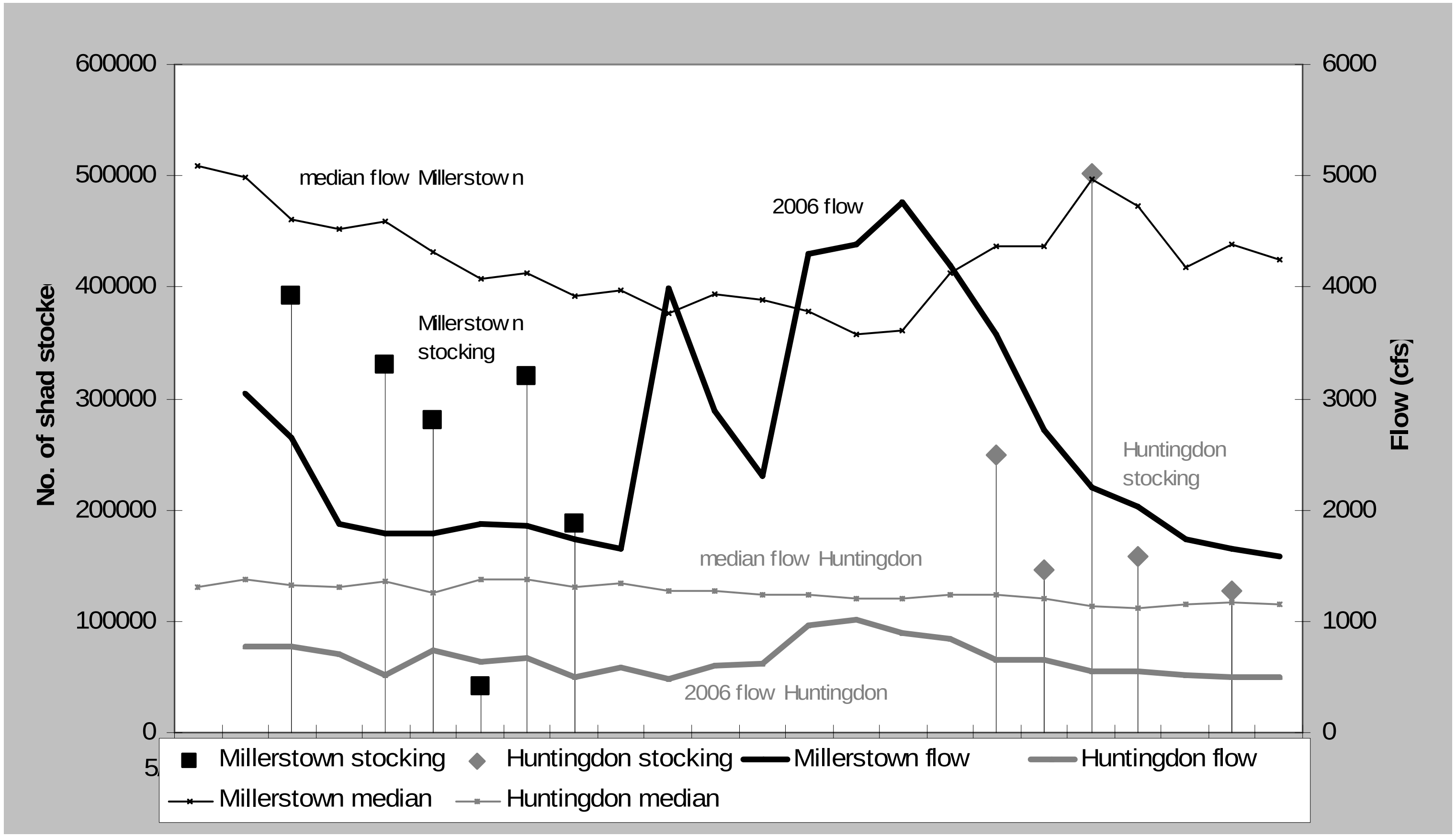


Figure 3. Number of American shad collected by haul seine and river flow, Susquehanna River, 2006.

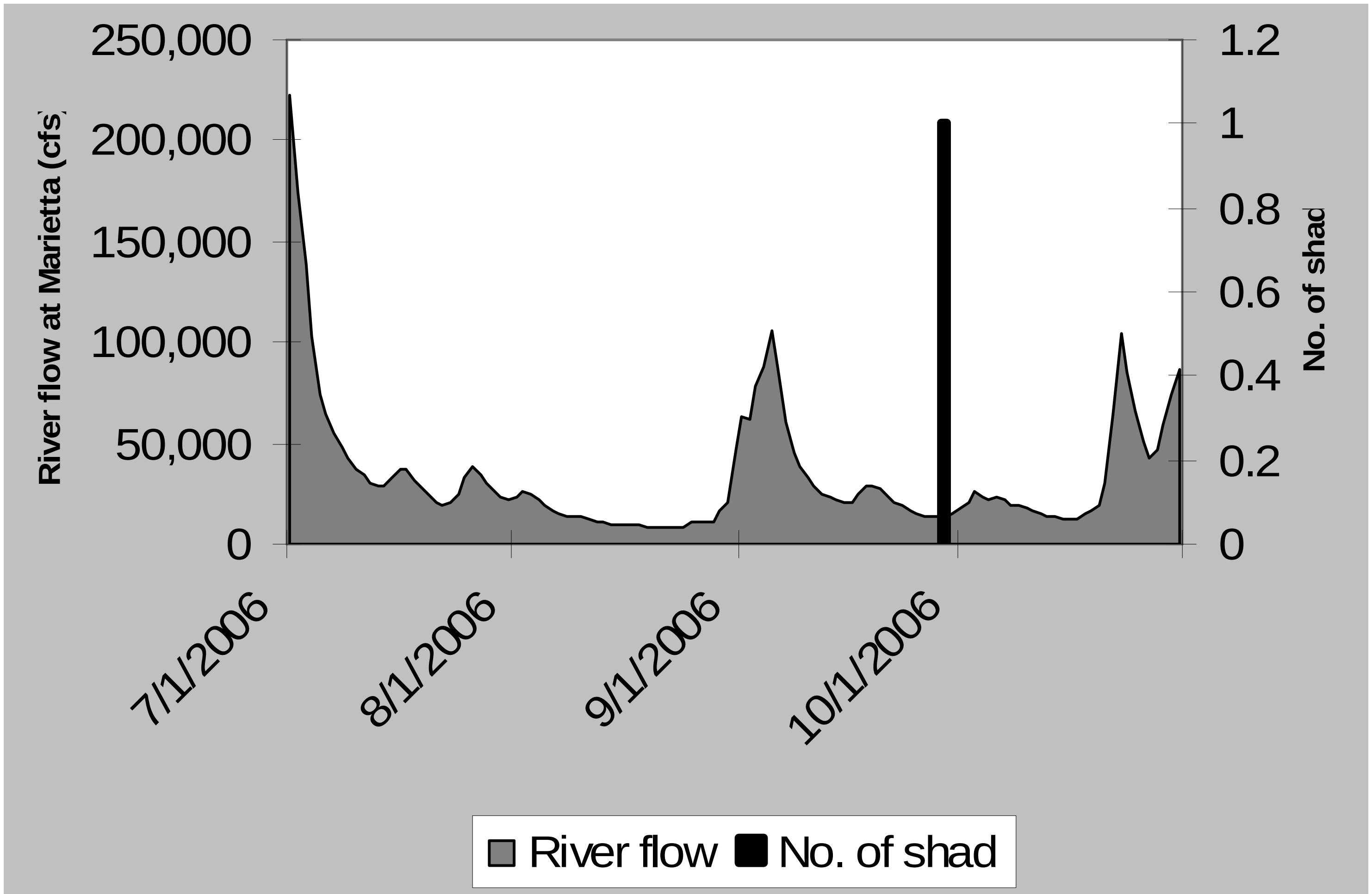
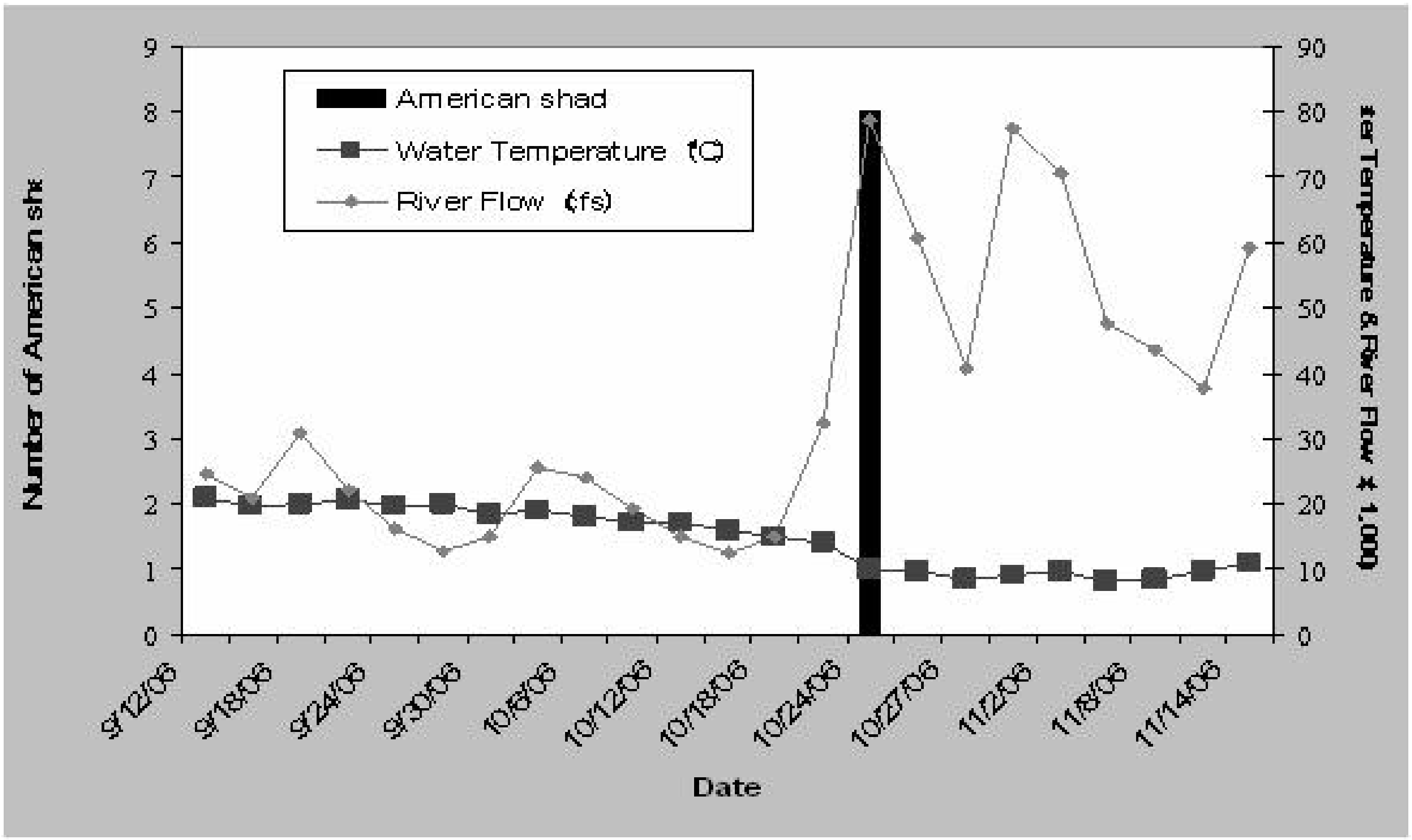


Figure 4. Number of YOY American shad collected by lift net and river flow, Susquehanna River, 2006.



Job V – Task 1

GENETIC ASSESSMENT OF SUSQUEHANNA RIVER SHAD

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ABSTRACT

The American shad (*Alosa sapidissima*) is an anadromous fish ranging from Canada to the southeastern United States. Concern over recent population declines has prompted implementation of several management actions, including closure of fisheries, dam removal or development of fish passages, and captive propagation for supplementation. We developed 15 new microsatellite markers for American shad and used these markers to examine the partitioning of genetic diversity among wild adult shad returning to the Susquehanna, Delaware, and Hudson river drainages. A high degree of genetic diversity was evident in all populations, as overall observed heterozygosity averaged 0.820 and numbers of alleles averaged 15.69. Allelic frequency heterogeneity was observed between all three river drainages and F_{ST} values ranged from 0.0010 to 0.0063. Assignment of adult shad back to river of collection was poor (ranging from 19% for Susquehanna-Lapidum to 51% for Delaware), and further supported low levels of population differentiation. Considerable genetic diversity was evident at the mitochondrial DNA regions cyt *b* and ND1; however sequence data was unable to identify significant genetic differences between the three rivers. Lack of significant population structure may be due to gene flow between populations, either through natural straying or directed movements (stocking) of fish between drainages. Historic and current restoration efforts have often relied on translocation of stocks between drainages to restore or supplement American shad populations. The current

wild population in the Susquehanna likely represents a mixture of multiple genetic sources, consistent with past and current management practices.

INTRODUCTION

The American shad (*Alosa sapidissima*) is an anadromous fish native to the rivers along the east coast of North America. Throughout the native range, shad populations have declined from historic abundance. Within the Susquehanna River, population declines are due to a variety of causes; they include loss of access to the river due to dams, exploitation, and altered habitat in the river, Chesapeake Bay, and the ocean. Multiple management strategies have been implemented to restore shad to the Susquehanna River, such as creating and improving fish passage, introductions from other populations in both the native and introduced range, and hatchery supplementation and stocking into tributaries and the mainstem of the lower Susquehanna River.

Hatchery propagation and stocking of American shad represent a major component of the restoration efforts in the Susquehanna. In a subsample of the returning adult population at Conowingo Dam West Fish lift in 2005, approximately 65% of adults were of hatchery origin (Hendricks 2005c). The hatchery program is supported by egg takes from individuals in neighboring rivers (Hudson and Delaware), as well as from the Susquehanna River. From 2000 to 2005, eggs from returning adults in the Hudson River and Delaware River contributed an average of 16.5 million fertilized eggs per year to stocking programs in the Susquehanna River (Hendricks 2005a). Additionally, approximately 160.5 L of eggs were obtained in 2005 from strip spawning or tank spawning adult females sampled from multiple sites in the lower Susquehanna River (Hendricks 2005b). Natural reproduction also occurs in the Susquehanna River.

The genetic stock structure of shad populations along the east coast has been examined using both nuclear and mitochondrial DNA. Genetic differences between populations along the east coast of North America, defined by drainage, were observed using microsatellite markers (Waters et al. 2000, Brown et al. 2000) and mitochondrial DNA haplotypes (Epifanio et al. 1995, Brown et al. 1996, Brown et al. 1999). Utilization of genetic differences between populations has allowed mixed stock analysis to identify the contribution of different stocks (rivers) to offshore fisheries (Brown et al. 1999).

Due to supplementation of the Susquehanna River with American shad from neighboring populations and the history of stocking from various additional populations, the current wild population would be expected to be a genetic mixture from multiple population sources. Alternatively if the reproductive success of the introduced populations was low, the genetic input into the Susquehanna population may have been insignificant and genetic differences between the Susquehanna and stocking sources would be expected.

Our primary objective was to use a combination of molecular markers to quantify current estimates of genetic diversity of the adult shad population on the Susquehanna relative to two neighboring populations. We developed 15 new microsatellite markers for American shad (Julian and Bartron *in press*) and used them to evaluate the partitioning of genetic diversity among adults returning to two sites in the lower portion of the Susquehanna River (Conowingo and Lapidum) as well as two neighboring rivers that are current sources of eggs for stocking (Delaware and Hudson rivers). In addition, we compared mitochondrial DNA sequences fro. Resulting data will aid in restoration efforts through improved understanding of genetic population structure, and aid in the understanding of life history characteristics and behavior of American shad. If genetic differences exist between groups of adult fish returning to different rivers, the information could assist in restoration efforts by guiding egg take and stocking strategies, the identification of which introduced stocks were successful in establishing reproducing populations, and aid in the understanding of life history characteristics and behavior of American shad.

METHODS

Sample Collection

Tissue samples were collected from two different locations on the Susquehanna River (Conowingo West Lift and Lapidum dams), the Delaware River, and the Hudson River. Fin clips from Conowingo and Lapidum dam were taken by USFWS personnel directly from frozen fish heads collected by the Pennsylvania Fish and Boat Commission (PAFBC). Otoliths were analyzed by the PAFBC to determine origin via the presence or absence of an oxytetracycline mark; only individuals of wild origin were utilized in the genetics study (96 from Conowingo, 62 from Lapidum). Samples from Delaware River (151 total) were taken by Mike Hendricks and PAFBC personnel. Keith Robinson of the Wyatt Group collected the 80 Hudson River samples. All samples were placed in 95% non-denatured ethanol until DNA extraction could be performed.

Microsatellite Marker Development

The results of the marker development are described in Julian and Bartron (*In press*; Appendix 1). A total of 15 highly variable markers were developed for American shad which should be useful for many applications such as population level analyses, parentage assignment, and broodstock management.

Microsatellite Analysis

Genomic DNA was extracted from fin clip tissue using the Purgene DNA extraction kit (Gentra Systems, Inc., Minneapolis, MN) following the manufacturer's guidelines. Isolated DNA was re-suspended in 100 μl of 10 mM Tris-HCl, pH 8.0, 1 mM EDTA.

Microsatellite analysis was performed using 14 loci described in Julian and Bartron (*In press*): *Asa*B20, *Asa*C10, *Asa*C51, *Asa*C59, *Asa*C249, *Asa*C334, *Asa*D21, *Asa*D30, *Asa*D31, *Asa*D42, *Asa*D55, *Asa*D312, *Asa*D392, and *Asa*D429. Each 15 uL PCR reaction consisted of 2.0 μl of genomic DNA extract, 1.75 X PCR buffer (10 mM Tris-HCl, pH 8.3; 50 mM KCl), 3.75 mM $MgCl_2$, 0.3175 mM each dNTP, 0.07-0.325 μM of each primer (forward primer fluorescently labeled with FAM, NED or HEX; Applied Biosystems, Foster City, CA), 1.2 units of Taq polymerase (Promega Corporation, Madison, WI), and deionized water added to achieve the final volume. The amplification cycle for all loci consisted of an initial denaturing at 94 °C for 2 min; 35 cycles of 94 °C denaturing for 45 sec, 56 °C annealing for 45 sec, 72 °C extension for 2 min; and a 5 min extension at 72 °C. An ABI Prism 3100®™ Genetic Analyzer (Applied Biosystems, Foster City, CA) was used for capillary electrophoresis. Genotypic data was analyzed and scored with Genescan 3.7.1 Analysis software and Genotyper 3.7 Fragment Analysis software (Applied Biosystems).

Mitochondrial DNA Analysis

Mitochondrial DNA was sequenced from two regions of the genome, a 515 base pair (bp) fragment of cytochrome B (cyt *b*) and a 975 bp fragment of NADH dehydrogenase subunit one (ND1). *Alosa* specific primers, *Alocytb* and *Alond1*, were amplified following the conditions detailed in Faria et al. (2006). Each 20 uL PCR reaction consisted of 3.0 μl of genomic DNA extract, 1.0 X PCR buffer (10 mM Tris-HCl, pH 8.3; 50 mM KCl), 2.0 mM $MgCl_2$, 0.25 mM each dNTP, 0.5 μM of each primer, 2 units of Taq polymerase (Promega Corporation, Madison, WI), and deionized water added to achieve the final volume. The amplification cycle for *Alocytb* consisted of an initial denaturing at 94 °C for 3 min; 40 cycles of 94 °C denaturing for 45 sec, 62 °C annealing for 45 sec, 72 °C extension for 3 min; and a 5 min extension at 72 °C. Amplification conditions for *Alond1* were identical except that the annealing temperature was 60

°C. After amplification, 7 units Exonuclease I and 1.4 units Shrimp Alkaline Phosphatase were added to each PCR reaction and the mixture was incubated for 30 min at 37 °C then 15 min at 80 °C. Sequencing reactions were performed following the ABI Prism Big Dye Terminator Cycle Sequencing protocols, and sequencing products were electrophoresed on an ABI Prism 3100®™ Genetic Analyzer (Applied Biosystems, Foster City, CA).

Statistical Analysis

Microsatellites: Genepop (Version 3.2; Raymond and Rousset 1995) was used to test for conformance to Hardy-Weinberg expectations and calculate pairwise estimates of allele frequency differences among collections. Statistical significance for all multiple comparison tests was determined using sequential Bonferroni adjustments (Rice 1989). F_{ST} values were generated between each pair of collections using FSTAT (Goudet 2001). Genetic distance between collections was summarized using the chord distance of Cavalli-Sforza and Edwards (1967) calculated with BIOSYS-1 (Swofford and Selander 1989). Maximum likelihood assignment tests using GeneClass (Version 1.0.02) were performed to determine the probability of an individual being classified back into the population from which it was collected (Cornuet et al. 1999). Samples were pooled and analyzed with Structure (Version 2.1; Pritchard et al. 2000) to determine if multiple populations were sampled.

Mitochondrial DNA: Sequencher v4.5 (GeneCodes Corporation, Ann Arbor, MI) was used for sequence alignments. Gene diversity and genetic differentiation between populations were estimated using DnaSP v4.1 (Rozas et al 2003).

RESULTS

Microsatellite analysis

Genotypes were obtained for a total of 387 American shad. Allele frequencies, observed heterozygosity, and the mean number of alleles were estimated for all collections (Table 1). All collections exhibited a high level of genetic diversity as a total of 256 alleles were observed over all 14 loci. Number of alleles per locus ranged from 8 alleles at *Asa*D429 to 34 alleles at *Asa*C249. The average number of alleles per collection ranged from 14.87 (Hudson) to 17.27 (Delaware) and averaged 15.69 alleles overall. Average observed heterozygosity per collection ranged from 0.813 (Susquehanna-Conowingo) to 0.838 (Delaware; Table 1). No deviations from Hardy-Weinberg were observed at any loci in any collection.

Some genetic structure was evident among the sampling collections. Pairwise tests of differences in allele frequencies between collections revealed significant genetic differentiation. Pairwise tests of allele heterogeneity revealed significant differences ($P<0.001$) between the Delaware and Hudson collections and also between the Delaware and both Susquehanna collections. Significant differences in allele heterogeneity were not observed between Hudson and Susquehanna collections. Unique alleles were present in all populations (18 in Susquehanna, 22 in Delaware, and 10 in Hudson).

Pairwise F_{ST} values (located in Table 2, below diagonal) ranged from 0.0010 (between Hudson and Susquehanna-Lapidum) to 0.0063 (between Hudson and Delaware) and averaged of 0.0026 over all collections. Although small, F_{ST} values were found to be significant ($P<0.008$) between Delaware and all other collections, and also between the Hudson and Susquehanna-Conowingo collections. The Susquehanna-Lapidum collection was not significantly different from the Hudson or the Susquehanna-Conowingo collections. Genetic chord distance values were less than 0.2079 between all populations (Table 2, above diagonal). The greatest distance was between the Delaware and Hudson collections and the smallest distance was between the Hudson and Susquehanna-Conowingo collections.

Maximum likelihood assignment tests were performed to determine the likelihood of a genotype being assigned back to the correct collection of origin (Table 3). Assignment success was highest for the Delaware collection, with 51.68% of animals correctly assigned (approximately twice what would be expected by chance alone). Assignment was lowest for the Susquehanna collections with only 36.46% (Conowingo) and 19.35% (Lapidum) correctly assigned back to origin. Less than 10% incorrect assignment occurred between the Delaware and Hudson collections which suggest genetic differentiation between those two rivers and mixing of genetic stocks in the Susquehanna.

Simulations were performed using Structure (Version 2.1; Pritchard et al. 2000) and samples were assigned to infer the number of contributing source populations (Table 4). A maximum of four possible populations was assumed based on our sampling from four different locations. When samples from all four locations were pooled, results of the analysis determined that it was most likely that all samples comprise one genetic population (K=1; Posterior probability=1.0000). Likewise, when the analysis was performed using only the two Susquehanna collections, posterior probabilities indicated the samples consisted of one population (K=1; Posterior probability=1.0009). These results may indicate historically high amounts of gene flow between the three drainages (natural or directed), and lack of overall significant genetic population differentiation may reflect contemporary demographic events.

Mitochondrial DNA Analysis

The data from mitochondrial regions cyt *b* and ND1 do not support genetic differentiation between the three rivers. Sequences were obtained for a total of 40 individuals at cyt *b* (11 Conowingo, 6 Lapidum, 12 Delaware and 10 Hudson) and 65 individuals at ND1 (17

Conowingo, 16 Lapidum, 16 Delaware, and17 Hudson). Base pair differences were observed at 7 nucleotide locations within the cyt *b* segment and 32 nucleotide locations within ND1; however no variable sites were diagnostic between sampling locations. A high degree of genetic diversity was evident as a total of 8 different haplotypes were observed for cyt *b* and 32 haplotypes were observed for ND1 (Table 5). Four of the 8 haplotypes observed at cyt *b* and 7 of the 32 haplotypes observed at ND1 were observed in two or more populations (Table 5). Although many haplotypes for both regions of mtDNA examined were observed in only one population, these observations were typically limited to one individual. Additional sampling most likely would have resulted in observations of those haplotypes in other populations. Haplotype diversity was 0.5013 for cyt *b* and 0.9235 for ND1. The average number of nucleotide differences among all individuals sequenced was 0.5718 for cyt *b* and 4.1644 for ND1. Nucleotide diversity was 0.00135 for cyt *b* and 0.00383 for ND1.

Estimates of genetic differentiation between populations were not significant for either mitochondrial DNA region (P=0.2459 for cyt *b*, P=0.3477for ND1). Net nucleotide divergences (D_a) between populations for cyt *b* ranged from -0.00002 to 0.00019 (Table 6).

DISCUSSION

Characterization and determination of genetic stock structure is an important component of restoration programs which entail translocations between potentially genetically different populations. Conservation strategies which consider unique populations when planning management practices may improve restoration success through the incorporation of genetically-based local adaptations. For example, in the absence of information, use of geographically proximate stocks as sources for supplementation (i.e. from the Hudson and Delaware River) most likely reflects the most genetically similar stocks to the Susquehanna. Use of geographically proximate or genetically similar stocks may confer an adaptive advantage and expedite restoration efforts by using stocks that are genetically adapted to similar selective factors. Additionally, supplementation programs that incorporate strategies to maintain genetic diversity are important when utilizing hatchery supplementation as a management strategy for recovery or restoration.

Microsatellite results indicated low levels of genetic differentiation between the wild reproducing American shad in the Susquehanna, Delaware and Hudson rivers. This result was not unexpected given the history of translocations of American shad from the Delaware, Hudson, and other sources into the Susquehanna. Observed estimates of pairwise F_{ST} among populations were generally considered low, indicating a high amount of gene flow between populations. Assignment to population of origin also supported high levels of gene flow due to the low population assignment to differentiate population of origin.

The lack of numerous distinct mitochondrial DNA haplotypes distinguishing between the Delaware, Hudson, and Susquehanna rivers was consistent with the low levels of population differentiation observed using microsatellite markers. Likewise, mitochondrial DNA estimates of genetic differentiation between rivers were also very low and not significant. Similar to our results, previous studies have been unable to resolve differences between the Hudson and the Delaware rivers using mitochondrial DNA. Waldman et al. (1996) found high levels of mitochondrial DNA diversity in American shad from multiple populations, but no genetic differentiation was observed between the Hudson, Delaware and Connecticut rivers. Likewise, Nolan et al. (1991) could not distinguish Delaware and Hudson river shad using mitochondrial DNA.

Stocking records indicate that fish from the Delaware and Hudson rivers have been heavily stocked into the Susquehanna for over 15 years as part of the recovery and restoration program to re-establish American shad in the drainage. Likewise, marked fish stocked into the Susquehanna from multiple origins return to the Susquehanna River to spawn (Hendricks 2005c). Similarly, offspring from natural reproduction by hatchery or wild individuals are also returning to the Susquehanna River; in 2005, approximately 35 % of Conowingo and 41 % of Lapidum fish collected were a result of wild reproduction according to otolith analysis of tetracycline marks in returning adults (Hendricks 2005c). Utilization of multiple stocks for restoration of the Susquehanna River American shad has resulted in a genetic mixture relatively non-distinguishable from currently used stocking sources. Most likely, individuals from both sources have been successful at interbreeding with each other and the returning wild population.

It is likely that the proportional contribution of stocking source and return rates from each stocking source has a large influence on gene frequencies and the current genetic structure within the Susquehanna. Estimates of F_{ST} indicated the Susquehanna population was slightly more similar to the Hudson than the Delaware; however this result may be simply a function of the proportion of Hudson versus Delaware fish stocked in the recent past. Between 2002 and 2004, approximately four times as many eggs were collected for stocking purposes from the Hudson than the Delaware. However in 2005, more eggs were collected from the Delaware (Hendricks 2005a). To determine if patterns of genetic diversity are a function of stocking levels, consistency in proportions and source populations stocked into the Susquehanna and subsequent genetic analysis of returning (and wild origin) American shad after multiple generations. Alternately, consistent stocking of equal numbers of American shad from source populations and subsequent genetic analysis may allow detection of a selective advantage between stocks.

Regardless of stocking histories, the effects of natural migration or straying may have also contributed towards homogenization of these populations. Based on a study by Melvin et al (1996) which estimated homing to natal river of American shad to be 97%, gene flow due to even the low levels of straying (3%; Melvin et al. 1996) between adjacent rivers could be enough to prevent significant genetic differentiation (Waldman et al. 1996). Genetic theory predicts that exchange of one migrant per generation between populations is adequate to prevent significant differences in gene frequencies over time (Hartl 1988).

The long term adaptive potential of the Susquehanna population seems limited given the current management strategy of stocking from outside sources. As a naturally-reproducing American shad population becomes established within the Susquehanna River, continued introductions of multiple stocks will not allow for local adaptation and reduce the potential for increased fitness (due to local adaptation) within the Susquehanna American shad population. If feasible, managers may want to consider increasing supplementation efforts from wild adults returning to the Susquehanna or using only one outside source river in order to minimize the potential for outbreeding depression. Additional sampling and analysis of geographically distant American shad populations may also provide more insight into relative levels of population genetic differences given the history of out-of-basin stocking for the populations sampled for this study.

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Table 1. Sample size (*N*), observed (H_o) and expected heterozygosity (H_e), and number of alleles per locus (N_a) for 14 microsatellite DNA markers for *Alosa sapidissima* sampled from the Susquehanna, Delaware and Hudson rivers. Average heterozygosities and numbers of alleles are reflected at the end of the table.

	Susquehanna			
Locus	Conowingo	Lapidum	Delaware	Hudson
***Asa*B20**				
(N)	96	62	149	80
111	0.000	0.000	0.023	0.000
114	0.016	0.000	0.013	0.006
120	0.125	0.129	0.111	0.119
123	0.125	0.153	0.101	0.119
126	0.068	0.081	0.091	0.075
129	0.188	0.210	0.198	0.200
132	0.323	0.250	0.309	0.381
135	0.052	0.040	0.067	0.013
138	0.031	0.024	0.017	0.031
141	0.031	0.048	0.023	0.031
144	0.036	0.048	0.040	0.025
147	0.005	0.000	0.007	0.000
151	0.000	0.008	0.000	0.000
171	0.000	0.008	0.000	0.000
H_o	0.792	0.871	0.886	0.762
H_e	0.823	0.847	0.830	0.783
N_a	11	11	12	10
***Asa*C010**				
(N)	95	61	148	79
261	0.005	0.000	0.003	0.000
269	0.126	0.230	0.155	0.190
273	0.000	0.016	0.007	0.000
277	0.011	0.016	0.034	0.013
281	0.084	0.131	0.122	0.082
289	0.011	0.000	0.007	0.000
293	0.068	0.049	0.054	0.076
297	0.058	0.082	0.051	0.133
301	0.063	0.066	0.074	0.057
305	0.305	0.197	0.223	0.241
309	0.105	0.090	0.081	0.082
313	0.074	0.049	0.108	0.089
317	0.079	0.049	0.020	0.019
321	0.011	0.008	0.017	0.000
325	0.000	0.008	0.014	0.006

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*C10 continued**				
329	0.000	0.000	0.003	0.000
333	0.000	0.000	0.007	0.000
337	0.000	0.000	0.000	0.006
341	0.000	0.000	0.000	0.006
345	0.000	0.000	0.007	0.000
349	0.000	0.008	0.014	0.000
H_o	0.832	0.820	0.885	0.861
H_e	0.853	0.871	0.883	0.863
N_a	13	14	19	13
***Asa*C051**				
(N)	95	60	142	77
236	0.000	0.017	0.000	0.000
248	0.032	0.017	0.035	0.019
252	0.000	0.008	0.000	0.000
256	0.000	0.000	0.000	0.006
260	0.221	0.408	0.342	0.260
264	0.221	0.150	0.222	0.201
268	0.074	0.042	0.032	0.006
272	0.000	0.008	0.007	0.006
276	0.011	0.017	0.018	0.019
280	0.053	0.025	0.032	0.013
284	0.063	0.083	0.077	0.143
288	0.105	0.075	0.049	0.084
292	0.084	0.058	0.092	0.104
296	0.047	0.008	0.039	0.032
300	0.042	0.050	0.028	0.039
304	0.011	0.025	0.004	0.019
308	0.016	0.008	0.011	0.045
312	0.011	0.000	0.011	0.000
316	0.005	0.000	0.004	0.000
320	0.005	0.000	0.000	0.000
H_o	0.895	0.700	0.803	0.753
H_e	0.871	0.795	0.814	0.853
N_a	16	16	16	15
***Asa*C59**				
(N)	95	62	149	79
257	0.000	0.000	0.000	0.013
273	0.005	0.000	0.010	0.000
277	0.011	0.008	0.020	0.006
281	0.005	0.000	0.013	0.006
285	0.058	0.040	0.094	0.082
289	0.058	0.048	0.050	0.063
293	0.079	0.089	0.081	0.038

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*C59 continued**				
297	0.095	0.153	0.057	0.089
301	0.321	0.355	0.389	0.354
305	0.137	0.145	0.097	0.146
309	0.016	0.008	0.023	0.006
313	0.005	0.000	0.013	0.000
317	0.000	0.000	0.003	0.000
325	0.000	0.000	0.003	0.000
337	0.079	0.065	0.057	0.076
341	0.063	0.032	0.044	0.063
345	0.026	0.016	0.003	0.032
349	0.037	0.040	0.040	0.019
357	0.000	0.000	0.000	0.006
361	0.005	0.000	0.000	0.000
H_o	0.853	0.839	0.799	0.835
H_e	0.848	0.817	0.812	0.827
N_a	16	12	17	14
***Asa*C249**				
(N)	93	62	148	78
207	0.000	0.016	0.000	0.000
243	0.005	0.000	0.003	0.013
247	0.038	0.000	0.020	0.000
251	0.086	0.048	0.071	0.032
255	0.065	0.065	0.041	0.038
259	0.054	0.081	0.061	0.026
263	0.032	0.040	0.054	0.026
267	0.140	0.210	0.182	0.212
271	0.091	0.113	0.091	0.103
275	0.043	0.024	0.030	0.045
279	0.027	0.032	0.027	0.051
283	0.038	0.040	0.044	0.064
287	0.016	0.056	0.037	0.032
291	0.005	0.016	0.027	0.026
295	0.027	0.056	0.047	0.026
297	0.000	0.000	0.000	0.006
299	0.027	0.032	0.034	0.045
303	0.032	0.008	0.020	0.051
307	0.027	0.024	0.027	0.006
311	0.027	0.016	0.010	0.000
315	0.038	0.008	0.017	0.013
319	0.022	0.008	0.010	0.071
323	0.011	0.016	0.014	0.006
327	0.022	0.000	0.010	0.019
331	0.016	0.000	0.007	0.019
335	0.022	0.008	0.010	0.019
339	0.016	0.016	0.027	0.006

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*C249 continued**				
343	0.005	0.016	0.007	0.013
347	0.016	0.008	0.014	0.013
351	0.016	0.008	0.003	0.006
355	0.011	0.008	0.010	0.000
359	0.011	0.016	0.014	0.000
363	0.005	0.000	0.010	0.006
367	0.011	0.000	0.014	0.000
371	0.000	0.000	0.003	0.000
375	0.000	0.000	0.003	0.006
387	0.000	0.008	0.000	0.000
H_o	0.903	0.903	0.912	0.897
H_e	0.948	0.923	0.935	0.924
N_a	32	28	34	29
***Asa*C334**				
(N)	93	58	149	75
100	0.005	0.000	0.000	0.000
102	0.011	0.000	0.023	0.013
110	0.000	0.000	0.003	0.000
114	0.005	0.000	0.020	0.000
118	0.043	0.009	0.040	0.027
120	0.000	0.000	0.003	0.000
122	0.167	0.207	0.151	0.193
126	0.102	0.060	0.067	0.073
128	0.000	0.000	0.003	0.007
130	0.108	0.078	0.081	0.067
132	0.000	0.009	0.000	0.000
134	0.048	0.009	0.037	0.033
136	0.011	0.017	0.000	0.007
138	0.011	0.026	0.010	0.007
140	0.011	0.017	0.013	0.000
142	0.011	0.009	0.007	0.013
146	0.022	0.000	0.013	0.000
150	0.065	0.138	0.074	0.133
152	0.005	0.017	0.000	0.000
154	0.253	0.233	0.272	0.240
156	0.022	0.026	0.010	0.020
158	0.059	0.060	0.074	0.087
160	0.000	0.009	0.000	0.007
162	0.027	0.069	0.050	0.040
166	0.011	0.000	0.013	0.020
168	0.000	0.000	0.003	0.000
170	0.000	0.000	0.000	0.007
178	0.005	0.000	0.020	0.007
180	0.000	0.000	0.003	0.000
182	0.000	0.000	0.003	0.000

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*C334 continued**				
186	0.000	0.000	0.003	0.000
188	0.000	0.009	0.000	0.000
H_o	0.882	0.862	0.906	0.853
H_e	0.877	0.871	0.877	0.871
N_a	21	18	25	19
***Asa*D021**				
(N)	96	62	147	75
241	0.000	0.016	0.000	0.000
249	0.068	0.040	0.044	0.093
253	0.021	0.016	0.014	0.020
257	0.047	0.024	0.041	0.080
261	0.016	0.008	0.000	0.013
265	0.297	0.282	0.262	0.247
269	0.120	0.153	0.173	0.120
273	0.021	0.032	0.010	0.040
277	0.188	0.129	0.146	0.140
281	0.078	0.097	0.102	0.073
285	0.036	0.032	0.068	0.040
289	0.073	0.121	0.099	0.073
293	0.016	0.040	0.041	0.047
297	0.016	0.008	0.000	0.007
301	0.005	0.000	0.000	0.007
H_o	0.813	0.887	0.850	0.960
H_e	0.846	0.857	0.852	0.879
N_a	14	14	11	14
***Asa*D030**				
(N)	96	62	144	78
102	0.083	0.081	0.024	0.077
106	0.073	0.073	0.069	0.077
110	0.000	0.000	0.000	0.006
114	0.104	0.113	0.094	0.051
118	0.073	0.065	0.045	0.077
122	0.052	0.081	0.094	0.135
126	0.109	0.113	0.101	0.103
130	0.104	0.040	0.115	0.071
134	0.125	0.073	0.125	0.096
138	0.036	0.065	0.090	0.064
142	0.057	0.040	0.066	0.071
146	0.042	0.073	0.049	0.019
150	0.036	0.032	0.024	0.051
154	0.021	0.048	0.014	0.013
158	0.016	0.016	0.017	0.000
162	0.021	0.008	0.028	0.019
166	0.000	0.032	0.010	0.019

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*D30 continued**				
170	0.016	0.016	0.017	0.026
174	0.016	0.008	0.007	0.013
178	0.010	0.016	0.007	0.006
182	0.005	0.008	0.000	0.000
194	0.000	0.000	0.000	0.006
198	0.000	0.000	0.003	0.000
H_o	0.906	0.887	0.938	0.936
H_e	0.926	0.936	0.922	0.929
N_a	19	20	20	20
***Asa*D31**				
(N)	95	60	148	77
180	0.032	0.067	0.047	0.000
184	0.000	0.000	0.003	0.000
192	0.000	0.008	0.017	0.006
196	0.000	0.000	0.003	0.013
200	0.168	0.158	0.139	0.175
204	0.174	0.067	0.101	0.123
208	0.142	0.200	0.159	0.156
212	0.321	0.250	0.334	0.292
216	0.095	0.125	0.095	0.123
220	0.042	0.067	0.041	0.039
224	0.016	0.025	0.044	0.045
228	0.000	0.008	0.007	0.013
232	0.005	0.017	0.003	0.013
236	0.000	0.008	0.003	0.000
240	0.005	0.000	0.003	0.000
H_o	0.737	0.933	0.797	0.805
H_e	0.810	0.849	0.821	0.830
N_a	10	12	15	11
***Asa*D42**				
(N)	90	61	149	80
142	0.011	0.000	0.000	0.000
146	0.067	0.082	0.007	0.063
150	0.017	0.000	0.000	0.013
154	0.050	0.008	0.050	0.006
158	0.183	0.172	0.185	0.125
162	0.083	0.082	0.060	0.075
166	0.072	0.074	0.121	0.125
170	0.150	0.090	0.178	0.081
174	0.083	0.066	0.161	0.050
178	0.089	0.148	0.057	0.081
182	0.022	0.033	0.037	0.019
186	0.011	0.041	0.054	0.031
190	0.017	0.049	0.037	0.019

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*D42 continued**				
194	0.017	0.025	0.010	0.019
198	0.000	0.008	0.003	0.000
202	0.117	0.123	0.017	0.281
206	0.006	0.000	0.023	0.000
210	0.006	0.000	0.000	0.006
222	0.000	0.000	0.000	0.006
H_o	0.900	0.770	0.805	0.863
H_e	0.900	0.904	0.881	0.868
N_a	17	14	15	16
***Asa*D55**				
(N)	95	62	149	80
223	0.000	0.000	0.007	0.006
227	0.000	0.000	0.007	0.000
231	0.011	0.024	0.003	0.000
235	0.453	0.492	0.419	0.506
239	0.026	0.040	0.064	0.044
243	0.074	0.040	0.067	0.069
247	0.042	0.040	0.013	0.050
251	0.168	0.137	0.161	0.162
255	0.095	0.089	0.117	0.087
259	0.100	0.089	0.097	0.044
263	0.011	0.032	0.037	0.006
267	0.005	0.016	0.003	0.013
271	0.011	0.000	0.000	0.006
279	0.005	0.000	0.003	0.006
H_o	0.684	0.677	0.812	0.688
H_e	0.743	0.723	0.767	0.703
N_a	12	10	13	12
***Asa*D312**				
(N)	96	60	149	79
128	0.005	0.008	0.000	0.000
132	0.005	0.017	0.003	0.038
136	0.057	0.083	0.017	0.082
140	0.010	0.042	0.040	0.063
144	0.146	0.067	0.134	0.063
148	0.125	0.175	0.171	0.139
152	0.198	0.258	0.225	0.310
156	0.161	0.142	0.114	0.127
160	0.109	0.075	0.107	0.089
164	0.073	0.033	0.094	0.051
168	0.026	0.042	0.034	0.006
172	0.021	0.017	0.040	0.013
176	0.021	0.008	0.010	0.013
180	0.016	0.017	0.003	0.006

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*D312 continued**				
184	0.010	0.008	0.003	0.000
188	0.000	0.008	0.000	0.000
192	0.010	0.000	0.000	0.000
200	0.005	0.000	0.000	0.000
244	0.000	0.000	0.003	0.000
H_o	0.885	0.917	0.852	0.861
H_e	0.880	0.867	0.867	0.847
N_a	17	16	15	13
***Asa*D392**				
(N)	94	61	148	78
225	0.000	0.000	0.003	0.006
233	0.005	0.016	0.003	0.000
237	0.011	0.016	0.010	0.006
241	0.293	0.295	0.277	0.244
245	0.032	0.008	0.014	0.013
249	0.000	0.008	0.007	0.026
253	0.016	0.016	0.041	0.038
257	0.005	0.000	0.017	0.032
261	0.037	0.049	0.037	0.019
265	0.037	0.057	0.044	0.038
269	0.074	0.041	0.074	0.038
273	0.106	0.090	0.071	0.135
277	0.085	0.090	0.125	0.064
281	0.016	0.016	0.034	0.032
283	0.000	0.000	0.007	0.000
285	0.000	0.008	0.007	0.000
289	0.101	0.148	0.068	0.173
291	0.000	0.000	0.003	0.000
293	0.048	0.049	0.068	0.051
297	0.048	0.066	0.047	0.045
301	0.037	0.000	0.014	0.013
305	0.005	0.000	0.000	0.000
309	0.005	0.008	0.003	0.000
313	0.021	0.008	0.014	0.026
317	0.000	0.008	0.000	0.000
321	0.000	0.000	0.003	0.000
325	0.016	0.000	0.003	0.000
333	0.000	0.000	0.007	0.000
H_o	0.851	0.787	0.905	0.846
H_e	0.874	0.866	0.881	0.881
N_a	20	19	26	18

Locus	Susquehanna Conowingo	Lapidum	Delaware	Hudson
***Asa*D429**				
(N)	95	61	148	78
131	0.000	0.008	0.007	0.000
135	0.026	0.033	0.020	0.019
139	0.000	0.008	0.007	0.000
143	0.211	0.221	0.189	0.218
147	0.068	0.049	0.054	0.032
151	0.205	0.189	0.223	0.205
155	0.232	0.172	0.193	0.186
159	0.116	0.148	0.142	0.179
163	0.137	0.148	0.128	0.109
167	0.000	0.025	0.020	0.045
171	0.005	0.000	0.017	0.006
H_o	0.737	0.820	0.885	0.756
H_e	0.827	0.845	0.840	0.834
N_a	8	10	11	9
Mean				
H_o	0.813	0.814	0.838	0.816
(S.E.)	0.027	0.028	0.25	0.026
H_e	0.857	0.85	0.851	0.844
(S.E.)	0.013	0.014	0.012	0.015
N_a	15.67	14.93	17.27	14.87
(S.E.)	1.56	1.26	1.72	1.34

Table 2. Matrix indicating distance coefficients and F_{ST} values for *Alosa sapidissima* collected in the Susquehanna, Delaware, and Hudson rivers. Numbers above the diagonal are Cavalli-Sforza and Edwards (1967) chord distance. Numbers below the diagonal are pairwise F_{ST} estimates. Italics indicate significant F_{ST} values. Population abbreviations are as follows.

	Susquehanna River			
Collection	Conowingo	Lapidum	Delaware	Hudson
S. R. Conowingo	*****	0.1914	0.1668	0.1897
S. R. Lapidum	0.0020	*****	0.1962	0.1976
Delaware River	*0.0015*	*0.0023*	*****	0.2079
Hudson River	*0.0025*	0.0010	*0.0063*	*****

Table 3. Maximum likelihood assignment (Cornuet et al. 1999) of *Alosa sapidissima* individuals from collection of origin to each of the four sampling locations. Bold represents the number of individuals correctly assigned back to collection of origin (on diagonal).

	Number assigned to population					
From Population	Conowingo	Lapidum	Delaware	Hudson	Total	% to self
S. R. Conowingo	**35**	18	27	16	96	36.46
S. R. Lapidum	16	**12**	16	18	62	19.35
Delaware River	39	19	**77**	14	149	51.68
Hudson River	18	20	8	**34**	80	42.50

Table 4. Posterior probabilities from Structure (Version 2.1; Pritchard et al. 2000) when samples from all locations were combined and when only samples collected from the Susquehanna were included. Bold indicates the most likely number of populations (K) for each case.

	Posterior Probability	
	Susquehanna - Conowingo&Lapidum	All populations combined
K		
1	**1.0009**	**1.0000**
2	0.0018	0.0000
3	0.0009	0.0000
4	0.0009	0.0000

Table 5. Number of *Alosa sapidissima* individuals observed by collection location exhibiting each haplotype at mtDNA regions cyt *b* and ND1.

cyt *b*	**Sampling Location**			
Haplotype	Conowingo	Lapidum	Delaware	Hudson
A				1
B			1	
C		2	1	1
D	2		1	
E				1
F			1	1
G	3			1
H	6	4	8	5
# haplotypes observed	3	2	5	6

ND1	**Sampling Location**			
Haplotype	Conowingo	Lapidum	Delaware	Hudson
A				1
B			1	
C	1			
D		1		
E	3			
F		1		
G			1	
H			1	
I	2		1	
J				1
K	1		2	
L	1			
M	1			

N				1
O				1
P			1	
Q			1	
R	1	1	2	
S		1		
T		3	1	4
U				1
V				2
W				1
X		1		
Y			1	
Z	1			
AA	1	1	1	1
BB		1		
CC	3	3	2	
DD		1		
EE	1			1
FF	1	2	1	3
# haplotypes observed	12	11	13	11

Table 6. Net number of nucleotide substitutions (D_a) among *Alosa sapidissima* collections based on cyt *b* and ND1 gene regions. Numbers for ND1 are above the diagonal and numbers for cyt *b* are below.

Collection	Susquehanna River Conowingo	Lapidum	Delaware	Hudson
S. R. Conowingo	*****	0.00023	-0.00013	0.00011
S. R. Lapidum	0.00019	*****	0.00049	-0.00005
Delaware River	-0.00002	0.00004	*****	0.0002
Hudson River	0.00010	0.00005	-0.00002	*****

Job V – Part 2

ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 2006

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ABSTRACT

A total of 180 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2006. Based on tetracycline marking, 50% of the 177 readable otoliths were identified as wild and 50% 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 1986-2000 year classes, stocking of approximately 314 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 2.10 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.

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

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

METHODS

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad which entered the West lift. 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 2006. Age composition data was gathered as follows: for 1996 to 2006, age composition data were collected from the aforementioned otolith analysis. For 1991-1995, age composition data were taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1989 and 1990, age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transporting mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991).

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

RESULTS AND DISCUSSION

A total of 180 shad was sacrificed for otolith analysis from Conowingo Dam in 2006. 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 88 (50%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 89 (50%) fish exhibited tetracycline marks including single, triple, quadruple and quintuple marks. 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 1989-2006 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).

Length frequencies, age frequencies, mean total length, and mean weight are detailed in Tables 3 to 7. In general, age, length and weight have increased over time, with a decreasing trend from 2004 to 2006. 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 2000, 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 1986-2000, 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 2000, transport of an average of 2.10 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 2006. High river flows in 2003 and 2004 negatively impacted survival of hatchery fish, while reduced egg availability was problematic in 2005 and 2006. Cohorts beyond 2000 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 0.09 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 0.30. 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 0.56 and 0.54, respectively.

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=0.174). 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).

Job V – Part 2

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

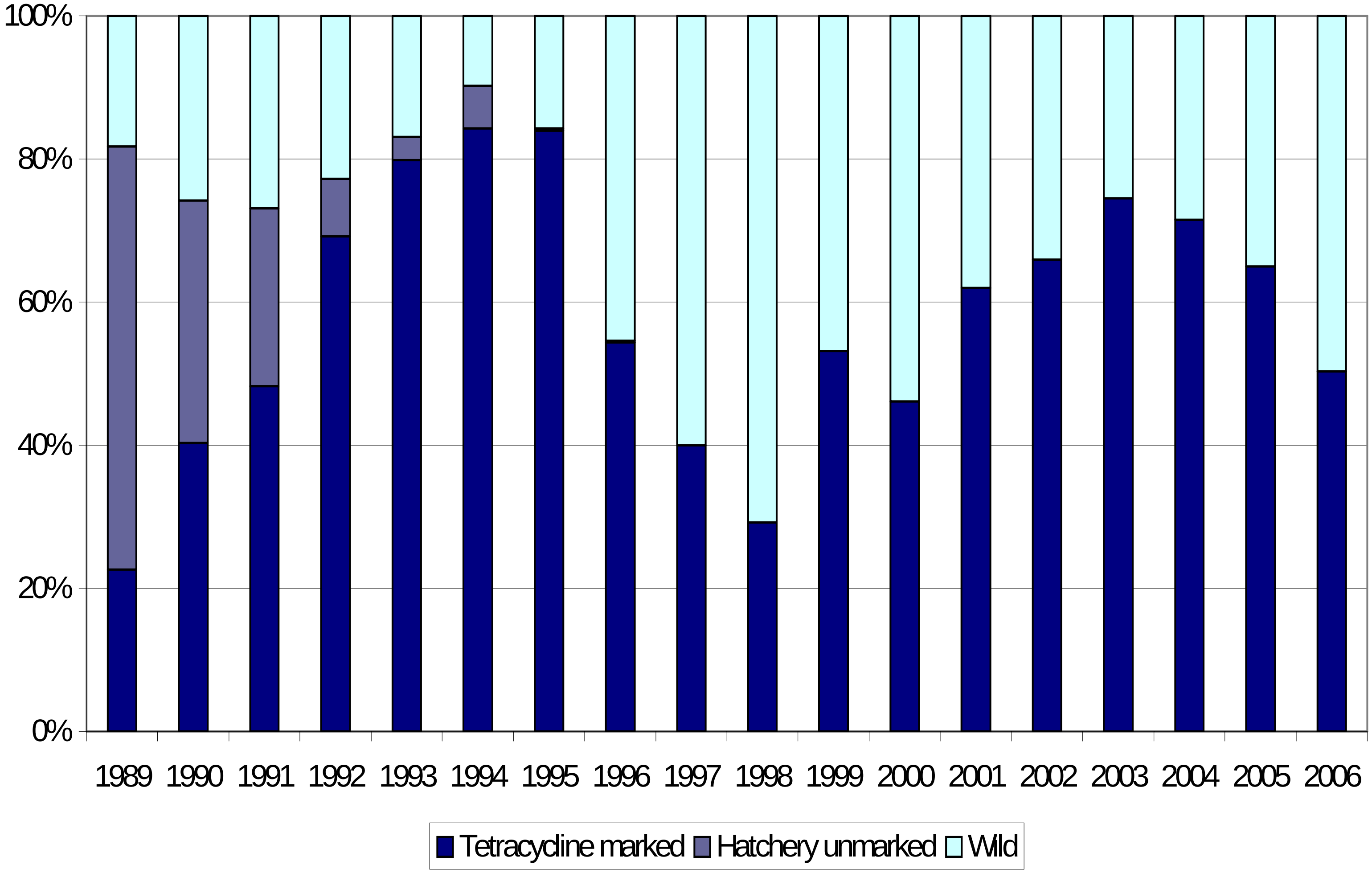


Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

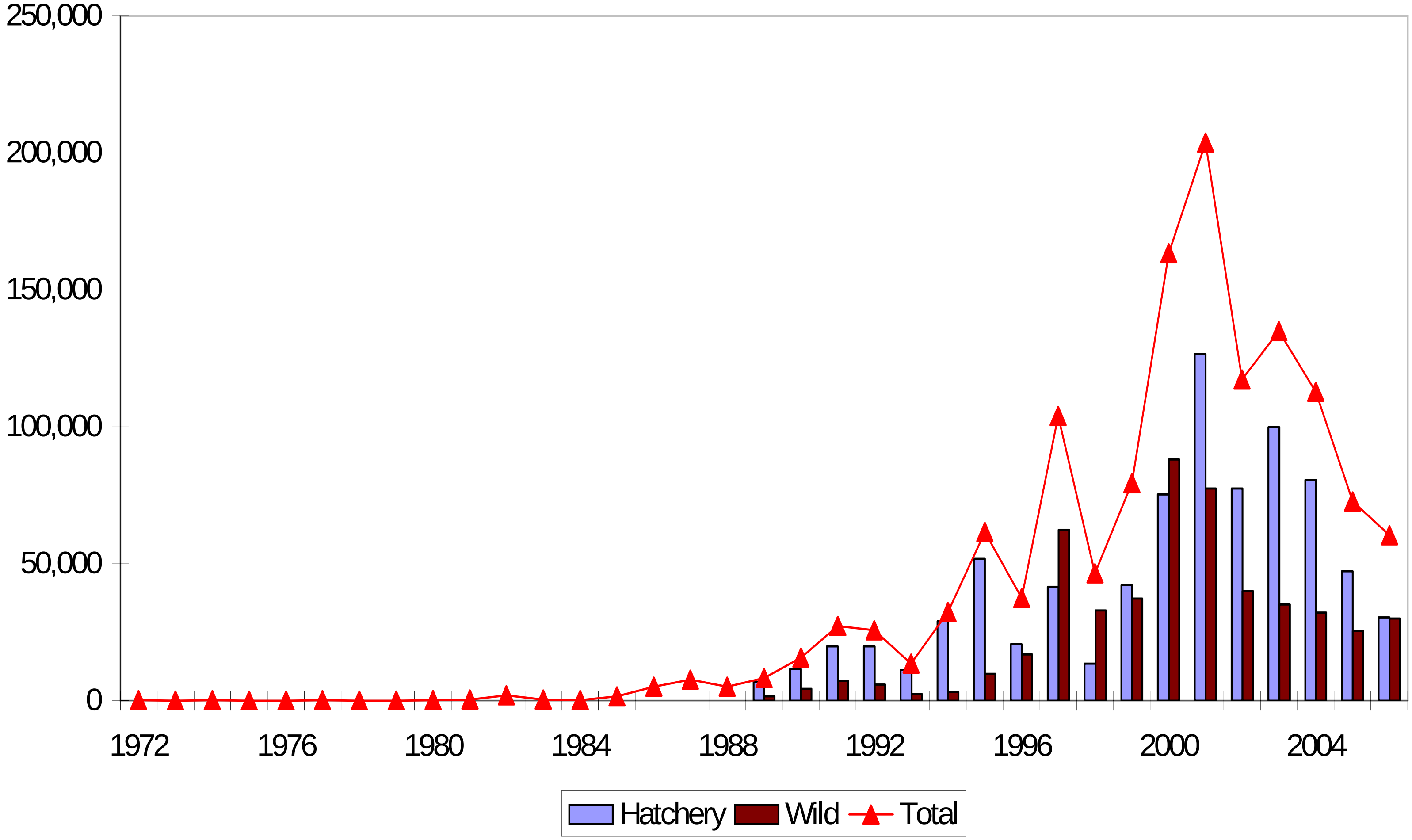
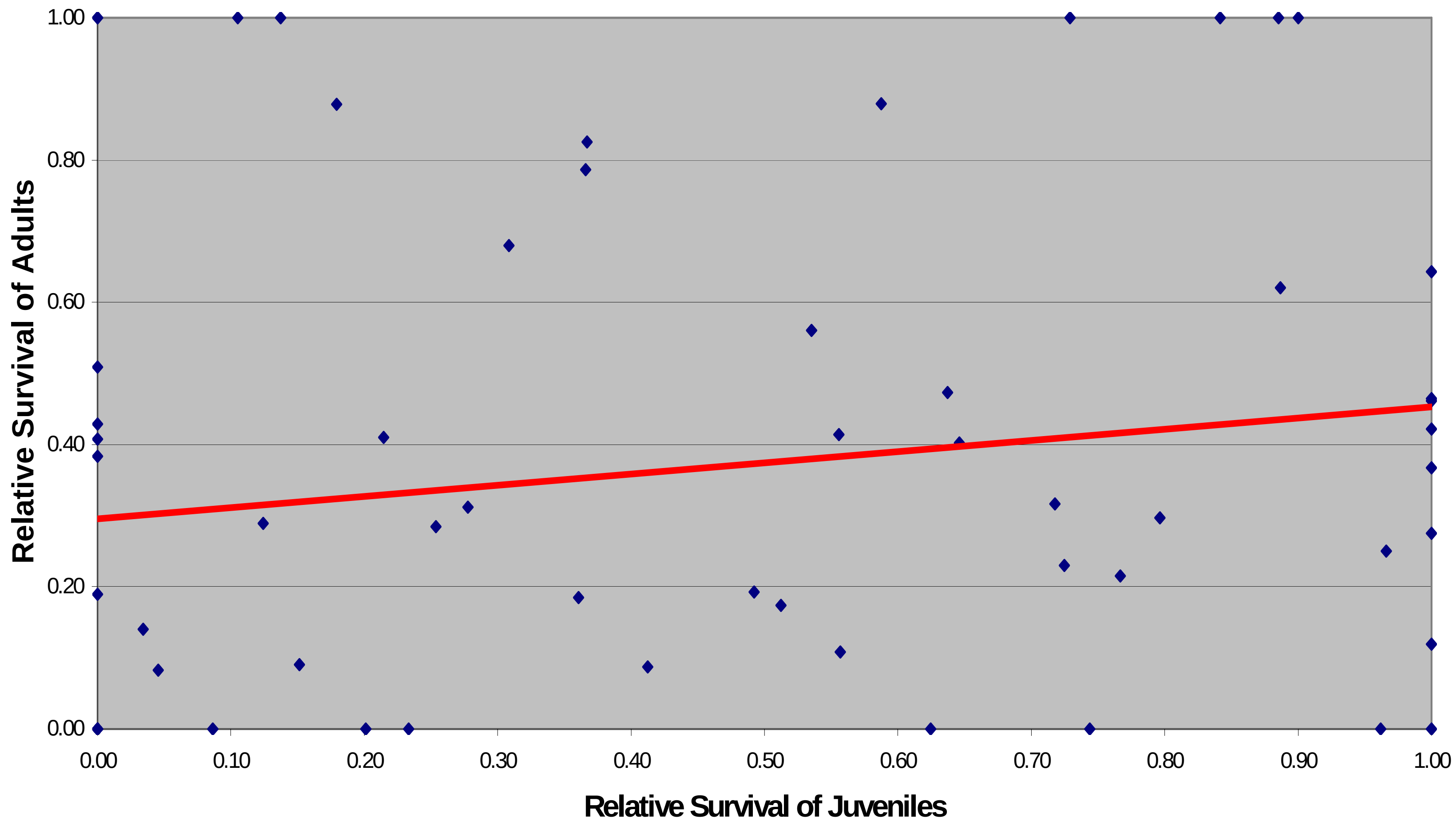


Figure 3. Stocking site/cohort specific relative survival of juvenile shad vs. adult shad, Susquehanna River, 1995-2002.



Job V – Part 2

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2006.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

Conowingo Dam		Conowingo Dam N	Conowingo Dam %
Wild Microstructure, No TC Mark		88	50%
Hatchery Microstructure			
No TC Mark*			0%
Single TC Mark	Day 3 or 5	43	24%
Double TC Mark	Days 3,6 or 3,7		0%
Triple TC Mark	Days 3,6,9	31	18%
	Days 5,9,13		0%
	Days 3,13,17		0%
	Days 3,9,12	3	2%
	Days 9,12,15		0%
Quadruple TC Mark	Days 5,8,13,17		0%
	Days 3,6,9,12	1	1%
	Days 3,6,9,15	1	1%
	Days 3,9,12,15	7	4%
Quintuple TC Mark	Days 3,6,9,15,18		0%
	Days 3,6,9,12,18		0%
	Days 3,6,12,15,18	3	2%
	Total Hatchery	89	50%
	Total readable otoliths	177	
	Unreadable Otoliths**	3	
	Total	180	

*Includes poor grinds and otoliths with autofluoresence obscuring mark.

**Includes missing, broken and poorly ground otoliths.

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

Year	Sample: One in ??	Hatchery Larvae Susquehanna N	%	below Conowingo Dam N	%*	Fingerling N	%*	Unmarked** N	Naturally reproduced N	%	Total sample 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
Totals		2,121	61	153	4	25	1	241	1,310	34	3,850

*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, 1993-2006.

Males

TL - mm	1993	1994	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006
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
425	27		80	56	47	13	40	32	5	5	12	14	26	21
450	6		107	44	34	26	22	55	20	9	27	15	33	21
475			71	32	24	19	15	27	34	14	24	19	31	12
500			18	13	6	2	4	12	20	24	12	12	11	4
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

Females

TL - mm	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
250		no												
275		data												
300														
325														
350			1											
375	3		1	2			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
475	14		64	28	28	11	20	14	16	4	11	10	19	28
500	4		91	36	20	27	26	12	36	14	14	24	44	33
525	1		47	49	12	24	14	21	39	32	19	26	34	21
550			14	17	10	6	8	5	18	42	21	12	29	9
575			8	7	3		4	4	2	15	23	11	11	
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

Table 3. (continued).

Sexes Combined

TL - mm	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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
400	27		31	47	50	6	13	7	4	11	8	2	20	9
425	34		82	57	50	13	43	32	5	5	12	15	27	26
450	13		113	55	38	30	34	58	23	10	32	19	39	31
475	14		135	60	52	30	35	41	50	18	35	29	50	40
500	4		109	49	26	29	30	24	56	38	26	36	55	37
525	1		51	58	13	25	15	24	40	40	19	29	38	22
550			16	19	10	6	8	5	18	44	21	13	29	9
575			8	7	3		4	4	2	15	25	11	11	
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

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

Job V – Part 2

Table 4. Age-frequency of American shad collected in the Susquehanna River at the Conowingo West Fish Lift, 1995-2006.

Wild Males

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

Hatchery Males

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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
5	74	32	12	10	8	17	31	24	10	27	18	10
6	12	1	2		2	3	5	6	12	6	18	2
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
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

Wild Females

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2												
3		3	2			1					1	
4	4	20	23	8	14	11	11	5	4	1	9	5
5	7	14	16	28	22	13	27	14	7	9	11	33
6	2	6	9	9	8	6	10	18	11	3	18	3
7				1	1			4	4	5	3	2
8								1		1	3	
9											1	
??		6			2			1			1	
Total	13	49	50	46	47	31	48	43	26	19	47	43
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

Hatchery Females

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2			1									
3									1		1	
4	10	24	5	4	10	2	7	8	8	4	9	9
5	79	60	11	6	24	14	29	29	23	34	22	33
6	26	10	12	5	5	8	24	24	33	13	53	11
7	7	5	2		1	2	4	5	9	13	13	6
8								2	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
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

Table 5. Mean total length and weight of adult American shad collected at the Conowingo Dam West Fish Lift, 1993-2006.

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

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Table 6. Mean total length (mm) at age for American shad collected at the Conowingo Dam West Fish Lift, 1995-2006.

Otolith age	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005	2006
Male												
2		392										442
3	410	424	416	431	420	454	478	419	429	366	411	394
4	445	463	447	454	443	460	465	471	458	387	441	442
5	466	484	488	473	472	488	486	502	488	430	474	460
6	477	526	481		482	515	494	527	512	444	496	483
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
5	511	526	515	521	508	526	521	547	540	461	521	501
6	515	473	538	539	521	541	537.5	554	560	486	531	522
7	566	533	560	495	540	549	537	580	579	495	549	535
8								579	570	498	571	537
9											620	573
10												
11											575	

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

Otolith age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Male												
2		546										630
3	610	662	667	614	642	838	949	669	740	590	608	557
4	840	869	834	750	717	828	831	986	919	834	797	811
5	936	967	1022	861	855	983	956	1126	1090	1025	982	921
6	1022	1220	1018		885	1195	1009	1413	1336	1094	1160	1047
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
5	1343	1440	1524	1311	1234	1425	1340	1619	1726	1345	1437	1248
6	1418	1513	1647	1474	1382	1495	1496	1657	1817	1572	1555	1468
7	1826	1321	1695	1210	1500	1885	1460	1841	1989	1739	1740	1589
8								1675	2080	1715	1613	1605
9											2470	2050
10												
11											1900	

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

Job V – Part 2

Table 8. Sex ratio of American shad collected at the Conowingo Dam West Fish Lift, 1993-2006.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
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

Table 9. Otolith age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2006.

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%

Job V – Part 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%

Sexes Combine	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%

Job V – Part 2

Table 10. Scale age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2006.

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%

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%

Table 10. (continued).

Sexes Combine	**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%

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	60,335			0.6	0.6	4.5	11.9	52.8	26.1	2.8	0.6	50%	0%	0%	50%

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

Used scale ages for 1988-1996, ot. 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%

* 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**
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
2004										0	501	7,515	10,521	32,481	9,018
2005											0	171	812	7,447	6,854
2006												0	0	869	2,782
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	77,695	21,227
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
Number of larvae to return 1 adult:	724	487	477	641	183	305	206	271	203	174	68	95	262	174	446
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	0.0022

Mean number of larvae to return 1 adult (1986-2000): 314

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

	Cohort														
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
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	1,020				
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	3,476
2003									0	181	1,858	10,316	7,894	10,651	905
2004										0	200	2,993	4,190	12,935	3,591
2005											0	93	443	4,062	3,738
2006												0	0	860	2,751
Total recruits to lifts:	4,904	3,295	2,837	3,439	7,727	15,164	19,495	45,628	47,155	52,752	94,566	48,149	18,612	31,983	14,462
Adults transported/1000:	4.17	7.20	4.74	6.47	15.08	24.66	15.67	11.72	28.68	56.37	33.83	103.95	44.50	75.79	163.3
No. of adults transported to return 1 adult:	0.85	2.19	1.67	1.88	1.95	1.63	0.80	0.26	0.61	1.07	0.36	2.16	2.39	2.37	11.29

Mean number of adults transported to return 1 adult (1986-2000): 2.10

Job V – Part 2

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	0	0	0		0.00	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	56	20,358	28		0.42	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	37	12,157	63		0.46	1.00
2001	1,859,345	Juniata & Susq. R.	Susq.	39	11,867	64		0.47	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.	1	341	11		0.08	0.05
2001	140,821	Conodoguinet Cr.	Susq.	1	266	19		0.14	0.03
2001	169,545	W. Conewago Cr.	Susq.	0	0	0		0.00	0.09
2001	210,831	Conestoga R.	Susq.	9	2,843	135		1.00	0.11
2001	182,490	Swatara Cr.	Susq.	1	266	15		0.11	0.56
2001	676,982	N. Br. Susq. R.	Hudson	4	1,586	23	53	0.17	0.51
2002	1,906,173	Juniata R.	Hud/Susq.	10	3,108	16		0.09	0.15
2002	216,560	Juniata R.	Susq.	9	3,068	142		0.79	0.37
2002	101,350	W. Br. Susq. R.	Hud/Susq.	3	1,023	101		0.56	0.54
2002	2,000	Conodoguinet Cr.	Susq.	0	0	0		0.00	0.00
2002	18,924	Conestoga R.	Susq.	1	341	180		1.00	0.00
2002	15,000	Swatara Cr.	Susq.	0	0	0		0.00	0.00
2002	21,000	N. Br. Susq. R.(PA)	Hudson	0	0	0		0.00	0.00
2002	158,790	N. Br. Susq. R.(NY)	Susq.	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	29	0.00	1.00

AMERICAN EEL SAMPLING AT CONOWINGO DAM 2006

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BACKGROUND

The Atlantic States Marine Fisheries Commission (ASMFC) is considering changes to its Interstate Fishery Management Plan for American Eel (*Anguilla rostrata*) (FMP). The American Eel Management Board (state directors) recently reviewed advice from the American Eel Technical Committee with respect to potential management changes needed to address modern population declines. The Board tasked the American Eel Plan Development Team with developing a Public Information Document (PID) to explore issues related to American eel management and potential changes to the FMP. Specifically addressed in the PID are efforts to modify fishing regulations and to provide safe upstream (elvers) and downstream (silver eels) passage at hydroelectric dams. Such improved passage for eels will increase habitat availability and improve escapement of adult eels

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.

Job V – Task 3

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 upriver. Specialized passages designed to accommodate eels are needed to allow them access to the watershed above dams.

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.

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 8 through June 26, 2006. Sampling was limited to the west side of the dam. A modified Irish elver ramp was used to sample for elvers (Figure 2) and eel pots with a 6 mm square mesh, were set around the base of the West Fish Lift to catch larger eels. The West Fish Lift was also operated for six lifts, in an attempt to determine the feasibility of sampling for juvenile eels. Stream flow, temperature and other water quality parameters were monitored at collection sites. A data logger was deployed to collect water temperature four times per day during the sample period (Figure 3). 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 turbine generation, and heavy rainfalls, (Figure 3) the ramp would become inoperable during periods of low water level. The ramp was moved inside the West Fish Lift raceway and an outrigger system was developed to try and improve the stability of the ramp. This placement did not prove to be any more reliable than when the ramp was operating in the variable water conditions. Additional refinement in attaching the ramp will need to be developed to further improve reliability.

RESULTS

Eels were captured throughout the period sampled (Table 1). Length frequencies ranged from 83 to 735 mm TL (Figures 4 and 5). Captured eels captured were sedated, measured (Figure 6), fin clipped (Figure 7) and released. Sub samples of juvenile eels were collected for oxytetracycline (OTC) marking of otoliths to validate aging techniques. These eels were marked by immersing them in a 550 ppm OTC bath for 6 hours. They were then held in a pond for one year. Otolith samples from these eels are currently being processed. The largest capture of elvers occurred during a period of low lunar fraction on July 16 (Figure 8). Captures of eels in pots during 2006 also showed a correlation to lunar fraction (Figure 9).

The West Fish Lift has been in operation since 1972 and eel captures in the West Fish Lift have declined significantly since 1974 (Figure 10). This decline may be due to modifications of attraction flows to increase trap efficiency for American shad passage, a decline in eel abundance or a combination of these factors. In years with substantial eel captures in the West Fish Lift, most fish were taken during June. Modern lift operations are usually terminated by early to mid-June, which may further limit captures of eels.

We believe that abundance estimates could be made by individually marking eels. Current data analysis has shown that the larger eels caught in the eel pots are becoming trap happy (Figure 11). Historically it was thought that eel migration was determined by water temperature and stream flow; however we are also trying to determine if lunar phase may influence migration patterns. If lunar phase influences migration the most active elver migration will occur during the lunar cycles in May, June, and July (Figure 12) during 2007 efforts will be made to improve reliable continuous operation of the elver ramp, to continue to collect biological and environmental data on the timing and abundance of eels below Conowingo Dam and to develop some experimental elver collection devices.

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.

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.

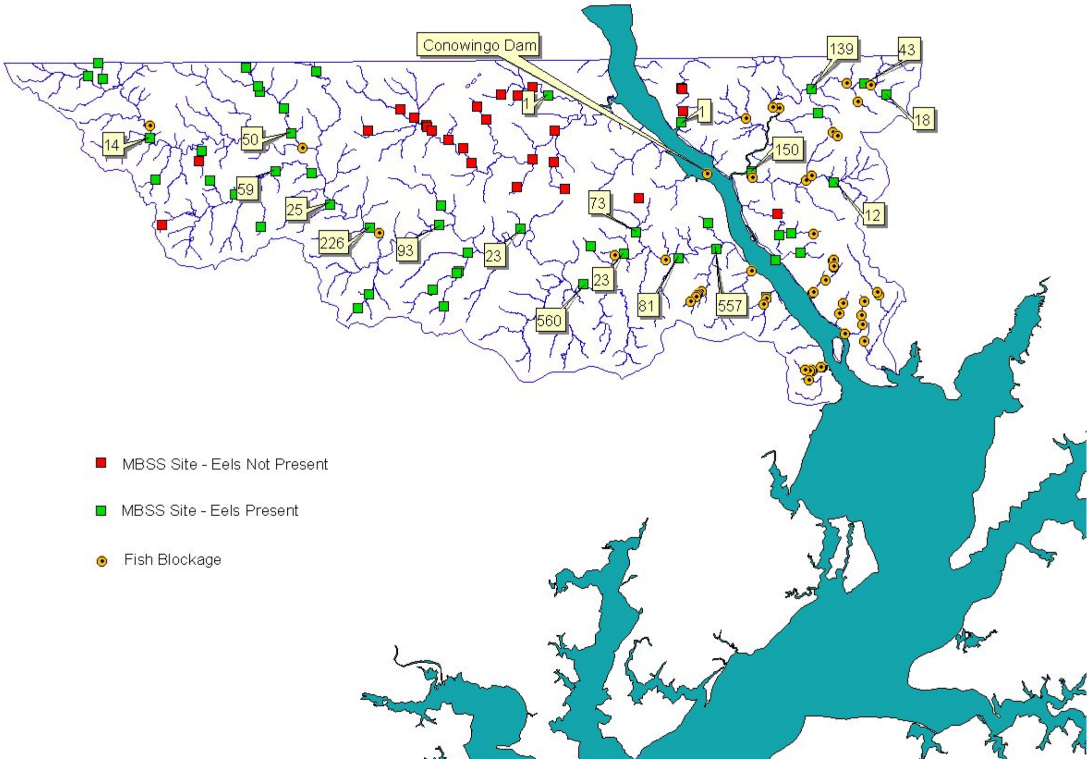

Figure 2. Photo of an Irish Elver Ramp used to sample elvers (young American eels) at the base of Conowingo Dam during 2005.

Figure 3. River flow and temperature below Conowingo Dam, 2006.

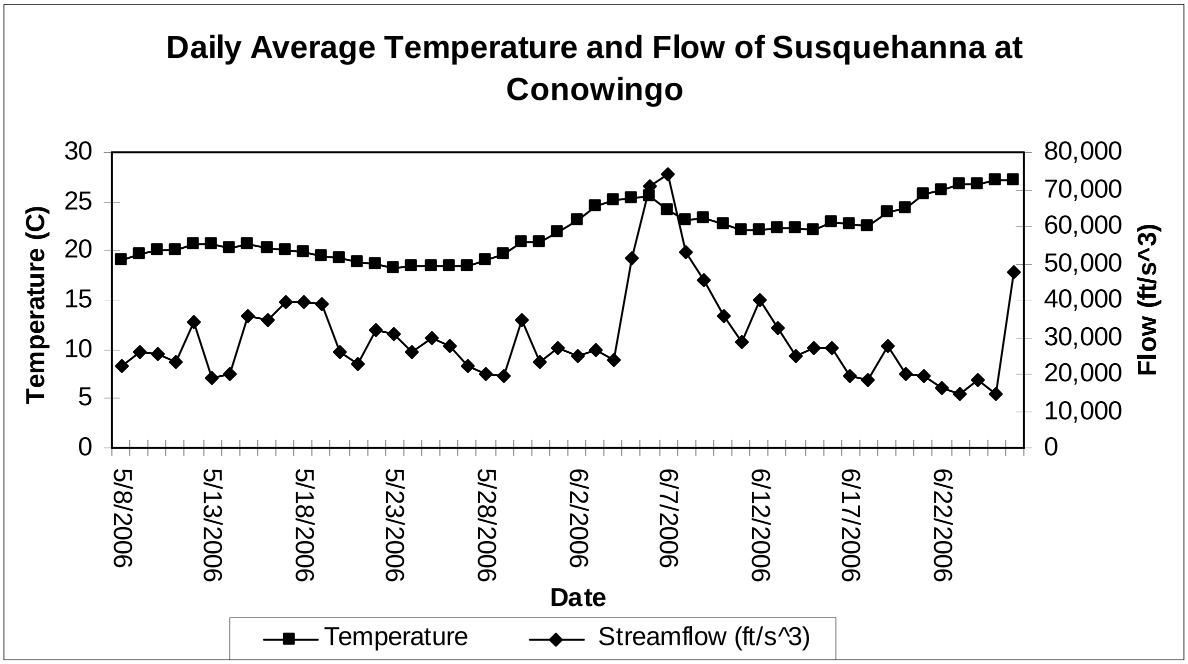

Figure 4. Length frequencies of elvers captured in the Irish Elver Ramp at the base of Conowingo Dam during 2006.

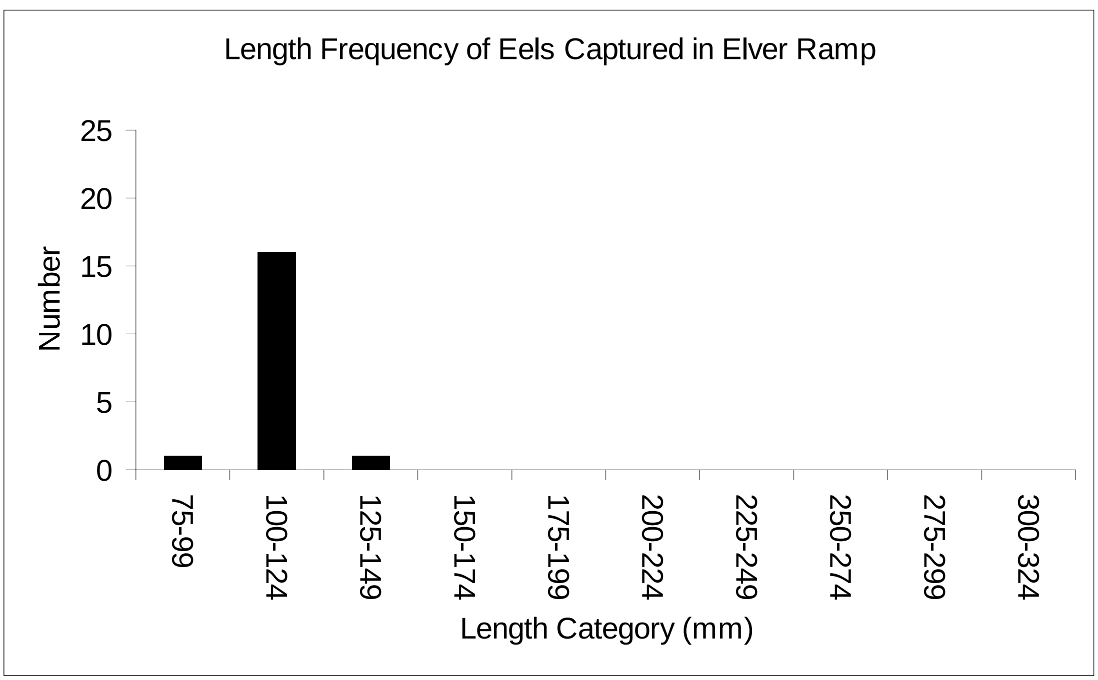

Figure 5. Length frequencies of eels captured in the eel pots at the base of Conowingo Dam during 2006

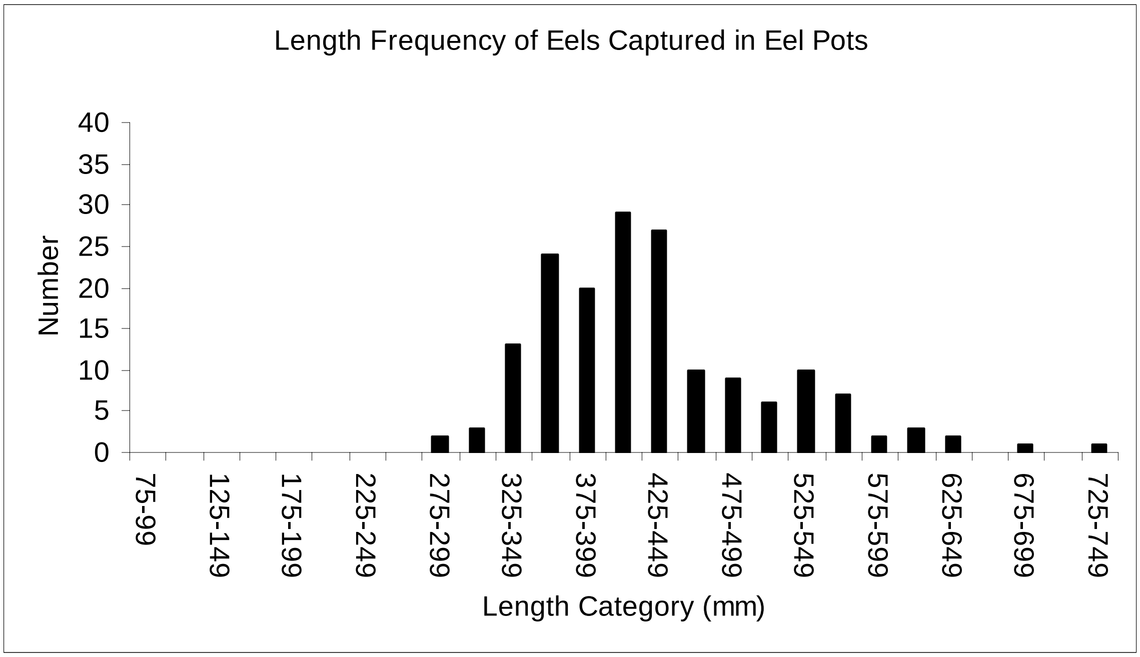

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Figure 6. Elver that was captured in modified Irish elver ramp.

Figure 7. Fin clipped American eel captured in eel pot.

Figure 8. Number of elvers captured against lunar fraction by sample date. Zero lunar fraction is a new moon and 1.0 lunar fraction is a full moon.

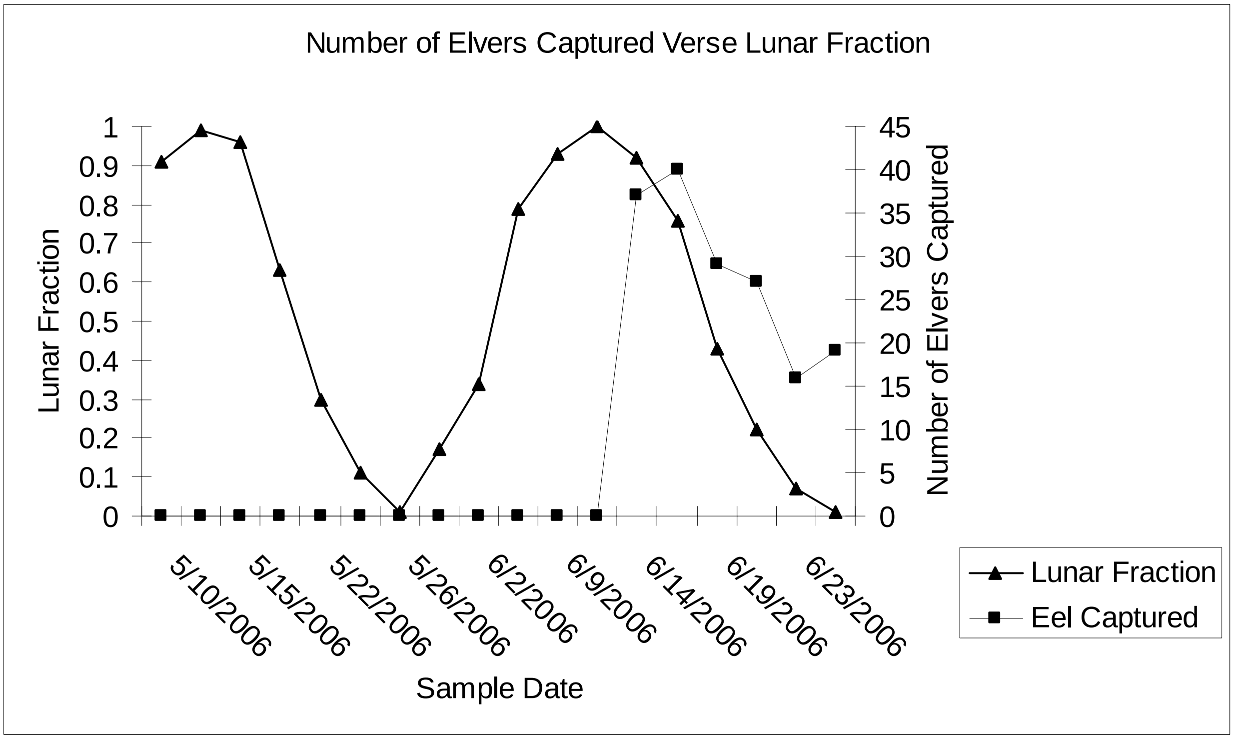

Figure 9. Number of eels captured against lunar fraction by sample date. Zero lunar fraction is a new moon and 1.0 lunar fraction is a full moon.2006

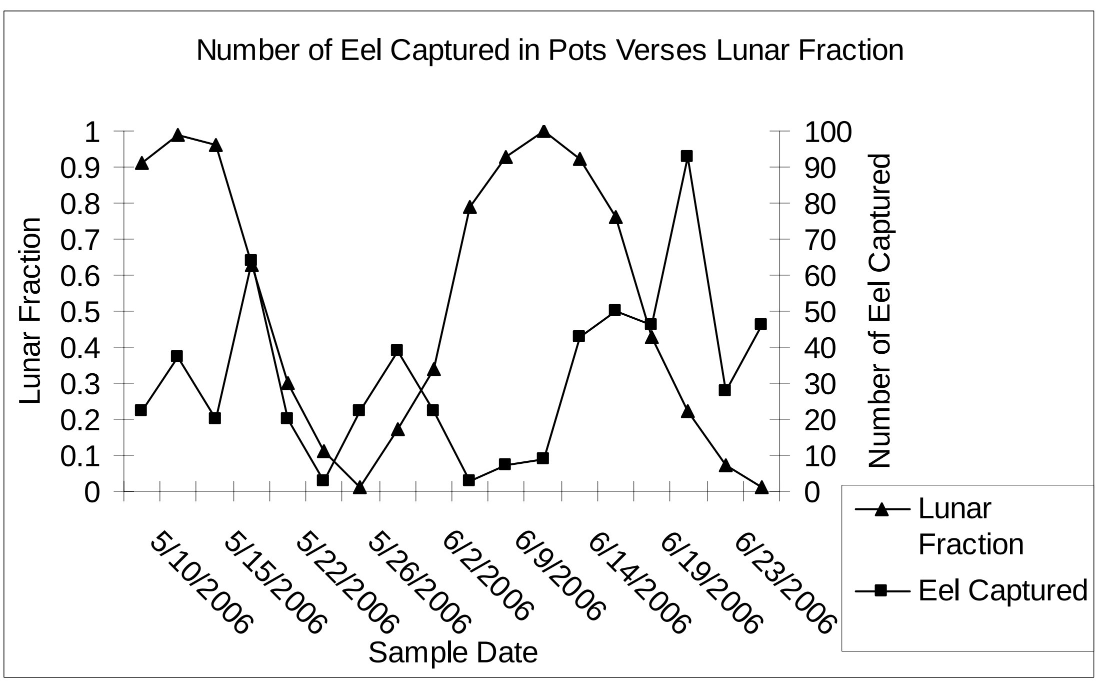

Figure 10. Number of eels caught in the West Fish Lift from 1973 to 1997

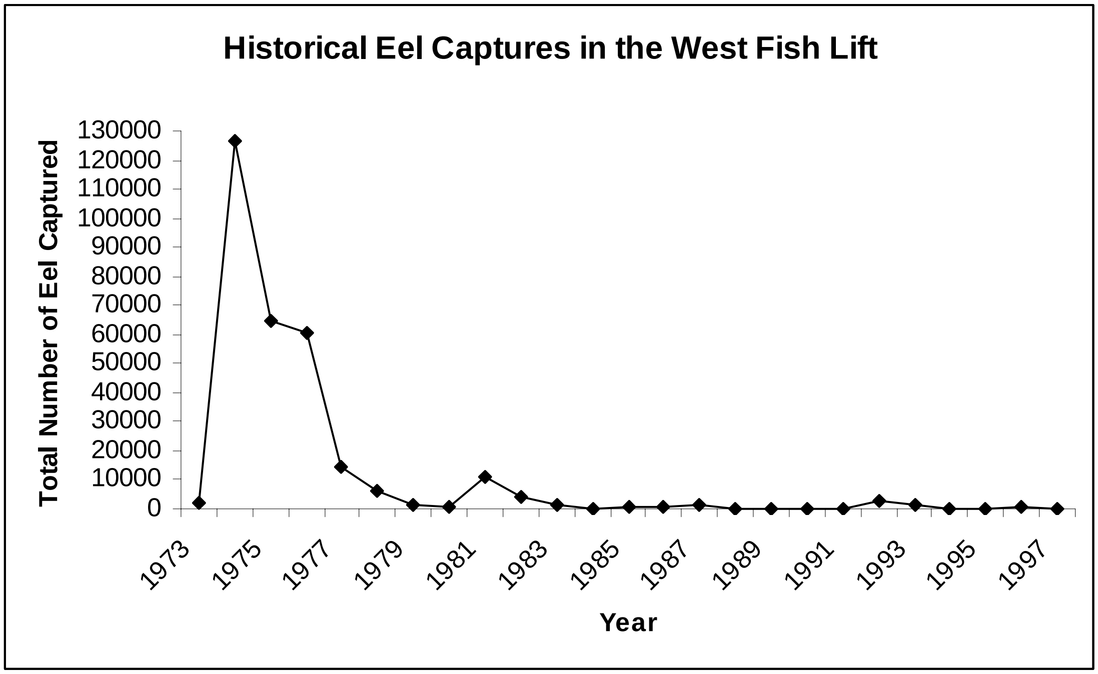

Figure 11. Eel recapture rates by gear selectivity at the base of Conowingo dam. 2006

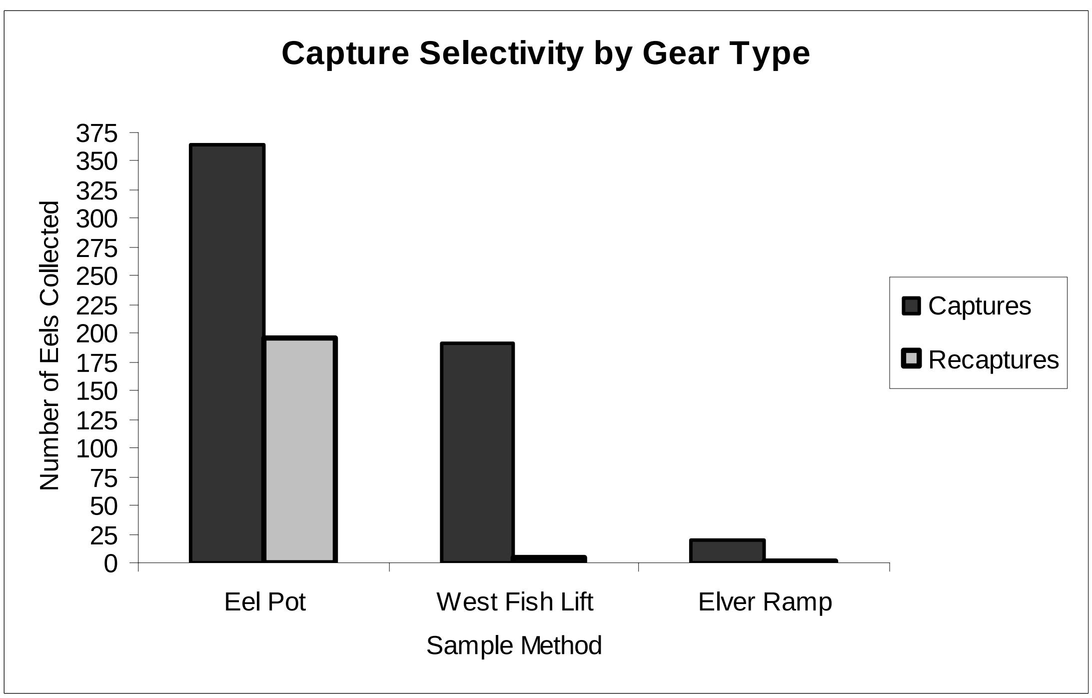

Figure 12. Lunar cycle for 2007 and predicted migration patterns at Conowingo Dam 2007

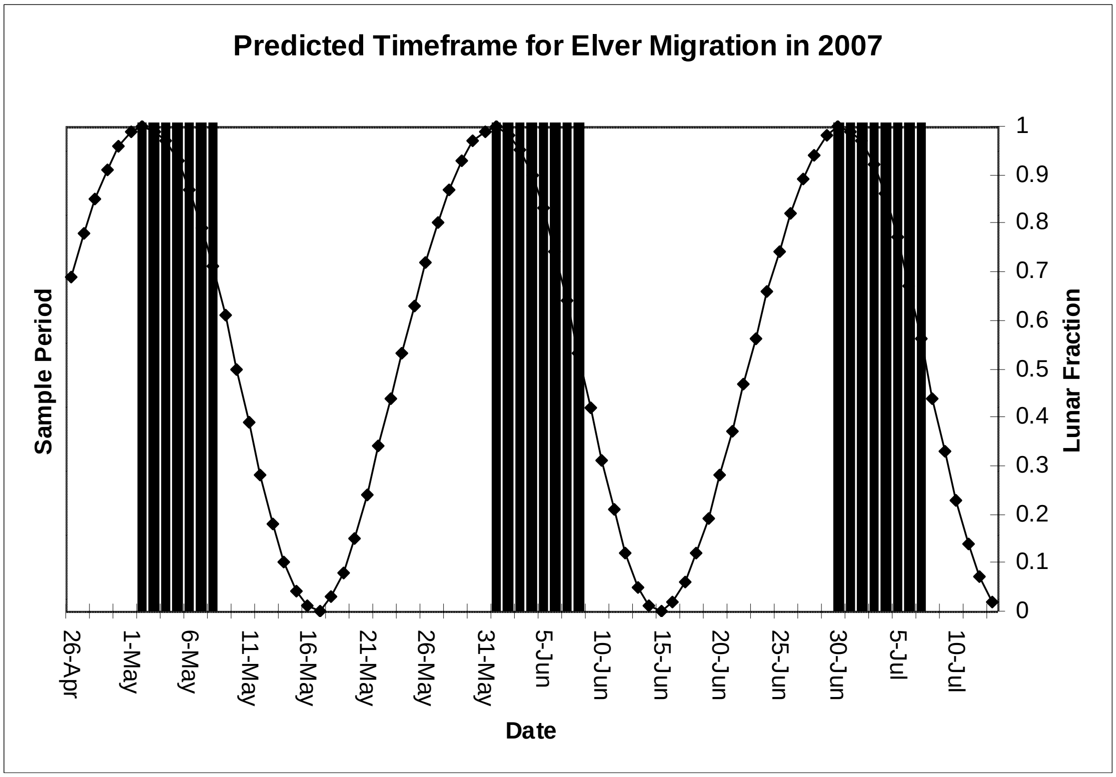

Table 1. Number of eels caught at the base of Conowingo Dam on the Susquehanna River by an Irish Elver Ramp,West Fish Lift and Eel Pots (data are combined for four pots per collection date).

Collection Date	Unit Effort (Days)	Eels Collected in Elver Ramp	Eels Collected in Eel Pots	Eels Collected in West Fish Lift	Total Eel Captured	Average number of Eels Caught per Day
5/10/2006	2	0	22	0	22	11.0
5/12/2006	2	0	37	0	37	18.5
5/15/2006	3	0	20	0	20	6.7
5/19/2006	4	0	63	0	63	15.8
5/22/2006	3	0	20	0	20	6.7
5/24/2006	2	0	3	0	3	1.5
5/26/2006	2	0	22	0	22	11.0
5/31/2006	5	0	39	0	39	7.8
6/2/2006	3	0	22	0	22	7.3
6/7/2006	5	0	3	0	3	0.6
6/9/2006	2	0	7	0	7	3.5
6/12/2006	3	0	9	0	9	3.0
6/14/2006	2	6	12	34	52	26.0
6/16/2006	2	8	3	38	49	24.5
6/19/2006	3	3	7	36	46	15.3
6/21/2006	2	0	52	36	88	44.0
6/23/2006	2	2	10	16	28	14.0
6/26/2006	3	0	14	32	46	15.3
Total	50	19	365	192	576	12.9

Table 2. Recapture rates for eels collected in Eel Pots during the study at the base of Conowingo Dam on the Susquehanna River.

Sample Date	Number of Eels Collected	Number of Eels Marked	Cumulative Number of Eels Captured	Cumulative Percentage of Eels Marked
5/18/2005	2	0	2	0
6/1/2005	5	1	8	12.5
6/7/2005	11	1	19	10.5
6/8/2005	9	2	28	14.3
6/10/2005	3	0	31	12.9
6/13/2005	3	0	34	11.8
6/17/2005	23	2	57	10.5
6/20/2005	20	4	77	13
6/23/2005	5	3	82	15.9
6/27/2005	55	10	141	16.3
7/6/2005	0	0	172	13.4
7/8/2005	4	0	181	12.7
7/11/2005	0	0	182	12.6
7/15/2005	20	1	202	11.9
7/22/2005	17	7	219	14.2
7/26/2005	11	3	231	14.7
8/2/2005	20	10	251	17.5

Job VI

POPULATION ASSESSMENT OF AMERICAN SHAD IN THE UPPER CHESAPEAKE BAY

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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 two years. The Maryland Department of Natural Resources (DNR) is committed to restoring these species to the Susquehanna River Basin to sustainable, self-producing populations.

METHODS AND MATERIALS

Adults American Shad

Field Operations

American shad were angled from the Conowingo tailrace (Figure 1) on the Susquehanna River two to five times per week from 25 April through 31 May 2006. 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.

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 (1980-2006) 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.

Adult Hickory Shad

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.

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.

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.

RESULTS

Adult American shad

Sex and Age Composition

The 2006 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.63:1. Of the 360 fish sampled by this gear, 338 (94.2%) were aged directly from their scales (Table 1). American shad not aged directly because of regenerated scales, were not assigned an age.

Males were present in age groups 3-7 while females were found in age groups 3-9 (Table 1). The 2002 year-class of males (age IV) was the most abundant age group sampled, accounting for 48% of the total catch. For females, the 2002 (age IV) was the most abundant age group, accounting for 46%, of the total catch.

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line was 16.2% for males and 16.3% for females (Table 1). The arcsine-transformed proportions of Conowingo tailrace American shad repeat spawners (sexes combined) had been increasing until 2006 when it decreased (Figure 3).

Relative Abundance

During east lift operations from 03 April to 05 June 2006, clerks counted 56,899 American shad passing the viewing window. Peak passage was on 03 May when 6,130 American shad were recorded. Breakdown of the 84 marked fish observed is listed below.

Tag Color	Year Tagged	Number Observed
Orange	2006	80
Green	2005	1
Yellow	2003	1
Blue	2002	2

Total tags = 84

In 2006, the west lift at Conowingo Dam operated from 19 April to 2 June. The 3,970 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 14 May when 339 American shad were recorded. Fourteen tagged American shad were recaptured in 2006 from the west lift

The Conowingo tailrace American shad relative population estimate in 2006 was 168.165 (95% confidence intervals 135,455-199,493; 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 were not significantly different since 2002 (hook and line: r^2=0.68, P= 0.08; Table 3 and Figure 5) while fish lifts geometric mean CPUEs have decreased significantly since 2002 (r^2=0.92, P=0.01; 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.

Adult Hickory shad

Relative Abundance

Estimates of annual recreational hook and line (1998-2005) catch-per-angler-hour (CPAH) in Deer Creek ranged from 4.3 to 8.3 and have varied without trend since 1998 (r^2=0.09, P=0.41; Table 6).

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.

Job VI

Juvenile American and Hickory Shad

Relative Abundance

No juvenile American shad were caught in the Susquehanna River during the inriver summer seining, in 2006. Young-of-the-year bluegill were the predominate fish caught.

DISCUSSION

Adult American shad

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.).

Juveniles American shad

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.

Adult Hickory shad

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.

Job VI

Juvenile Hickory shad

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.

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Job VI

Table 1. Numbers of adult American shad and repeat spawners by sex and age sampled from the Conowingo tailrace in 2006.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	0	--	0	--	0	--
3	17	0	1	0	18	0
4	62	2	95	0	157	2
5	43	12	74	7	117	19
6	6	5	19	8	25	13
7	2	2	12	12	14	14
8	0	--	6	6	6	6
9	0	--	1	1	1	1
Totals	130	21	208	34	338	55
Percent Repeats	16.2		16.3		16.3	

Table 2. Conowingo tailrace population estimate of adult American shad in 2006.

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

2006 survey results:

C = 39,596
M = 343
R = 80

Therefore:

$$N = \frac{(39596 + 1)(343 + 1)}{(80 + 1)} = 168,165$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N = \frac{(39,597 + 1)(343 + 1)}{(64.28 + 1)} = 199,493$$

$$\text{Lower } N = \frac{(39,597 + 1)(343 + 1)}{(99.56 + 1)} = 135,455$$

Table 3. Conowingo Dam tailrace hook and line data, 1982-2006.

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

Table 4. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2006.

Year	Number of Interviews	Total Fishing Hours	Total Catch of American Shad	Mean Number of American Shad Caught Per Hour (CPAH)
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49
2006	78	227.3	305	1.34

Table 5. Summary of the spring American shad logbook data, 1999-2006.

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

Table 6. Summary of the spring hickory shad log book data from Deer Creek, 1998-2006.

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

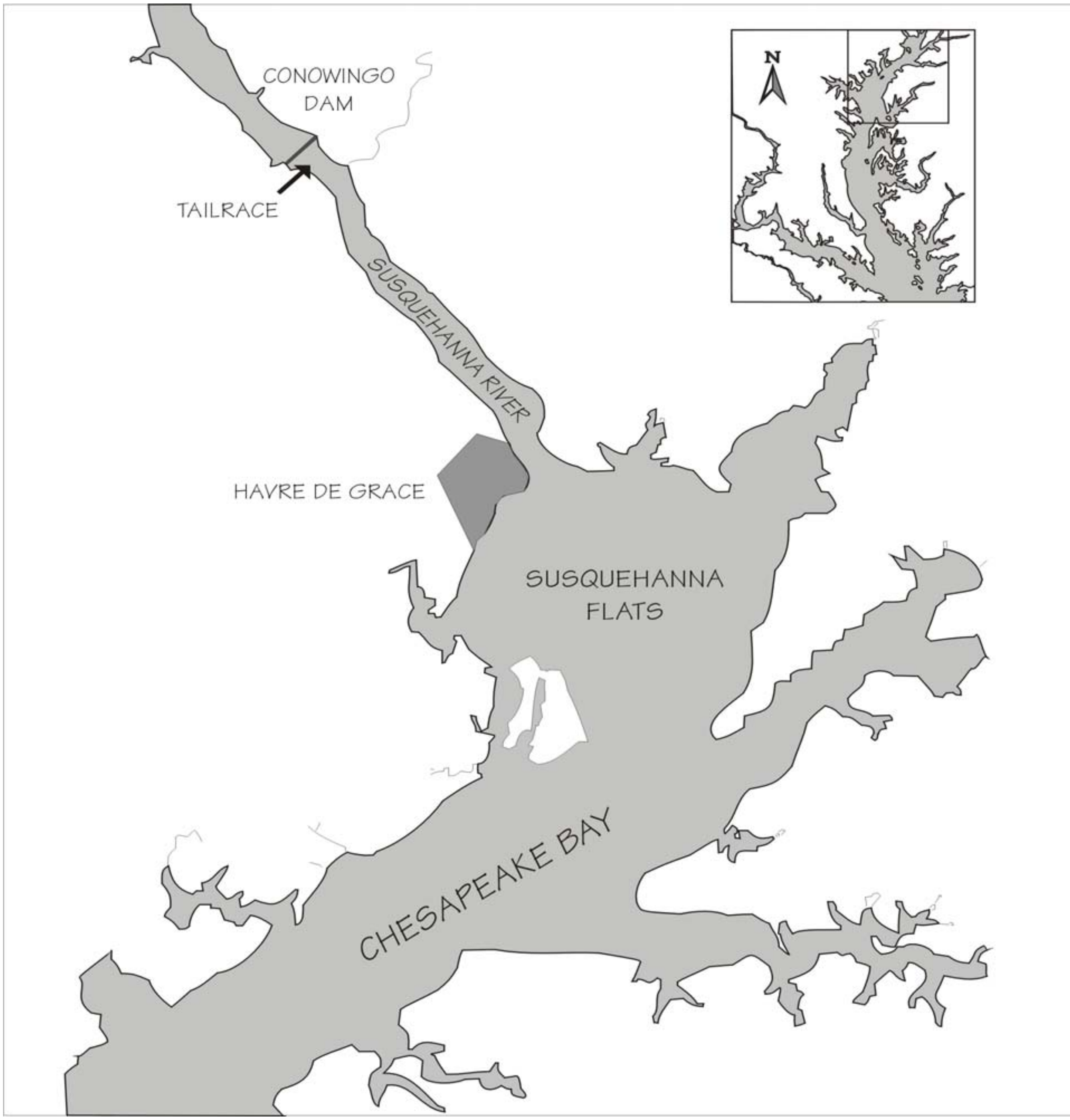

Figure 1. Location of the hook and line sampling in Conowingo Dam tailrace in 2006.

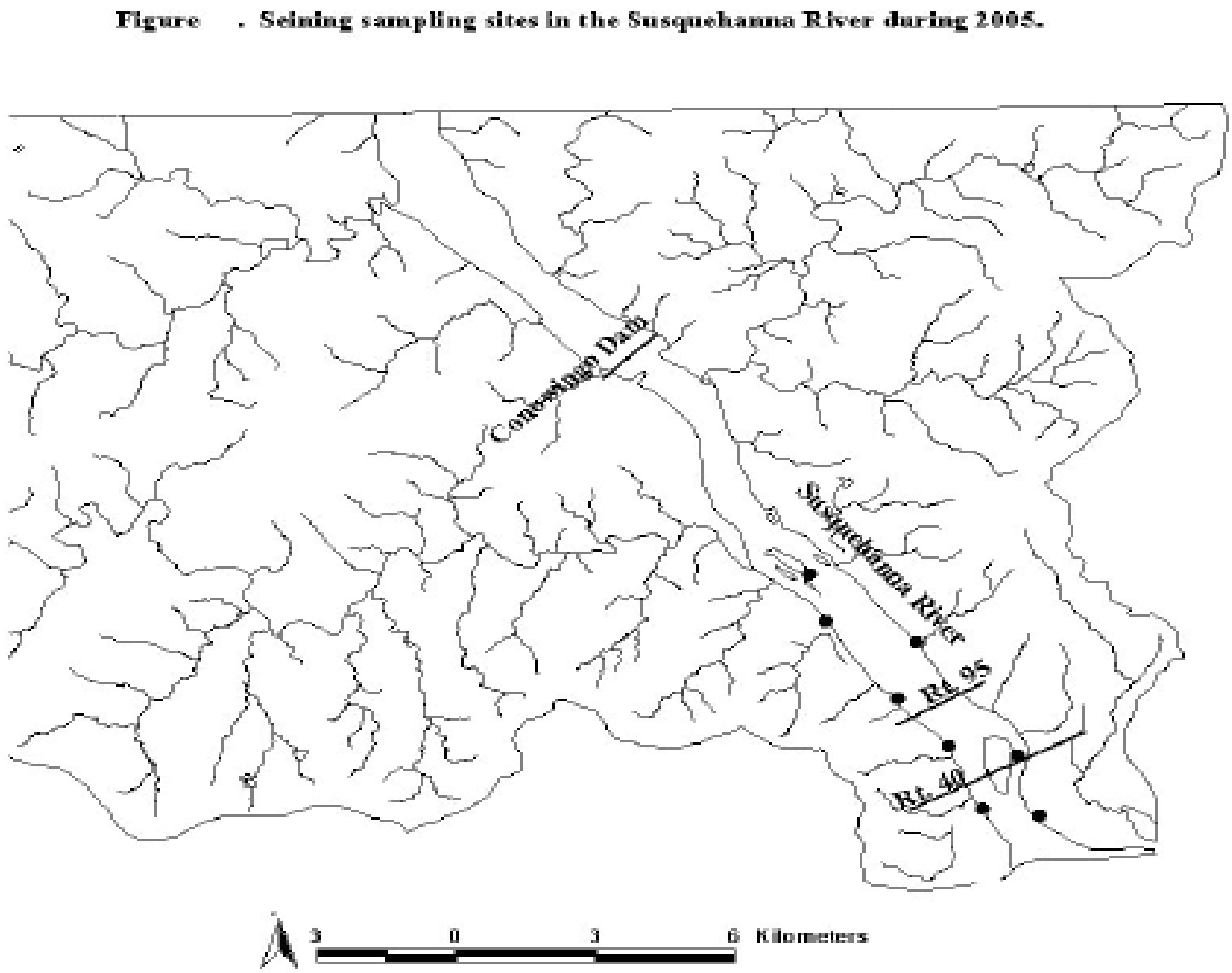

Figure 2. Distribution of the 2006 seine sites (black circles) on the Susquehanna River.

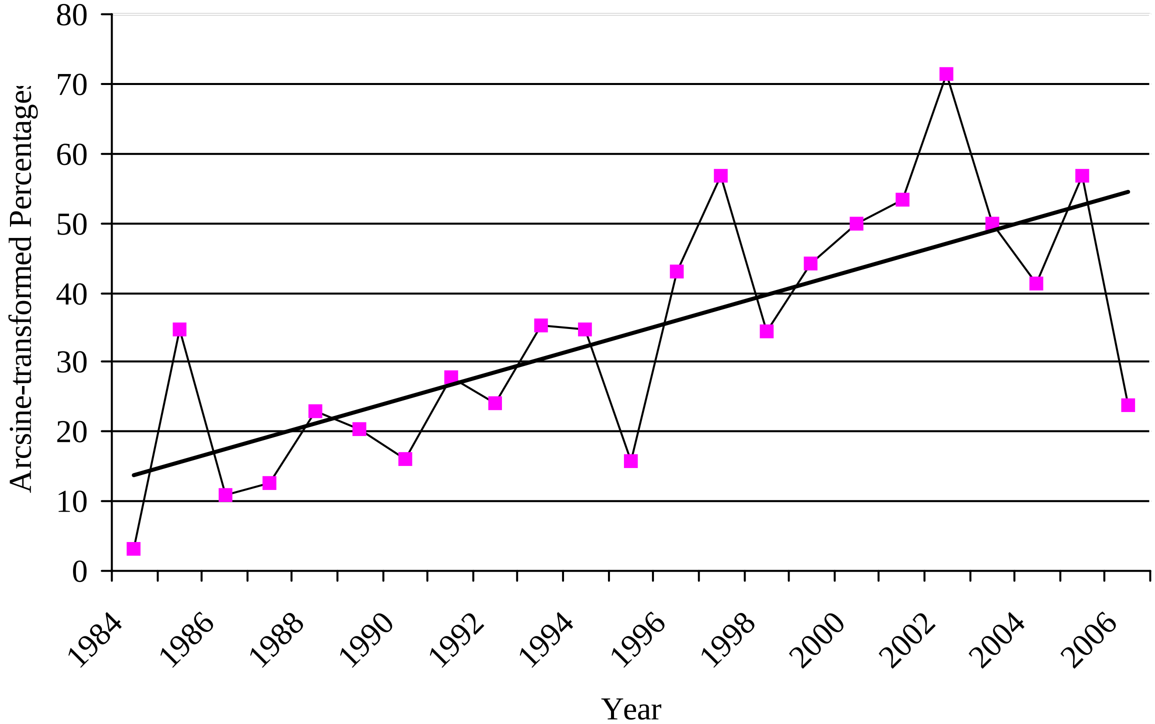

Figure 3. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2006).

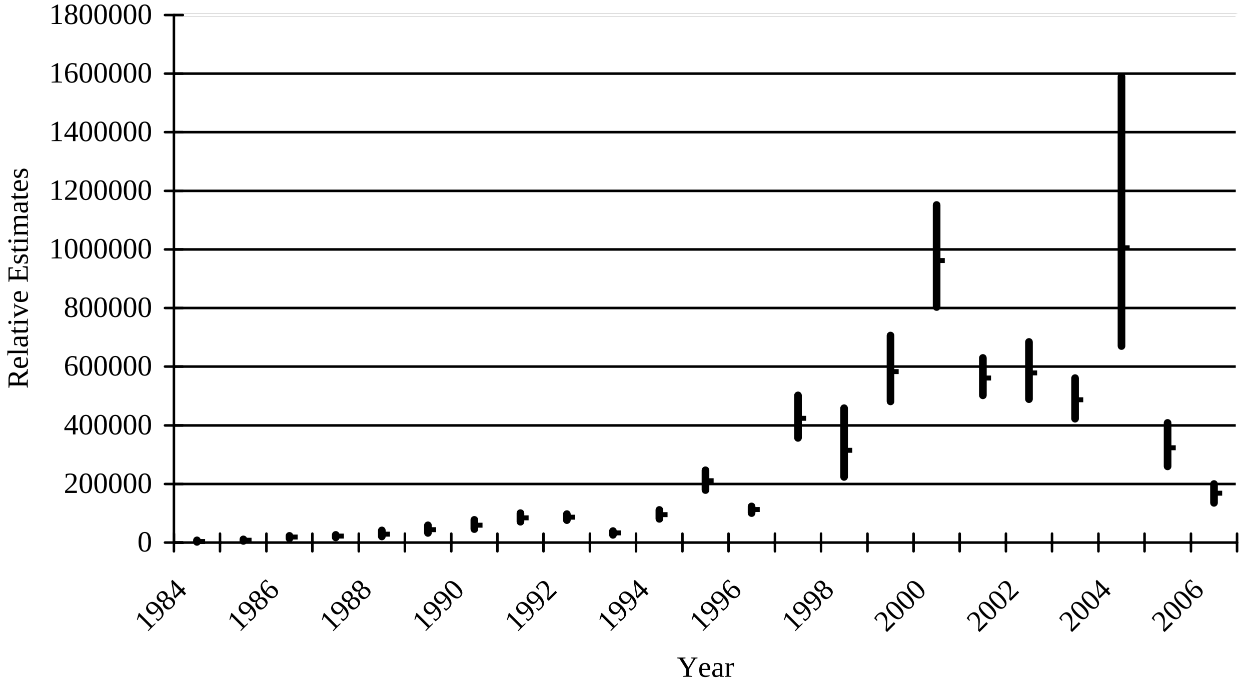

Figure 4. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2006.

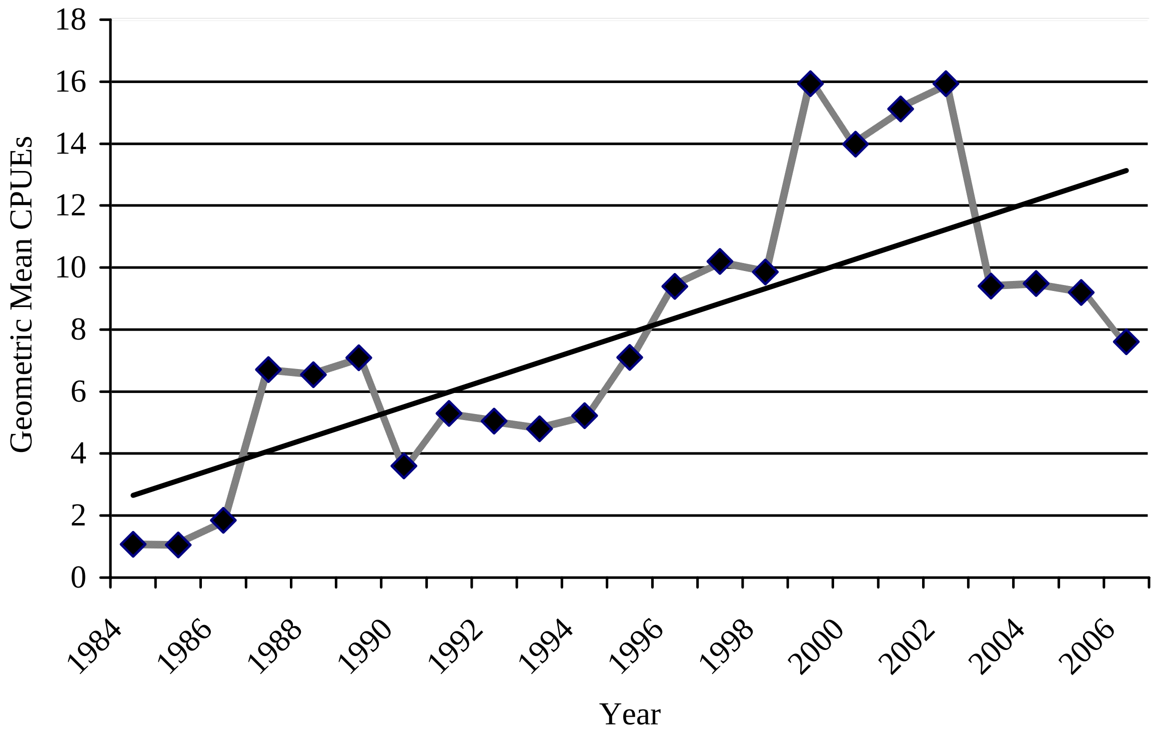

Figure 5. Geometric mean CPUEs from Conowingo Dam tailrace hook and line sampling, 1984-2006.

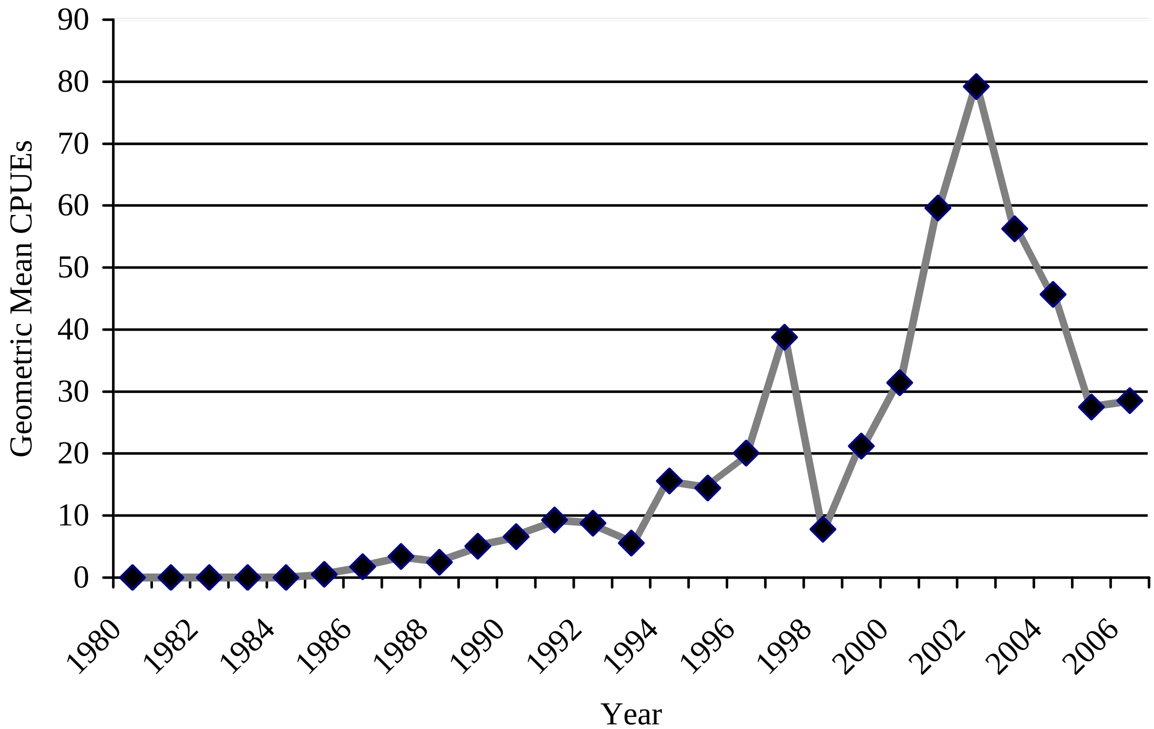

Figure 6. Geometric mean CPUE of American shad from the lifts at Conowingo Dam.

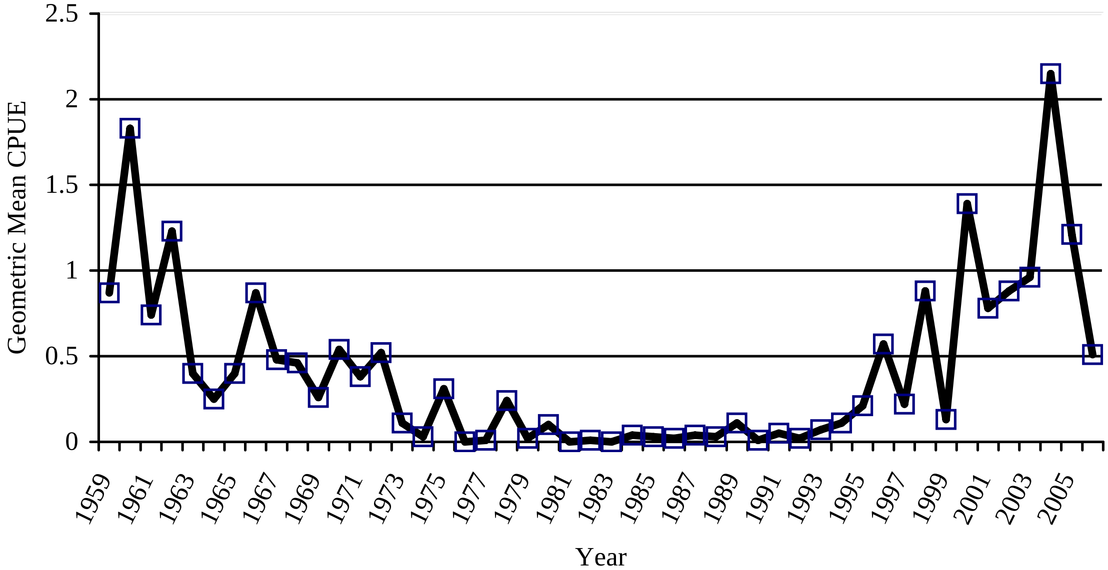

Figure 7. Baywide juvenile American shad geometric mean CPUEs, 1959-2006.

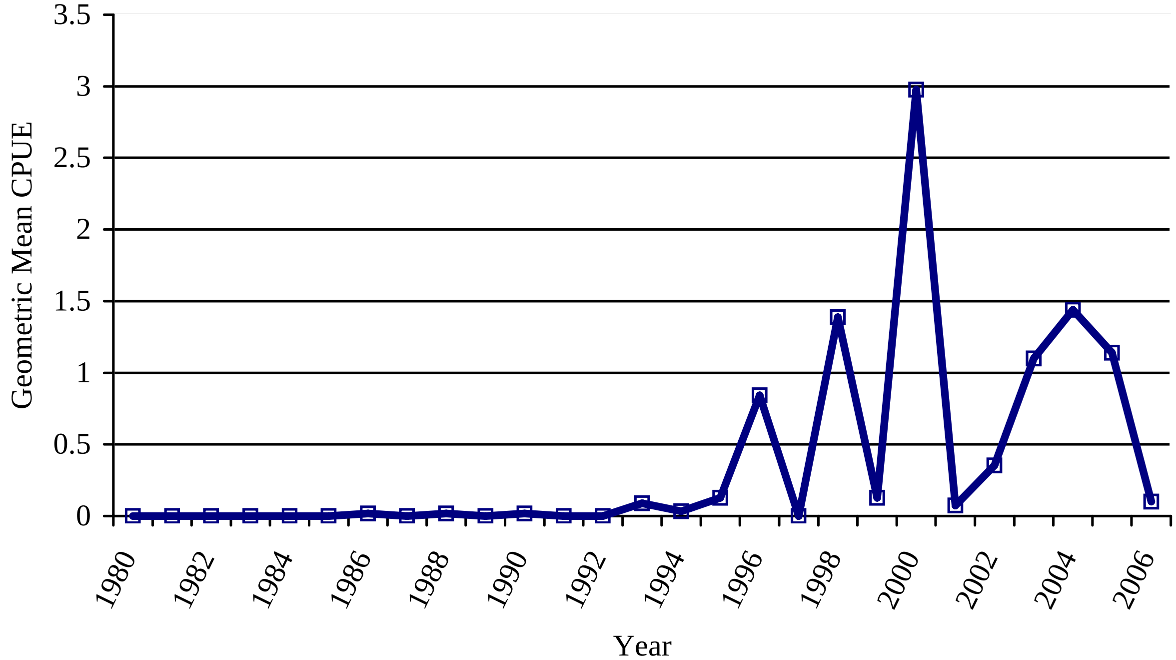

Figure 8. Upper Chesapeake Bay juvenile American shad geometric mean CPUEs, 1980-2006.