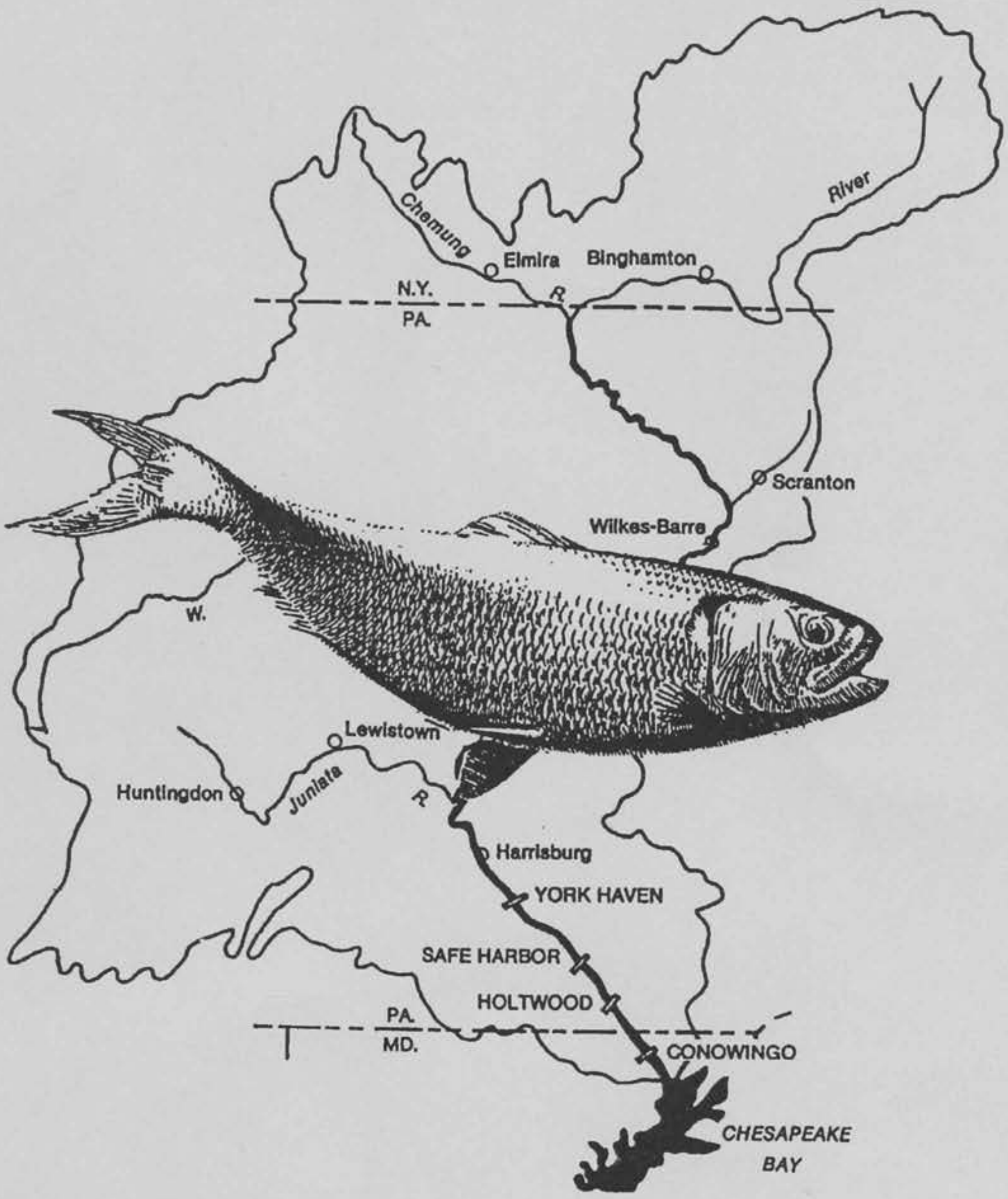
Restoration of American Shad to the Susquehanna River

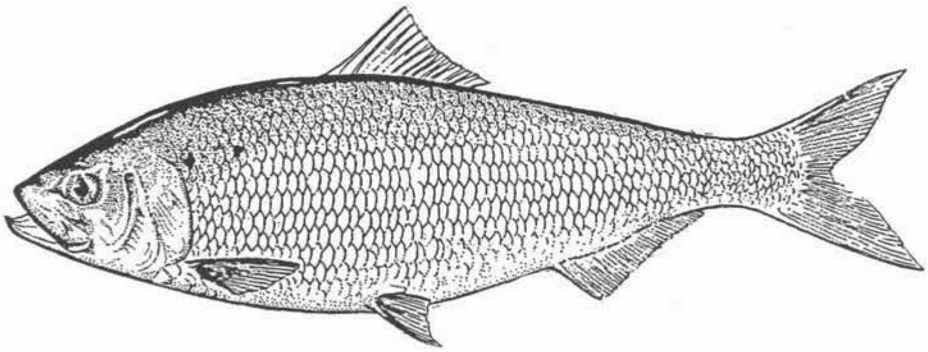
Annual Progress Report
2005



Susquehanna River
Anadromous Fish Restoration Committee

February 2006

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2005

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

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

FEBRUARY 2006

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EXECUTIVE SUMMARY

This 2005 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 directly passed 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 parties to return migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

Spring 2005 was characterized by relatively low river flows and cool water temperatures, ideal conditions for attracting migratory fish. The Conowingo East lift began operations on April 15, shad first appeared in abundance on April 20, and the lift operated every day thereafter through June 8 when high water and low catch terminated operations. For the season the East lift operated 52 days, made 541 lifts and passed 377,762 fish. Gizzard shad (305,378) and American shad (68,926) comprised over 99% of all fish passed. Other alosines included only 4 blueback herring and no alewives or hickory shad. About 80% of the season total of American shad passed the East lift during May 1-20 with peak day passage on May 11. A total of 112 Maryland DNR tags were observed here, all but seven of which were 2005 (78) and 2004 (27) fish tagged in the tailrace.

West lift operations started on April 26 and continued intermittently until June 6 for a total of 30 operating days. The facility fished for 166 hours and made 295 separate lifts. Total catch amounted to 94,767 fish (36 taxa) including 82,412 gizzard shad, 3,896 American shad, 1,692 channel catfish and 1,179 carp. No other alosines were collected. Sex ratio in the American shad run was 1.2 to 1 favoring females. Every 50th shad collected throughout the season was killed for otolith analysis and scale samples. A total of 1,135 shad were used for tank spawning on-site at Conowingo Dam and 445 fish were transported to York Haven Dam for a telemetry study.

The tailrace lift at Holtwood operated on 36 days during April 27 through June 10, fishing for 318 hours and making 403 lifts. The spillway lift (severely damaged in late 2004) operated on only 2 days making 7 lifts in 9.3 hours of operation. Facilities were not operated during May 6-14 due to mechanical breakdowns. Spillage occurred only during the first week of the season in 2005 compared to every day at Holtwood during the 2004 season. This, coupled with relatively low and stable water temperature, led to the third highest annual shad passage count since lift startup in 1997. A total of 34,189 American shad were passed in 2005 (10 times that of 2004) with all but 91 fish using the tailrace lift. Other fish in combined Holtwood collections included 52,708 gizzard shad and 3,844 others. Shad passage rate at Holtwood in 2005 was 49.6% of those passed at Conowingo East lift, the highest level since 2001 when 56.4% were passed.

The Safe Harbor fish lift operated for 298 hours during 37 days between May 2 and June 13 and made 322 lifts. The facility did not operate on May 11-15 due to Holtwood shutdown. Total fish passage for the season was 111,778 fish including 25,425 American shad and 44,387 gizzard shad. Most common other fish in collections were quillback (29,062), channel catfish (5,345), walleye (2,651) and shorthead redhorse (2,290). Safe Harbor passed about 74% of the American shad counted at Holtwood.

Fish ladder operations at York Haven's East Channel Dam occurred on 44 consecutive days between May 5 and June 17 with American shad observed passing the site on all but 3 of the first 4 days. For the season, total fish passage at York Haven amounted to 35,940 fish including 12,882 gizzard shad, 1,772 American shad (7% of Safe Harbor total), and 21,286 others (18 species). Most American shad (65%) passed York Haven during the 15-day period May 19 – June 2.

Maryland DNR collected shad for tag and release by angling in the Conowingo tailrace. Total catch was 412 shad of which 394 were tagged and released. This was the lowest catch per effort since 1995. Using recapture (tag sightings) from the East lift (78 tags), a shad population index was calculated for the Conowingo tailrace of about 322,000 fish, the lowest annual estimate since 1998. Since 2001, DNR has conducted a roving creel census of anglers below Conowingo Dam. The CPUE (number of shad per angler hour) was lower in 2005 than in prior surveys. Scale analysis from DNR angling samples showed that most males were aged 4-6 with 29.5% repeat spawning, and most females were ages 4-7 with 30.1% repeat spawners.

Based on analysis of 274 readable otoliths from adult shad taken at Conowingo West lift, 178 (65%) were of hatchery origin and 96 (35%) were wild. Another 158 otoliths were examined from shad taken in gill net collections at Lapidum. Of these, 94 (59%) were hatchery and 64 (41%) were wild. The majority of hatchery fish in both collections (224 or 82%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River or mainstem Susquehanna below Sunbury. Remaining tagged fish (1 to 22 each) carried various double, triple, quadruple, and quintuple marks. Based on the analysis of hatchery vs. wild adult shad returning to Conowingo, age of fish, and known stocking numbers, PFBC calculated that, on average for the fully recruited year-classes of 1986-1998, it took an average 181 stocked larvae to produce each trapped or passed adult shad returning upstream.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River above Catskill, NY and PFBC completed Delaware River egg collections at Smithfield Beach, PA. The Hudson effort started late due to NYDEC license problems with the contractor and produced only 2.92 million eggs in 13 nights with 72.4% viability. Delaware River collections amounted to 6.21 million eggs in 18 shipments with 31.8% viability. In a fifth year attempt at tank spawning at Conowingo Dam, Normandeau Associates used two tanks and completed 11 spawning trials using 1,135 American shad to produce 8.0 million eggs of which 23.9% were viable. Fish received 150 ug doses of LHRH hormone in either pellet or liquid injections.

In a third year effort, Normandeau also tank-spawned 712 hickory shad (mostly angled) in 8 trials and produced 28.73 million eggs of which 61.4% were viable. USFWS completed a third year effort to collect and strip spawn American shad in the lower Susquehanna River near Lapidum. They worked with a commercial fisherman using gill nets during eight nights over a 4-week period in May and netted 169 shad. Collections included only 12 bucks and few ripe females. No eggs were sent to Van Dyke from this source in 2005. Total American shad egg collections from all locations in 2005 amounted to 17.1 million with an overall viability of 36.6%.

In 2005, Van Dyke Hatchery produced 5.21 million American shad fry and 17.16 million hickory shad larvae. Of the American shad, 3.57 million were stocked in the Susquehanna drainage as follows: 2.23 million in the Juniata River; 1.02 million in the Susquehanna below Sunbury; and 335,000 in the West Branch. The North Branch (including NY waters), lower Susquehanna tributaries, and the Raritan River (NJ) were not stocked in 2005 due to reduced numbers of larvae available. Van Dyke American shad were also stocked into the Schuylkill (798,700), Lehigh (668,800) and the Delaware at Smithfield (169,800). Hickory shad larvae were stocked at the Muddy Creek access in Conowingo Pond (5.36 million), the Delaware River (3.2 million) and two Delaware tributaries (8.6 million). All fish were distinctively marked with tetracycline, with hickory shad larvae receiving twice the TC concentration as American shad.

As was the case in 2002-2004, juvenile shad collections were relatively weak in 2005. The haul seine at Columbia, PA produced only 23 shad in 15 weeks of effort (90 hauls). These fish were taken in small numbers (1-5) on 11 dates between July 20 and October 20. Otolith analysis showed that 21 (91%) of these fish were wild. The usually productive lift net at Holtwood attempted shad collections on 27 nights during the period September 13 through November 30. A total of 200 shad was collected, all in three nights between October 25 and 31. Fifty-five shad from this collection were analyzed and 31 fish (56%) were wild.

Peach Bottom APS intakes were sampled on 16 occasions (24-hour screen washes) between October 12 and November 9 and produced 120 shad. Of these, 117 were processed and 54 (46%) were found to be wild. Conowingo strainers produced a total of 25 shad, 83% of which were wild. Overall, juvenile collections at and above Conowingo provided 368 shad of which 230 were analyzed for tetracycline marks. Of these, 58.5% were naturally produced and 41.5% were of hatchery origin.

During July-September seine sampling in the upper Chesapeake Bay (Flats), Maryland DNR collected 244 juvenile shad. Catch per unit effort in 2005 was very similar to that from 2003-2004. Though otoliths from 2005 collections have not yet been analyzed, results from the 2004 fish showed they were all wild. DNR gill netting at seven sites in the Susquehanna River below Conowingo produced one shad.

The first year of a 2-year genetic assessment of Susquehanna shad was completed by USFWS Northeast Fishery Center (NEFC). This study is aimed at defining the egg source origin of wild American shad returning to the Susquehanna River to spawn. Adult shad tissue samples were taken from fish at Conowingo Dam (277), Lapidum (162), Hudson River (91) and Delaware

River (155). Otolith analysis indicated that 96 fish from Conowingo and 64 from Lapidum were wild. Using tissue samples from wild fish, microsatellite libraries were developed and DNA sequencing produced 1200 sequences that have potential microsatellite loci. During 2006, these sequences will be screened for quality of repeats, allelic variability, and the potential to amplify in other alosines species. All 406 wild fish from the four locations will be genotyped.

Under contract to PFBC, an underwater acoustics study was completed at Holtwood Dam. High frequency sound can theoretically be used to repel or guide adult shad. Earlier studies using radiotagged shad at Holtwood indicated that many fish entered the tailrace fish lift entrance but did not proceed through the crowder gates to the lift hopper. The purpose for this study was to setup and test whether or not high frequency sound can be used to "push" shad past the crowder, thereby increasing passage success. Although fish were startled by the sound it remains unclear whether or not this technology can enhance fish passage effectiveness at Holtwood.

USFWS staff from Annapolis set elver traps and baited eel pots near the Conowingo West lift to determine if various life stages of American eel could be attracted and collected at that site. A single trap and 2-3 baited pots were tethered to the catwalk of the West lift in the dead-end corner nearest the west shore. These were fished for 78 days between May 18 and August 2, being checked on 17 occasions. The elver ramp produced 43 fish of which 41 measured less than 200 mm. Eel pots produced 251 eels, all but one larger than 250 mm and ranging up to 750 mm. Most eels were fin-clipped and overall recapture rate was 17.5%. Elver abundance was greatest during the period of lowest light (new moon) whereas the capture trend for larger eels appeared less related to lunar phase.

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 Delaware rivers, Van Dyke hatchery culture and marking, juvenile shad netting and other surveys above Conowingo Dam, the Holtwood acoustics study 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 lower Susquehanna River shad egg collections and 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 services of a contract fisherman to work with USFWS on Susquehanna egg collections and for genetics supplies and analysis at NEFC. Contributions to the special account in 2005 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 2005

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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 was 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 2005 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. 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 over 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 was maintained for the period 1 to 8 June.

Fishway Operation

East lift operation began 15 April with no recorded American shad passage. There were also no American shad recorded on 18 April. On 20 April, a total of 674 American shad were recorded, which triggered every day operations. The season ended on 8 June due to an extended period of high water temperature, the advanced spawning condition of American shad, and several days of low recorded passage of the target species. The lift was operated a total of 52 days during the 2005 season, and only experienced mechanical problems on 15 May. A faulty shieve wheel bearing on the hopper prevented any further lifts, limiting fish passage to the morning. The problem was fixed the next day, 16 May, enabling operations to resume in the afternoon. Generally, daily operation began at 0800 h and continued until approximately 1900 h. 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 2005 were similar to those described in RMC (1992) and Normandeau Associates, Inc. (1999). Fishing time and/or lift frequency was determined by fish abundance, but the hopper was cycled at least hourly throughout the day. The method of lift operation was also influenced by fish abundance. When a great number of fish were in the fishing channel, the crowder was not operated; instead the crowder screen was raised and then lowered trapping fish over the hopper. This mode of operation, called "fast fish", involved leaving the crowder in the normal fishing position and raising the hopper frequently to remove fish that accumulated in the holding channel. The specific entrance(s) used to attract fishes was dictated by the station discharge and which turbine units were operating. For example, when turbine units 8, 9, 10, and 11 or any combination of large turbines were operating, entrance C was the primary entrance used to attract fishes. Under these conditions the attraction flow through the other entrances was negated or disrupted. Depending on flow, and or generation, entrance C or A was utilized throughout the 2005 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 377,762 fish of 26 species and two hybrids were passed upstream into Conowingo Pond. Gizzard shad (305,378), American shad (68,926), quillback (2,145), carp (540), and smallmouth bass (256), were the dominant species passed. Gizzard shad and American shad comprised 80.8% and 18.2%, respectively, of the season total; the two species together accounting for 99% of the total fish passed. Other common fishes included shorthead redhorse (131), striped bass (89), channel catfish (83), and walleye (47). Alosids, (American shad, and blueback herring) comprised 18.2% of the total catch. Peak passage occurred on 23 April when 20,897 fish (nearly 93% gizzard shad) were passed.

American Shad Passage

The East lift collected and passed 68,926 American shad (Table 1). Collection and passage of shad varied daily with 6.1% (4,217) of the shad passed from 20 to 30 April, 40.9% (28,254) passed from 1 to 10 May, 39.1% (26,949) passed from 11 to 20 May, 11.5% (7,935) passed from 21 to 30 May, and 2.2%

(1,571) passed from 31 May to 8 June (Figures 1 and 2). On 4 of the 48 days of operation, American shad passage exceeded 4,000 fish. Peak passage of 5,235 American shad occurred on 11 May.

American shad were collected at water temperatures of 52.7 to 77.0°F and at natural river flows of 12,200 to 56,100 cfs (Table 2 and Figure 1). The natural river flow and water temperature during the four highest days of passage, (1, 4, 11 and 13 May), ranged from 18,900 cfs to 48,000 cfs and 56.0°F to 63.0°F, respectively. The average daily river flow on those days when American shad passage exceeded 1,000 fish was approximately 24,257 cfs. The average daily river flow during the operational season was 27,350 cfs.

The hourly passage of American shad for the East lift is given in Table 3. Peak passage of shad (65,889 or nearly 95.6% of total passage) occurred between 900 and 1859 h. The highest hourly shad passage rate, 8,117, was recorded from 1400 to 1459 h. Generally, shad passage increased during the morning hours, peaked and remained steady throughout the day, then sharply declined during early evening hours.

Alosids

No hickory shad or alewives were passed during the 2005 season. Only 4 blueback herring were collected and passed in spring 2005.

SUMMARY

East fish lift operation was initiated on 15 April with the first American shad passed on 20 April. The East fish lift passed 68,926 American shad from 20 April through 8 June. The total number of American shad passed during the 2005 season was the lowest passage total in East lift operations since 1998, and is the first time in six years which the lift has failed to surpass the 100,000 mark (Table 4). Several other East Coast rivers also experienced smaller runs of American shad in 2005, (Richard St. Pierre, personal communication). During the season, the East fish lift passed a total of 112 American shad that were captured, tagged and released downstream of Conowingo Dam by the Maryland DNR. Of these tagged fish, 78 were green (2005), 27 pink (2004), 4 orange (2003), 2 yellow (2003 gill net), and 1 blue (2002).

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 105 American shad lift mortalities (0.15% of the total shad passed) were observed in 2005, lower than the 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.

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2005. No operation on April 16, 17, and 19.

Date:	*4/15*	*4/18*	*4/20*	*4/21*	*4/22*	*4/23*	*4/24*	*4/25*
Start Fishing Time:	*12:45*	*12:00*	*10:00*	*9:00*	*9:15*	*9:25*	*9:25*	*9:00*
End Fishing Time:	*15:00*	*15:00*	*17:00*	*17:00*	*17:25*	*18:00*	*16:14*	*18:00*
Hours of Operation:	*2.3*	*3.0*	*7.0*	*8.0*	*8.2*	*8.6*	*6.8*	*9.0*
Number of Lifts:	*3*	*3*	*11*	*10*	*11*	*13*	*9*	*12*
Water Temperature (°F):	*52.7*	*55.4*	*58.9*	*59*	*60*	*60.5*	*58.7*	*59.6*
American Shad	0	0	674	210	523	1,546	241	733
Blueback Herring	0	0	0	0	0	0	0	0
Gizzard shad	499	4,191	14,673	10,334	13,877	19,318	3,656	12,516
Striped bass	0	0	0	0	0	1	0	1
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	0	0	0	0	0	2
American eel	0	0	0	0	0	0	0	0
Sea lamprey	0	0	2	1	2	3	0	4
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	2	1	0	1	2
Quillback	0	0	1	0	0	1	0	1
White sucker	0	0	3	0	1	2	0	0
Shorthead redhorse	0	0	2	0	0	1	1	0
White catfish	0	0	0	0	0	0	1	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	7	0	0	0	0	0	1	0
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	1	0	0	1	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	1	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	1	0	0	0
Smallmouth bass	0	0	9	7	12	24	2	14
Largemouth bass	0	0	0	0	3	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	0	0	0	0
TOTAL	*506*	*4,191*	*15,364*	*10,555*	*14,420*	*20,897*	*3,904*	*13,273*

Table 1

Continued.

Date:	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
Start Fishing Time:	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*
End Fishing Time:	*16:30*	*17:00*	*16:30*	*15:30*	*14:00*	*18:00*	*17:50*	*18:00*
Hours of Operation:	*7.5*	*8.0*	*7.5*	*6.5*	*5.0*	*9.0*	*8.8*	*9.0*
Number of Lifts:	*9*	*9*	*8*	*8*	*6*	*16*	*12*	*13*
Water Temperature (°F):	*60.5*	*57.2*	*55.4*	*55.3*	*55.4*	*56*	*58.5*	*57.1*
American Shad	99	148	8	3	32	4,776	552	2,731
Blueback Herring	0	0	0	0	0	0	0	0
Gizzard shad	13,757	9,355	6,470	4,798	3,154	15,231	9,810	8,976
Striped bass	0	0	0	0	0	0	1	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	0	0	0	1	0	4	1	5
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	2	0	1	0	0	0	0	1
Quillback	0	0	0	0	0	2	2	0
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	1	12	3	4	5	4
White catfish	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	1	0	0	0	0	0	0
Flathead 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
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	0	0
Smallmouth bass	0	5	6	7	3	5	6	18
Largemouth bass	0	0	1	1	1	0	1	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	1	0	0	0
TOTAL	*13,858*	*9,509*	*6,487*	*4,822*	*3,194*	*20,022*	*10,378*	*11,735*

Table 1

Continued.

Date:	*5/4*	*5/5*	*5/6*	*5/7*	*5/8*	*5/9*	*5/10*	*5/11*
Start Fishing Time:	*10:00*	*9:00*	*8:30*	*8:00*	*7:10*	*8:00*	*8:00*	*8:00*
End Fishing Time:	*19:00*	*18:00*	*18:30*	*19:00*	*18:30*	*19:00*	*17:30*	*18:30*
Hours of Operation:	*9.0*	*9.0*	*10.0*	*11.0*	*11.3*	*11.0*	*9.5*	*10.5*
Number of Lifts:	*16*	*13*	*13*	*15*	*15*	*14*	*15*	*16*
Water Temperature (°F):	*57.2*	*57.2*	*56.2*	*56.84*	*57.2*	*57.6*	*59*	*61.7*
American Shad	4,230	1,888	2,773	3,274	3,266	3,376	1,388	5,235
Blueback Herring	0	0	2	0	0	0	0	0
Gizzard shad	8,689	6,973	5,377	4,225	2,732	4,713	12,678	12,316
Striped bass	1	0	0	0	0	1	0	3
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	1	0	0	0	1	1
American eel	0	0	0	0	0	0	0	0
Sea lamprey	3	1	0	1	2	0	0	0
Rainbow trout	0	1	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	1	0
Carp	3	0	1	0	0	0	5	15
Quillback	0	2	3	1	0	0	2	4
White sucker	0	0	0	0	0	0	2	0
Shorthead redhorse	1	6	10	2	0	7	10	9
White catfish	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	2	1	0	1	0
Channel catfish	0	0	0	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	0	0	0	0	1	0	1	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	1	0
Smallmouth bass	4	3	4	3	5	13	22	21
Largemouth bass	0	0	0	0	1	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	3	2	0	1	4	6
TOTAL	*12,931*	*8,874*	*8,174*	*7,510*	*6,008*	*8,111*	*14,116*	*17,610*

Table 1

Continued.

Date:	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19
Start Fishing Time:	*7:30*	*8:00*	*7:30*	*7:30*	*13:00*	*8:00*	*11:00*	*8:00*
End Fishing Time:	*18:30*	*18:30*	*18:40*	*10:40*	*19:00*	*18:00*	*19:00*	*18:00*
Hours of Operation:	*11.0*	*10.5*	*11.2*	*3.2*	*6.0*	*10.0*	*8.0*	*10.0*
Number of Lifts:	*17*	*15*	*17*	*5*	*11*	*16*	*12*	*15*
Water Temperature (°F):	*63*	*63*	*62.1*	*63*	*67.7*	*67.8*	*68.2*	*68.4*
American Shad	3,445	4,046	3,854	2,095	1,155	3,402	684	2,051
Blueback Herring	0	0	0	0	0	0	0	0
Gizzard shad	8,360	5,931	10,906	2,884	10,545	6,042	7,663	6,341
Striped bass	0	0	0	0	0	0	1	1
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	0	0	0	0	2	0	1	1
American eel	0	0	0	0	0	0	0	1
Sea lamprey	0	1	0	0	0	0	0	0
Rainbow trout	0	0	0	1	1	0	0	1
Brown trout	0	0	0	0	0	0	0	0
Tiger musky	0	0	0	4	0	0	0	0
Carp	0	22	16	9	68	3	152	1
Quillback	65	18	608	285	47	9	172	92
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	13	3	1	23	1	3	0
White catfish	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	3	0	0	0
Channel catfish	6	0	0	1	0	0	0	10
Flathead 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	1
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	1	0
Bluegill	1	0	1	1	0	1	0	0
Smallmouth bass	6	12	3	4	8	2	2	0
Largemouth bass	0	1	0	0	0	0	1	2
Yellow perch	3	0	8	0	6	5	2	0
Walleye	1	2	1	1	0	0	5	2
TOTAL	*11,887*	*10,046*	*15,400*	*5,286*	*11,858*	*9,465*	*8,687*	*8,504*

Table 1

Continued.

Date:	5/20	5/21	5/22	5/23	5/24	5/25	5/26	5/27
Start Fishing Time:	*7:30*	*8:00*	*7:30*	*7:30*	*7:30*	*8:00*	*8:00*	*7:30*
End Fishing Time:	*18:00*	*19:30*	*18:15*	*18:00*	*16:30*	*17:30*	*17:00*	*16:30*
Hours of Operation:	*10.5*	*11.5*	*10.8*	*10.5*	*9.0*	*9.5*	*9.0*	*9.0*
Number of Lifts:	*14*	*16*	*14*	*11*	*9*	*10*	*9*	*9*
Water Temperature (°F):	*67.1*	*67.1*	*67.1*	*67.1*	*68*	*66.8*	*66.4*	*66.4*
American Shad	982	1,574	1,879	406	144	452	974	698
Blueback Herring	1	0	0	0	0	0	0	0
Gizzard shad	5,956	10,023	4,279	2,102	3,827	2,679	3,143	1,363
Striped bass	0	0	0	1	3	4	0	5
Hybrid striped bass	0	0	0	0	0	0	0	0
White perch	2	2	0	0	0	2	0	0
American eel	0	0	0	0	0	1	0	0
Sea lamprey	0	2	0	0	1	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	0	0	1	0	0	0	0	0
Tiger musky	1	0	0	0	0	0	0	0
Carp	18	8	15	128	36	8	2	0
Quillback	65	267	179	16	10	7	1	3
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	2	0	1	0	0	1	0
White catfish	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	1	0	0	0
Channel catfish	5	0	0	5	13	5	0	4
Flathead catfish	0	0	0	0	0	0	0	0
Rock bass	1	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	1	1
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	1	0	0	0	0	0	1
Smallmouth bass	2	4	3	1	2	2	1	0
Largemouth bass	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	3	0	0	2	3	6	1	0
TOTAL	*7,036*	*11,883*	*6,356*	*2,662*	*4,040*	*3,166*	*4,124*	*2,075*

Table 1

Continued.

Date:	*5/28*	*5/29*	*5/30*	*5/31*	*6/1*	*6/2*	*6/3*	*6/4*
Start Fishing Time:	*7:30*	*7:30*	*7:45*	*8:00*	*7:30*	*7:30*	*7:30*	*7:30*
End Fishing Time:	*15:00*	*15:00*	*16:30*	*16:00*	*16:00*	*16:00*	*15:00*	*15:00*
Hours of Operation:	*7.5*	*7.5*	*8.8*	*8.0*	*8.5*	*8.5*	*7.5*	*7.5*
Number of Lifts:	*6*	*7*	*8*	*7*	*6*	*6*	*6*	*7*
Water Temperature (°F):	*68.9*	*68.2*	*68.4*	*70.2*	*71.3*	*69.9*	*70.7*	*70.7*
American Shad	377	730	701	145	188	429	327	140
Blueback Herring	0	0	0	0	0	0	1	0
Gizzard shad	750	819	1,397	185	63	1,094	287	143
Striped bass	1	0	1	10	1	13	0	0
Hybrid striped bass	1	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	2
Sea lamprey	0	0	1	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	2	0	0	0	0	0	0	0
Tiger musky	0	0	0	0	0	0	0	0
Carp	0	0	1	5	4	0	2	0
Quillback	1	4	7	2	3	92	16	3
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	0	0	0	0	0
White catfish	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	6	0	1	4	2	0	3
Flathead catfish	0	0	1	0	0	0	0	0
Rock bass	0	0	0	0	0	0	0	0
Redbreast sunfish	4	2	1	0	0	0	0	2
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0
Bluegill	0	1	0	0	0	0	0	0
Smallmouth bass	1	0	0	0	0	2	0	0
Largemouth bass	0	0	0	0	0	1	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	1	0	0	0	0	2	0
TOTAL	*1,137*	*1,563*	*2,110*	*348*	*263*	*1,633*	*635*	*293*

Table 1

Continued.

Date:	6/5	6/6	6/7	6/8	Total
Start Fishing Time:	*7:30*	*7:30*	*8:00*	*8:00*	
End Fishing Time:	*15:00*	*14:00*	*14:00*	*13:30*	
Hours of Operation:	*7.5*	*6.5*	*6.0*	*5.5*	***434.32***
Number of Lifts:	*5*	*5*	*4*	*4*	***541***
Water Temperature (°F):	*71.8*	*73.6*	*76.6*	*77*	
American Shad	188	42	39	73	**68,926**
Blueback Herring	0	0	0	0	**4**
Gizzard shad	67	18	136	57	**305,378**
Striped bass	20	10	5	5	**89**
Hybrid striped bass	0	0	0	0	**1**
White perch	0	0	0	0	**15**
American eel	0	0	0	1	**5**
Sea lamprey	0	0	0	0	**35**
Rainbow trout	0	0	0	0	**4**
Brown trout	1	0	0	0	**4**
Tiger musky	0	0	0	0	**6**
Carp	0	5	3	0	**540**
Quillback	49	35	70	0	**2,145**
White sucker	0	0	0	0	**8**
Shorthead redhorse	0	0	5	0	**131**
White catfish	0	0	0	0	**1**
Brown bullhead	0	1	0	0	**9**
Channel catfish	2	6	0	1	**83**
Flathead catfish	0	0	0	0	**1**
Rock bass	0	0	0	0	**5**
Redbreast sunfish	3	1	3	0	**19**
Green sunfish	0	0	0	0	**1**
Pumpkinseed	0	0	0	0	**1**
Bluegill	0	0	0	1	**10**
Smallmouth bass	1	0	7	0	**256**
Largemouth bass	1	0	0	0	**14**
Yellow perch	0	0	0	0	**24**
Walleye	0	0	0	0	**47**
TOTAL	332	118	268	138	**377,762**

Table 2.

Summary of American shad catch, Maryland DNR recaptures, daily average river flow water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Conowingo Dam East fish passage facility in 2005. No operation on April 16,17 and 19.

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
15-Apr	0	*0*	56,100	*52.7*	15	11	C	310	22.0	107.8	0
18-Apr	0	*0*	41,200	*55.4*	17	11	C	310	21.3	106.9	0
20-Apr	674	*0*	34,400	*58.9*	18	11	C	310	21.8	108.0	0
21-Apr	210	*0*	38,400	*59.0*	17	11	C,A	310	20.2	106.5	0
22-Apr	523	*0*	30,900	*59.9*	17	11	C	310	20.8	106.6	0
23-Apr	1546	*0*	31,400	*60.5*	17	7	C	310	21.40	106.9	0
24-Apr	241	*1P*	38,100	*58.7*	17	5	C,A	310	17.90	107.7	0
25-Apr	733	*1P*	36,200	*59.6*	18	8	C	310	21.20	106.6	0
26-Apr	99	*0*	37,500	*60.5*	24	8	C	310	22.50	106.5	0
27-Apr	148	*0*	44,800	*57.2*	22	8	C	310	22.50	107.8	0
28-Apr	8	*0*	48,000	*55.4*	28	11	C	310	21.3	106.2	0
29-Apr	3	*0*	40,200	*55.3*	17	11	C	310	22.10	107.2	0
30-Apr	32	*0*	38,400	*55.4*	30	11	C	310	21.20	107.1	0
1-May	4776	*2O,1G*	36,200	*56.0*	19	5	A,C	310	17.40	108.4	0
2-May	552	*0*	32,000	*58.5*	22	11	C	310	20.80	107.3	0
3-May	2731	*0*	31,400	*57.1*	18	11	C,A	310	19.90	107.0	0
4-May	4230	*1P*	32,100	*57.2*	21	7	A	310	19.50	106.9	0
5-May	1888	*2G, 1P*	29,200	*57.2*	24	7	C,A	310	20.10	106.8	0
6-May	2773	*3P*	28,500	*56.2*	25	11	C,A,C	310	21.50	107.2	0
7-May	3274	*4G*	27,500	*56.9*	26	7	C,A	310	20.60	107.9	0
8-May	3266	*1B*	25,700	*57.2*	18	4	A	310	17.50	108.2	0
9-May	3376	*2G, 2P, 1Y*	23,200	*57.6*	25	6	C,A	310	20.00	107.8	0
10-May	1388	*1P*	21,900	*59.0*	26	6	C	310	21.30	108.5	0
11-May	5235	*4G, 4P, 1Y*	22,200	*61.7*	26	6	C	310	21.10	107.8	0
12-May	3445	*6G, 3P*	20,300	*63.0*	28	6	A,C	310	20.30	107.7	0

Table 2

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
13-May	4046	*8G,2P*	18,900	*63.0*	28	5	C,A	310	20.10	106.8	0
14-May	3854	*3G*	18,500	*62.1*	28	4	A	310	18.10	106.6	0
15-May	2095	*1P*	18,600	*63.0*	30	2	A	310	17.00	106.1	0
16-May	1155	*2G, 1O, 1P*	18,400	*67.7*	30	6	C	310	21.20	107.5	0
17-May	3402	*12G, 1P*	18,200	*66.1*	30	4	A	310	19.10	107.1	0
18-May	684	*2G, 1P*	16,200	*68.2*	30	5	C,A	310	19.50	107.1	0
19-May	2051	*5G, 1O, 1P*	16,600	*68.4*	30	5	C,A	310	20.1	106.6	0
20-May	982	*5G, 1P*	16,300	*67.1*	30	5	A,C	310	20.5	107.5	0
21-May	1574	*10G*	16,300	*67.1*	25	4	A	310	18.90	106.6	0
22-May	1879	*6G*	16,100	*67.1*	25	2	A	310	17.00	107.4	0
23-May	406	*2G*	15,100	*67.1*	28	6	A,C	310	20.30	107.4	0
24-May	144	*0*	18,800	*68.9*	29	5	A,C	310	20.20	106.8	0
25-May	452	*1P*	14,700	*66.8*	30	5	C,A	310	19.70	106.8	0
26-May	974	*0*	18,800	*66.4*	25	4	A	310	19.00	106.3	0
27-May	698	*1G*	18,600	*66.4*	27	4	A	310	18.20	106.7	0
28-May	377	*0*	12,800	*68.9*	30	4	A	310	18.40	107.1	0
29-May	730	*1G*	18,500	*68.2*	30	4	A	310	18.30	107.4	0
30-May	701	*2G*	18,100	*68.4*	30	2	A	310	17.70	107.0	0
31-May	145	*0*	18,100	*70.2*	30	4	A	310	18.8	107.2	0
1-Jun	188	*0*	12,200	*71.3*	30	6	A	310	19.3	107.4	0
2-Jun	429	*1P*	12,700	*69.9*	30	5	A,C	310	18.3	107.4	0
3-Jun	327	*0*	12,600	*70.7*	30	3	A	310	18.2	107.4	0
4-Jun	140	*0*	13,100	*70.7*	30	5	A	310	17.8	107.8	0
5-Jun	188	*0*	12,000	*71.8*	30	5	A,C	310	18.1	107.8	0
6-Jun	42	*0*	14,900	*73.6*	30	2	A,C	310	18.8	107.1	0
7-Jun	39	*0*	14,700	*76.6*	30	7	A,C	310	18.6	107.3	0
8-Jun	73	*0*	14,500	*77*	30	5	A	310	18.7	107.2	0

* Tag color: B = blue, G = green, OR = orange, P = pink, Y = yellow

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2005. No operation on April 16, 17, and 19.

Date:	*4/15*	*4/18*	*4/20*	*4/21*	*4/22*	*4/23*	*4/24*	*4/25*	*4/26*	*4/27*	*4/28*	*4/29*
Observation Time-Start:	*13:00*	*13:00*	*10:30*	*9:15*	*9:30*	*9:00*	*9:15*	*9:15*	*9:00*	*9:00*	*9:00*	*9:40*
Observation Time-End:	*15:25*	*15:30*	*17:30*	*17:30*	*17:45*	*18:30*	*17:00*	*18:30*	*17:00*	*17:30*	*17:00*	*16:00*
Military Time (hrs)												
0700 to 0759												
0800 to 0859												
0900 to 0959				20		36	38	13	33	7	4	0
1000 to 1059				34	7	13	24	9	6	17	1	1
1100 to 1159				26	39	140	6	1	5	12	1	0
1200 to 1259			7	27	23	169	23	11	8	2	0	0
1300 to 1359	0	0	62	9	88	266	7	42	10	2	1	0
1400 to 1459	0	0	238	34	78	233	36	80	13	4	0	0
1500 to 1559	0	0	171	13	82	232	83	119	16	19	1	2
1600 to 1659			146	4	67	196	24	153	8	42	0	
1700 to 1759			50	43	139	167		132		43		
1800 to 1859						94		173				
1900 to 1959												
Total	**0**	**0**	**674**	**210**	**523**	**1,546**	**241**	**733**	**99**	**148**	**8**	**3**

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:	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*9:00*	*8:00*	*8:00*	*8:30*	*8:00*	*7:30*
Observation Time-End:	*14:30*	*18:30*	*18:00*	*18:30*	*19:30*	*18:30*	*19:00*	*19:30*	*19:00*	*19:30*	*18:00*	*19:00*
Military Time (hrs)												
0700 to 0759												1
0800 to 0859								53	138		28	119
0900 to 0959	4	4	80	18	10	41	110	47	54	61	120	97
1000 to 1059	1	6	30	22	75	41	64	27	100	112	75	210
1100 to 1159	3	51	7	27	294	19	127	266	219	74	54	560
1200 to 1259	3	339	7	27	481	21	75	212	458	163	84	781
1300 to 1359	12	1,217	14	24	704	45	227	184	383	198	120	781
1400 to 1459	9	1,808	73	179	587	268	311	263	502	258	342	544
1500 to 1559		856	125	563	569	559	464	394	426	374	273	684
1600 to 1659		332	86	652	410	397	715	359	550	613	163	609
1700 to 1759		103	130	787	516	388	458	657	282	831	129	429
1800 to 1859		60		432	392	109	222	545	154	501		420
1900 to 1959					192			267		191		
Total	**32**	**4,776**	**552**	**2,731**	**4,230**	**1,888**	**2,773**	**3,274**	**3,266**	**3,376**	**1,388**	**5,235**

Table 3

Continued.

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:	*7:30*	*8:00*	*8:00*	*8:00*	*13:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	*7:30*	*8:00*
Observation Time-End:	*19:00*	*19:00*	*19:00*	*11:45*	*19:30*	*18:30*	*19:30*	*18:30*	*18:30*	*20:00*	*18:30*	*18:30*
Military Time (hrs)												
0700 to 0759	39										19	
0800 to 0859	174	189	183	458		20	35	61	42	34	83	54
0900 to 0959	497	307	176	766		361	13	482	66	142	362	45
1000 to 1059	484	671	378	510		404	4	260	129	97	224	83
1100 to 1159	382	560	286	361		608	21	196	86	48	227	112
1200 to 1259	321	186	413			588	51	98	105	52	186	12
1300 to 1359	431	197	331		94	481	90	171	53	122	255	9
1400 to 1459	425	180	406		65	315	65	118	57	68	154	15
1500 to 1559	310	185	273		27	123	110	125	61	58	124	17
1600 to 1659	163	287	317		156	249	24	244	130	89	98	7
1700 to 1759	118	630	606		237	162	105	196	62	360	78	19
1800 to 1859	101	654	485		418	91	103	100	191	301	69	33
1900 to 1959					158		63			203		
Total	**3,445**	**4,046**	**3,854**	**2,095**	**1,155**	**3,402**	**684**	**2,051**	**982**	**1,574**	**1,879**	**406**

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*	*8:00*	*8:00*	*8:00*	*7:30*	*8:30*	*8:30*	*8:30*	*8:00*	*9:00*	*8:00*
Observation Time-End:	*17:00*	*18:00*	*17:50*	*17:00*	*15:30*	*15:30*	*17:00*	*16:25*	*16:30*	*16:30*	*15:30*	*15:15*
Military Time (hrs)												
0700 to 0759						37						
0800 to 0859	5	4	15	48	21	38	2	0	0	10		0
0900 to 0959	20	6	96	108	115	51	123	15	17	78	56	0
1000 to 1059	9	8	191	24	127	39	125	30	19	26	132	2
1100 to 1159	10	10	211	233	75	365	47	58	6	117	69	27
1200 to 1259	8	15	103	85	39	144	100	31	7	155	7	36
1300 to 1359	9	9	87	16	0	43	87	10	55	39	42	19
1400 to 1459	9	21	91	57		13	103	0	19	2	17	43
1500 to 1559	29	34	74	84			78	1	53	0	4	12
1600 to 1659	45	227	80	43			36		12	2		1
1700 to 1759		118	26									
1800 to 1859												
1900 to 1959												
Total	**144**	**452**	**974**	**698**	**377**	**730**	**701**	**145**	**188**	**429**	**327**	**140**

Table 3

Continued.

Date:	6/5	6/6	6/7	6/8	
Observation Time-Start:	*8:30*	*8:15*	*7:30*	*8:30*	
Observation Time-End:	*15:30*	*14:30*	*14:30*	*14:00*	**Total**
Military Time (hrs)					
0700 to 0759			0	1	**97**
0800 to 0859	10	2	0	40	**1,866**
0900 to 0959	34	9	16	7	**4,765**
1000 to 1059	50	1	4	16	**4,922**
1100 to 1159	36	0	7	7	**6,096**
1200 to 1259	34	17	3	2	**5,719**
1300 to 1359	16	9	5		**7,076**
1400 to 1459	6	4	4		**8,117**
1500 to 1559	2				**7,809**
1600 to 1659					**7,736**
1700 to 1759					**8,001**
1800 to 1859					**5,648**
1900 to 1959					**1,074**
Total	**188**	**42**	**39**	**73**	**68,926**

Table 4

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2005.

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**

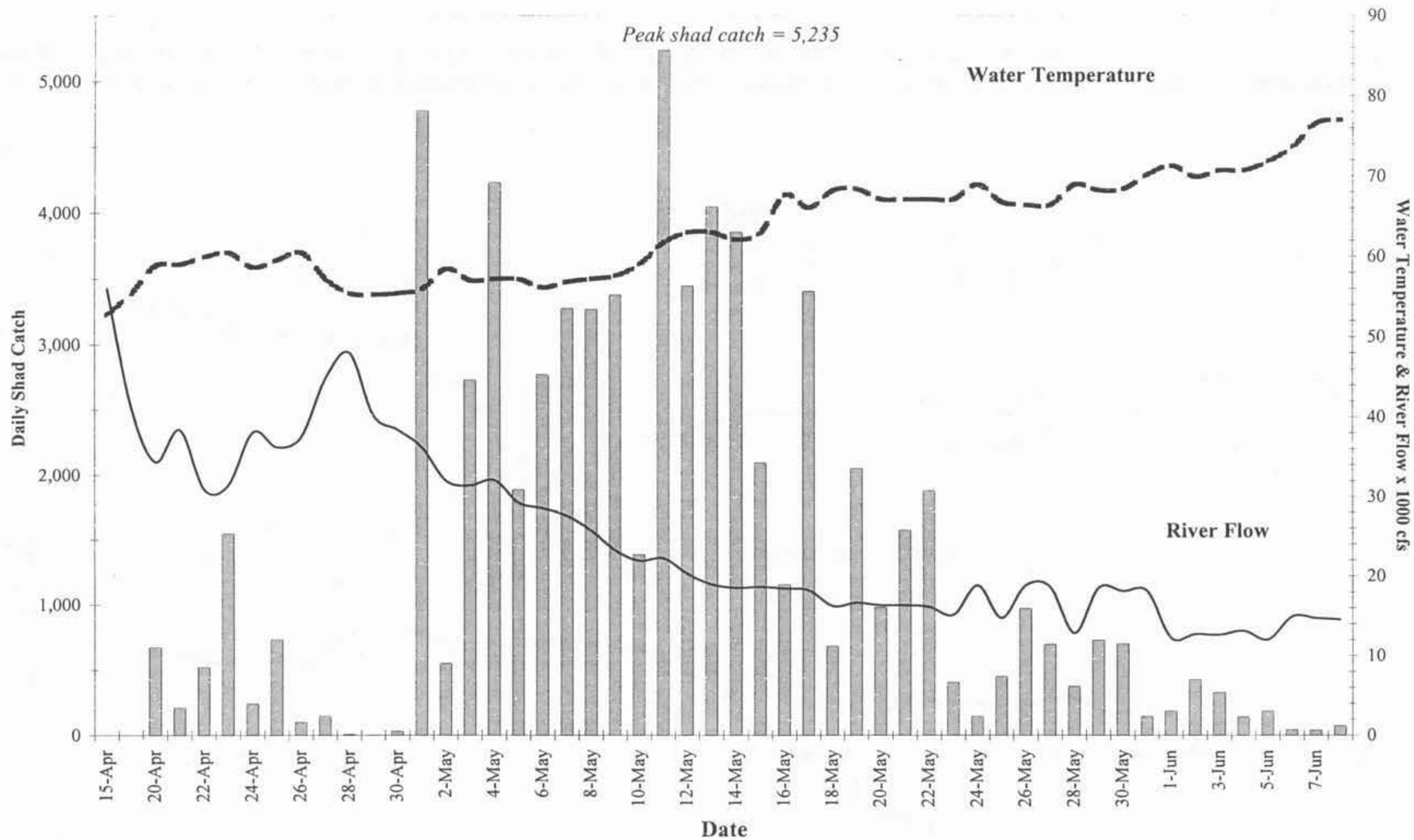

Fig. 1

A plot of river flow (x 1000 cfs) as measured at Holtwood Dam, and water temperature (°F) in relationship to the daily American shad catch at the Conowingo East Fish Lift, spring 2005. No operation on April 16, 17, and 19.

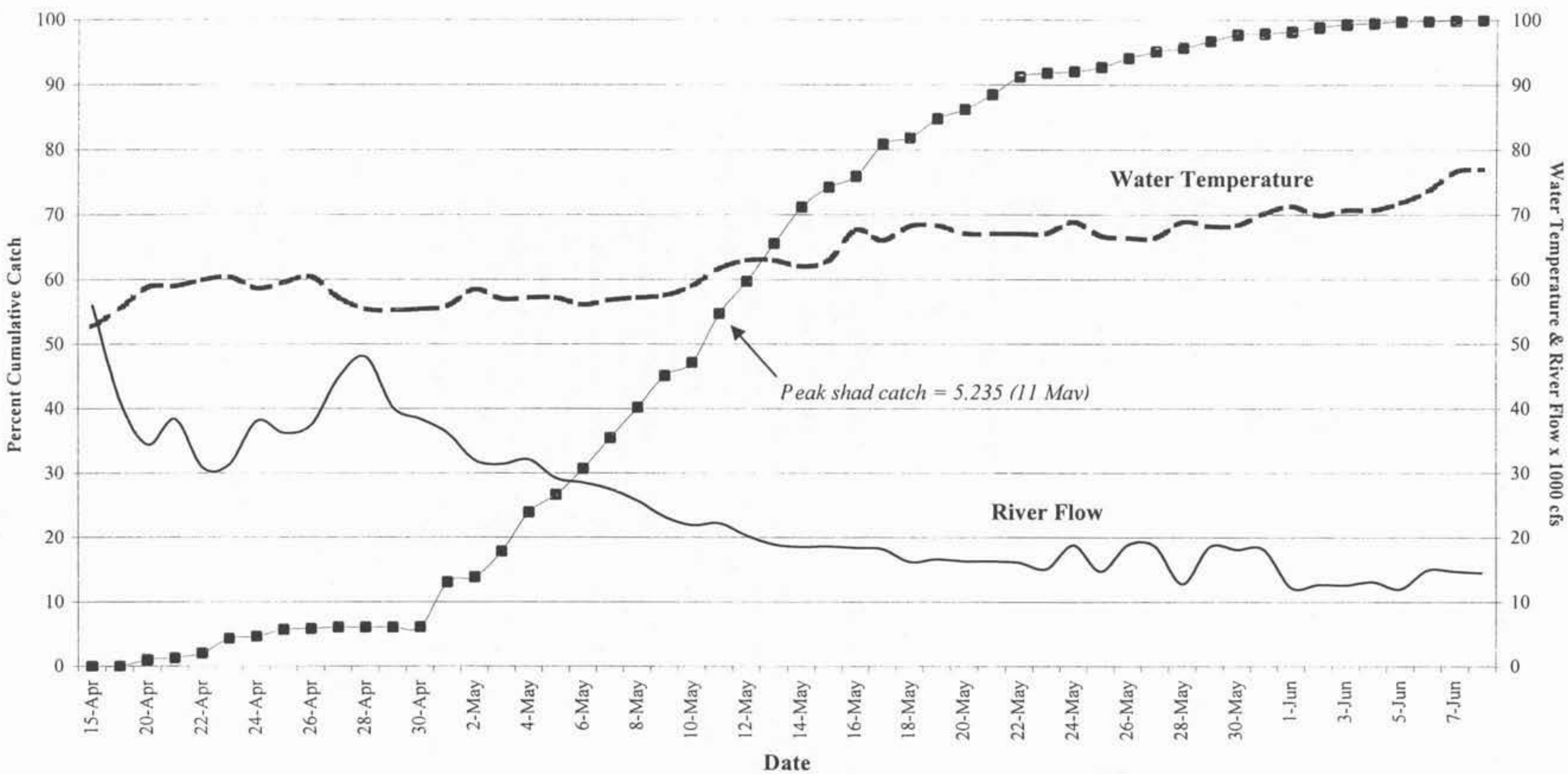

Fig. 2

A plot of river flow (x 1000 cfs) as measured at Holtwood Dam, and water temperature (°F) in relationship to the percent cumulative American shad catch at the Conowingo East Fish Lift, spring 2005. No operation on April 16, 17, and 19.

Job I - Part 2

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2005

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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 above the mainstem hydroelectric dams. During the spring runs of 1991 through 1996 the newer East fish lift at Conowingo Dam also served this purpose.

With fish passage available at Holtwood and Safe Harbor dams since 1997, the Conowingo East lift was operated to pass all fish into the project head pond in spring 2005 (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 lift operational and to administer an annual contract for West 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 2005 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, PA Fish and Boat Commission and Maryland DNR. These contributed funds are administered by the USFWS Susquehanna Coordinator.

The objectives of Conowingo West lift operations in 2005 included collection and enumeration of shad, river herring, other migratory and resident fishes; provision of live adult shad to Kleinschmidt Associates personnel for radiotagging and transport upstream for a telemetry study at York Haven project; and for on-site tank spawning and shad egg collection 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 2005.

METHODS

West 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 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 lift operating period declined steadily from a high of about 50,000 cfs in late April to a low of 12,000 cfs in early June. Water temperature during the same period increased very gradually from 60 to 70° F. Lift operations began on April 27 and occurred on 30 of the next 38 days through June 3. Total fishing effort over this period amounted to 295 lifts and a fishing time of 165.5 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, York Haven telemetry, or for biological data were returned alive to the tailrace. Other species were identified, enumerated and returned to the tailrace. No live shad broodfish were provided to Maryland DNR for tank spawning in 2005. Every 50th shad in the West lift collection was sacrificed for otoliths and a scale sample was taken. Lengths and weights were measured, and sex ratios of shad in daily catches were recorded.

RESULTS

Figure 1 shows daily West lift shad catch, river flow and water temperatures for the 2005 season. Total catch at the West lift amounted to 94,767 fish of 39 taxa, including hybrids (Table 1). Gizzard shad, channel catfish, carp and white perch comprised 91% of this total. Alosine catch included 3,896 American shad and no river herring or hickory shad. Catch of American shad averaged 130 per operating day with peak day catches of 625 and 608 shad on May 15 and 22, respectively. Daily operating parameters and catch by major species is shown in Table 2.

Under contract to York Haven Power Company, Kleinschmidt Associates transferred 445 American shad from the West lift to stocking sites near York Haven Dam. Normandeau Associates used 1,135 shad at the lift site for tank spawning (Job II, Part 3). Of the 277 shad sacrificed for hatchery vs. wild analysis by PFBC, 96 (35%) were shown to be of hatchery origin. Males averaged 457 mm in total length and 909 g while females averaged 526 mm and 1512 g. A total of 11 Maryland DNR tags were recovered at the West lift including 9 which were hook and line tagged in the tailrace in 2005 and two from 2004. Overall male to female sex ratio of shad in the West lift in 2005 was 1.0 to 1.2 (Table 3).

DISCUSSION

Spring 2005 water temperatures remained relatively cool (60-70° F) and river flows were below average (12,000-50,000 cfs) throughout the collection season. Peak day catches occurred on May 15 and 22 and overall, daily shad abundance was low with greater than 200 being taken on only seven dates. Most shad collected in 2005 were released alive back to the tailrace.

Aside from the truncated 2004 season, number of lift days and fishing hours in 2005 was reduced substantially from most prior years. West lift catch per effort of 23.5 shad per fishing hour, 13 shad per lift, and 130 shad per day were the lowest recorded since 1994 (Table 4). Operations and fish catch at the West lift during 1985-2005 are summarized in Table 5.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 2005.

Number of Days	**30**
Number of Lifts	**295**
Fishing Time (hours : minutes)	**165:51:00**
Number of Taxa	**36**
AMERICAN SHAD	3896
HICKORY SHAD	0
BLUEBACK HERRING	0
ALEWIFE	0
GIZZARD SHAD	82412
STRIPED BASS	489
Hybrid Striped Bass	3
White Perch	1102
American Eel	25
Brown Trout	12
Splake	3
Carp	1179
Comely Shiner	226
Spottail Shiner	5
Spotfin Shiner	230
Swallowtail Shiner	5
Quillback	848
White Sucker	1
Shorthead Redhorse	863
White Catfish	24
Yellow Bullhead	1
Brown Bullhead	713
Channel Catfish	1692
Flathead Catfish	9
Rock Bass	35
Redbreast Sunfish	80
Pumpkinseed	2
Bluegill	14
Smallmouth Bass	560
Largemouth Bass	33
White Crappie	1
Black Crappie	4
Banded Darter	1
Shield Darter	7
Tessellated Darter	1
Yellow Perch	33
Walleye	217
Atlantic Needlefish	31
Sea Lamprey	10
Total	**94,767**

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 27 April - 3 June, 2005.

Date:	27-Apr	28-Apr	29-Apr	2-May	3-May	4-May	5-May	6-May
Day:	WEDNESDAY	THURSDAY	FRIDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Number of Lifts:	9	13	11	15	16	10	13	13
Time of First Lift:	12:20	10:15	9:15	9:40	10:15	10:40	10:25	10:25
Time of Last lift:	16:10	15:39	15:00	16:20	17:15	17:25	17:00	16:45
Operating time (hours):	3:50	5:24	5:45	6:40	7:00	6:45	6:35	6:20
Average Water Temperature (°F):	59.0	58.7	57.3	59.2	59.6	58.8	58.5	58.4
American shad	53	19	29	87	21	473	119	212
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	3,075	6,850	3,450	5,950	8,550	2,300	6,550	5,100
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	1	4	4	1	8	0	6	14
Carp	0	22	7	15	8	4	21	17
Other species	25	54	62	151	59	56	124	109
Total	3,154	6,949	3,552	6,204	8,646	2,833	6,820	5,452

Date:	8-May	9-May	10-May	11-May	12-May	13-May	15-May	16-May
Day:	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY	MONDAY
Number of Lifts:	6	12	9	12	9	9	8	8
Time of First Lift:	10:00	10:10	12:30	10:40	10:40	10:20	12:35	10:30
Time of Last lift:	14:45	16:50	16:45	16:45	16:35	15:30	15:52	15:45
Operating time (hours):	4:45	6:40	4:15	6:05	5:55	5:10	3:17	5:15
Average Water Temperature (°F):	58.5	59.5	60.6	61.4	64.9	63.8	64.2	68.4
American shad	443	132	52	61	286	33	625	202
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	615	3,980	3,650	3,135	1,850	1,985	2,650	3,075
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	0	4	1	5	5	15	0	21
Carp	0	3	3	45	13	19	96	11
Other species	65	201	120	403	336	327	314	375
Total	1,123	4,320	3,826	3,649	2,490	2,379	3,685	3,684

Table 2

Continued.

Date:	17-May	18-May	19-May	20-May	22-May	23-May	24-May	25-May
Day:	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SUNDAY	MONDAY	TUESDAY	WEDNESDAY
Number of Lifts:	13	13	11	10	11	5	6	13
Time of First Lift:	10:25	10:30	10:05	9:30	8:20	10:15	10:40	10:10
Time of Last lift:	16:50	16:25	16:45	15:45	14:30	16:00	16:00	17:00
Operating time (hours):	6:25	5:55	6:40	6:15	6:10	5:45	5:20	6:50
Average Water Temperature (°F):	69.6	69.6	70.3	76.6	68.1	68.1	69.3	68.6
American shad	65	94	24	38	608	4	7	97
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	4,800	3,265	1,965	1,300	1,510	205	1,400	1,885
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	17	65	29	15	43	57	23	23
Carp	234	28	52	3	39	9	13	11
Other species	186	522	386	214	327	633	216	295
Total	5,302	3,974	2,456	1,570	2,527	908	1,659	2,311

Date:	26-May	27-May	30-May	31-May	2-Jun	3-Jun	
Day:	THURSDAY	FRIDAY	MONDAY	TUESDAY	THURSDAY	FRIDAY	**Total for the Year**
Number of Lifts:	7	5	7	8	5	8	**295**
Time of First Lift:	10:30	11:50	9:30	11:00	11:00	10:30	
Time of Last lift:	16:00	14:45	14:50	15:50	15:00	14:45	
Operating time (hours):	5:30	2:55	5:20	4:50	4:00	4:15	**165:51**
Average Water Temperature (°F):	67.8	68.2	68.5	70.3	69.6	69.6	
American shad	17	7	1	1	0	86	**3,896**
Blueback herring	0	0	0	0	0	0	**0**
Alewife	0	0	0	0	0	0	**0**
Gizzard shad	655	1,175	260	672	167	388	**82,412**
Hickory shad	0	0	0	0	0	0	**0**
Striped bass	31	15	24	5	30	23	**489**
Carp	2	55	2	426	13	8	**1,179**
Other species	282	47	422	113	235	132	**6,791**
Total	987	1,299	709	1,217	445	637	**94,767**

Table 3

American shad sex ratio information, Conowingo West Fish Lift, 2005. No operation on 30 April, 1,7,14,21,28,29 May and 1 June.

Date	Sample size	Males	Females	Male:Female Ratio
27-Apr	53	33	20	1:0.6
28-Apr	19	14	5	1:0.4
29-Apr	29	10	19	1:1.9
2-May	87	48	39	1:0.8
3-May	20	7	13	1:1.9
4-May	133	78	55	1:0.7
5-May	111	38	73	1:1.9
6-May	186	95	91	1:1
8-May	142	62	80	1:1.3
9-May	127	58	69	1:1.2
10-May	52	31	21	1:0.7
11-May	61	36	25	1:0.7
12-May	133	49	84	1:1.7
13-May	33	11	22	1:2.0
15-May	163	68	95	1:1.4
16-May	113	61	52	1:0.9
17-May	64	32	32	1:1
18-May	94	38	56	1:1.5
19-May	24	11	13	1:1.2
20-May	38	17	21	1:1.2
22-May	128	31	97	1:3.1
23-May	4	1	3	1:3.0
24-May	7	2	5	1:2.5
25-May	97	35	62	1:1.8
26-May	17	6	11	1:1.8
27-May	7	5	2	1:0.4
30-May	1	1	0	
31-May	1	0	1	
2-Jun	0	0	0	
3-Jun	86	41	45	1:1.1
Total	**2,030**	**919**	**1,111**	**1:1.2**

Table 4

Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods,* 1985-2005.

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**

*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 - 2005.

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

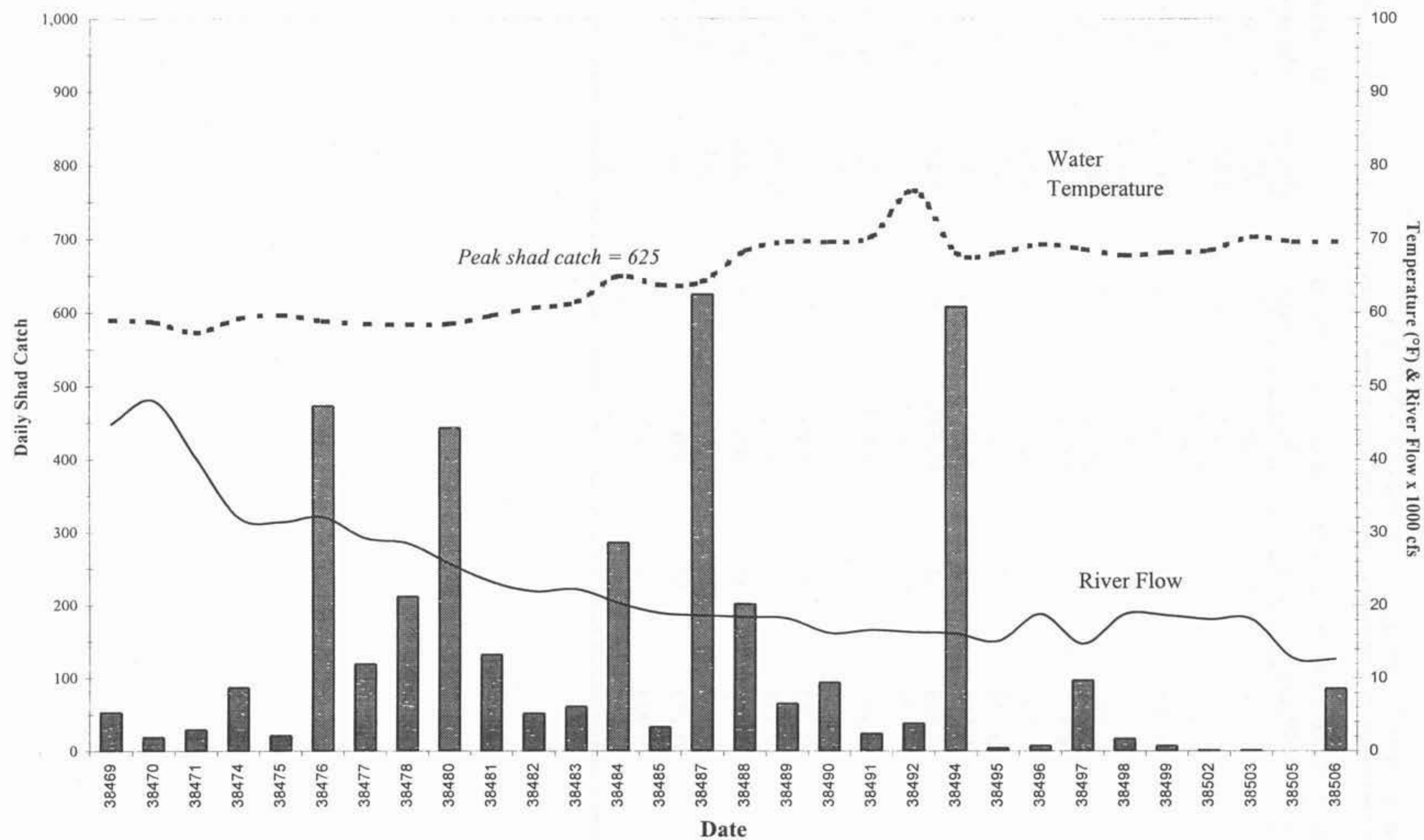

Fig. 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relationship to the daily American shad catch at the Conowingo West Fish Lift, spring 2005. No operation on 30 April, 1, 7, 14, 21, 28, 29 May and 1 June.

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 27 April 2005. The tailrace lift was operated for 36 days while the spillway lift operated on 2 days. Lift operations we terminated for the season on 10 June. Due to flooding from the remnants of Hurricane Ivan in September 2004, and three other high river flow events prior to the start of fish lift operations, the spillway lift incurred considerable damage and was unavailable for most of the season. The two days of spillway operation occurred without the use of the entrance gate which had been sheared off during the previously mentioned flood events. The tailrace lift, although functional, was hampered by various malfunctions and breakdowns of the crowder doors, the hopper hoist, the control room computer, and entrance gate A throughout the season. Fish lift operations were suspended, with agency concurrence, from 6 through 14 May to complete repairs to rubber dam numbers 1, 2, and 3 and to install new flashboards.

During the 2005 season the lifts passed 90,741 fish of 21 taxa plus two hybrids. Gizzard and American shad dominated the catch, and comprised nearly 96% of the total fish collected. American shad (34,189) was the only *Alosa* species captured with no river herring being observed at Holtwood in 2005. A total of 34,098 American shad (99.7% of total catch) was passed in the tailrace lift while the spillway lift accounted for only 91 American shad (0.3% of total catch). Collection and passage of shad varied daily with nearly 73% of total shad (24,952) passed during the 9-day period from 15 through 23 May. The highest daily shad catch occurred on 16 May when 5,158 shad moved upstream during 11 hours of operation. On a daily basis, shad passage was consistent through the fishway between 0900 hrs and 1800 hrs. Fishway operations were conducted at water temperatures ranging from 55.0°F to 78.6°F and river flows between 12,000 and 48,000 cfs. Spill events occurred only during the first 9 days of operation (prior to rubber dam and flashboard repair), and river temperatures did not rise above 70°F until 3 June.

Due to favorable river flow conditions in 2005, Holtwood fishway efforts focused on maximizing American shad passage and conducting a high frequency sound study funded by the Pennsylvania Fish and Boat Commission. Results of the sound study will be summarized in a separate report. Decreasing river flows throughout the passage season, coupled with river water temperatures below 70°F for most of the season, resulted in the third highest number of American shad passed since fishway start-up in 1997. Future operations will build on the past nine 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 2005. This year marked the ninth operational season. Objectives of 2005 upstream fishway operation were (1) monitor and maximize passage of migratory and resident fishes through the fishway; (2) make visual observations on fish behavior in response to the initiation and cessation of spillway flows during the 2005 season if river conditions permit; and (3) conduct the high frequency sound study in the tailrace crowder channel.

HOLTWOOD OPERATION

Project Operation

Holtwood Hydroelectric Project was built in 1910 and is situated on the Susquehanna River at 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 and 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, 7 miles upstream. Fishway operations at Holtwood began on 27 April 2005. In spring 2005, river flows less than station capacity allowed repairs of the damaged flashboards and rubber dams from 6 to 14 May. After repairs were completed, spill events did not occur throughout the remainder of the passage season. Passage operations ended on 10 June due to high water temperatures and lack of pre-spawned shad.

Fishway Design

The Holtwood fishway is sized to pass a design population of 2.7 million American shad equivalents (where 10 river herring equal one shad). The design incorporates numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998). The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough and swim upstream 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) and then lifted and sluiced into the trough. Fish swimming upstream through the trough pass 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 2005, all four of the rubber crest dams were kept inflated after repairs were completed and new flash boards installed. 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 2005, tailrace entrance gate A was used exclusively due to activities associated with the PFBC high frequency sound study, and the fact that spillway gate C had been rendered inoperable due to flood waters from the remnants of Hurricane Ivan in September 2004 and three other high flow events prior to this year's passage season.

Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch and was managed to maximize that catch. Pre-season equipment preparations began in March but were not completed until right before season start-up due to two high river flow events in late March and early April that hampered equipment inspections and testing. Constant oversight by PPL and Normandeau staff ensured that maintenance activities and most mechanical or electrical problems were dealt with immediately to minimize fish lift operational interruptions. As mentioned previously, the spillway lift was only operated on two days near the end of the season. Damage to the spillway entrance gate from flooding could not be repaired prior to or during the 2005 fish passage season.

The tailrace lift, although operable, encountered several problems during the season including a mechanical failure of entrance gate A drive mechanism, a broken bearing support weld on the tailrace hopper drive (which prevented conducting more than one lift per hour), crowder door drive mechanism malfunctions, and the failure of the fish lift control room computer hard drive which prevented the operation of the facility in the automatic mode. Unfortunately, problems with the tailrace crowder doors and hopper drive were not resolved since the necessary replacement parts or repairs could not be obtained or performed until well after the season ended.

At 1300 hrs on 19 May, the tailrace crowder doors failed to open after completing a lift. Repairs were initiated at 1430 hrs and it was discovered that the shaft drive for crowder door # 2 was binding as soon as power was applied to the motor. After several unsuccessful attempts to open the doors, it was observed that several American and gizzard shad had somehow managed to swim past or through the closed crowder doors and were calmly swimming around in the crowder tunnel area. Most of the American shad were hanging back just upstream of the closed crowder doors, while the gizzard shad tended to congregate upstream near the hopper pit. At 1800 hrs, a lift was made to clear the crowder tunnel area of fish. The lift was successful yielding approximately 200 American shad and 800 gizzard shad. The crowder was returned to the fish position, the crowder door shafts were unpinned, and the doors pushed to the full open position to prevent trapping any fish that entered the area after operations ended for the day. From 20 May until operations ended on 10 June, the tailrace crowder remained in the "fish" position with the crowder doors fully open.

A broken weld on the tailrace hopper drive support bearing was quickly repaired on 27 May, although it did not reduce the amount of vibration emanating from the drive unit. To prevent further damage and remain operational, the hopper drive was limited to one lift per hour at slow speed. These operational challenges, along with the necessary 10 day cessation of lift operations to install and repair the rubber dams and flashboards, may have prevented the Holtwood facility from passing an even higher percentage of American shad. 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 27 April. The tailrace lift was operated for 36 days during the season while the spillway lift operated on 2 days. The 2005 American shad passage rate was the highest observed since 2001. The passage rate may have been affected by the fish lift equipment problems and the 10-day suspension of fish lift operations (6 to 14 May), to repair and install the rubber dams and flashboards previously damaged by high river flows. 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 1997 and 1998. A three person staff consisting of a lift supervisor, supervising biologist and biological technician manned the lifts daily. A detailed description of the fishways major components and their operation are found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

Fish Counts

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

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

Table 1 lists the diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2005 operational period. A total of 90,741 fish of 21 taxa and two hybrids passed upstream into Lake Aldred. Gizzard shad (52,708) and American shad (34,189) comprised nearly 96% of all fishes passed. The 2005 American shad passage total was the third highest observed, (based on Conowingo results), in the nine years of fish lift operations (Tables 1, 5, and 6). Other abundant fishes passed included shorthead redhorse (1,159), walleye (892), and quillback (773). The peak one-day passage of all species occurred on 16 May, when 13,113 fish were passed, comprised mostly of gizzard shad (7,879) and American shad (5,158). The low 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 2005 included 36 green tags, (2005 hook & line), and 17 pink tags, (2004 hook & line).

American Shad Passage

A total of 34,189 American shad was passed at Holtwood during 2005 including 34,098 fish (99.7%) in the tailrace lift and 91 shad (0.3%) in the spillway lift. Collection and passage of shad varied daily with nearly 73% of total shad (24,952) passed during the 9 day period from 15 through 23 May. The highest daily shad catch occurred on 16 May when 5,158 shad moved upstream during 11 hours of operation. On a daily basis, shad passage was consistent through the fishway between 0900 hrs and 1800 hrs. Fishway operations were conducted at water temperatures ranging from 55.0°F to 78.6°F and river flows between 12,000 and 48,000 cfs. Spill events occurred only during the first 9 days of operation, (prior to rubber dam and flashboard repair), and river water temperatures did not rise above 70°F until 3 June, which may have allowed American shad in pre-spawn condition to swim upstream for a longer period of time prior to spawning. In 2004, the river water temperature rose above 70°F on 14 May, and fish passage operations ended approximately two weeks earlier than in 2005, due to observance of American shad in post-spawn condition.

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 112-ft to 119-ft. Typically, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2005, tailrace fishway operation coincided with various turbine operation-generation scenarios due to low spring river flows. The two days of spillway lift operation occurred at spillway elevations of 116-ft. Visual observations indicated that passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164-ft to 169-ft (Table 2). Rubber dam repairs and the installation of new flash boards and the slick bar occurred from 6 to 14 May when river flows dropped to a level allowing safe working conditions (< 29,000 cfs). After repairs were completed, river flows continued to drop, and forebay elevations during passage operations ranged between 168-169 feet.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Most shad, (26,682 or 78% of total) passed through the fishway between 0900 hrs and 1700 hrs. Generally, shad passage was consistent from 0900 hrs to 1800 hrs, and then gradually declined until operation ended each evening. The highest hourly passage rate occurred from 1500 hrs to 1600 hrs, accounting for of 3,957 shad.

The relative numbers of shad using the tailrace and spillway lifts are qualitatively assessed by viewing each hopper of fish and estimating the number of shad in each lift as they are sluiced into the trough. Due to the damage incurred by the spillway lift prior to this passage season, the spillway lift was operated only on two days near the end of the season in an effort to pass the small number of shad observed swimming in the area adjacent to the damaged spillway entrance gate. This information was summarized by lift and results applied to the daily shad passage count. The number of shad captured by each lift and/or the percentage of daily passage attributable to each lift was determined. Based on this assessment, for the season 34,098 and 91 shad were captured in the tailrace and spillway lifts, respectively (Table 4).

Passage Evaluation

Due to damage and mechanical problems resulting from the four high water events prior to the 2005 fish passage season, Holtwood fishway evaluation efforts focused on maximizing American shad catch in the tailrace lift and completing the high frequency sound study funded by the PFBC. Results of the sound study are summarized in a separate document prepared for the PFBC.

A summary of American shad passage at three river flow ranges is presented in Table 5. As stated in previous reports, low, stable river flows are more conducive to fish passage. In 2005, spill events occurred only during the first nine days of fishway operation. Most American shad (92%) passed at river flows less than 40,000 cfs, with the remaining shad passing at river flows less than 48,100 cfs – the maximum observed during the season (Table 5 and Figure 2). The 1999 and 2005 fish passage seasons closely resemble each other, characterized by low, stable and favorable river flows. Interestingly, Holtwood passed about 50% of total shad passed at Conowingo Dam, and Maryland DNR green and pink tags observed at Holtwood also amounted to 50% of those colored tags seen at Conowingo. Thus, it appears that hook and line tagged shad in Conowingo pond behave the same as untagged fish. Fish survival in the Holtwood fishways was excellent with no observed mortalities.

SUMMARY

In 2005, the Holtwood tailrace fish lift was operated for 36 days while the spillway lift operated 2 days. The spillway lift was inoperable for most of the season, while the tailrace lift, although functional most of the time, was impacted by several mechanical problems. These issues were dealt with as quickly as possible. A total of 34,189 American shad were passed into Lake Aldred, the third highest total and percentage of shad passed (based on Conowingo passage) since operations started in 1997 (Table 6).

The catch of shad at Conowingo Dam triggered the start of Holtwood operations on 27 April. A total of 34,098 American shad (99.7% of catch) was passed in the tailrace lift while the spillway lift accounted for 91 American shad (0.3% of catch). Collection and passage of shad varied daily with nearly 73% of total shad (24,952) passed during the 9-day period from 15 through 23 May. The highest daily shad catch occurred on 16 May when 5,158 shad moved upstream in 11 hours of operation. On a daily basis, shad passage through the fishway was consistent between 0900 hrs and 1800 hrs. American shad were collected and passed at water temperatures ranging from 56.0°F to 78.6°F, and river flows between 12,000 and 48,000 cfs.

A low, stable, river flow appears to be critical for enhancing shad passage rates. While the spillway lift was out of commission and the various mechanical problems encountered on the tailrace lift made fish passage extremely challenging, this season provided important insights into the various lift components and their settings that may improve passage rates in upcoming years. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis. Future operations of the fishway will build on the past nine years of operation experience.

RECOMMENDATIONS

1) Review the current maintenance program to identify additional equipment maintenance inspection and testing activities to reduce in-season disruptions to operation. Unusual conditions, (e.g. severe flood events) require a more thorough review of the impacts to the equipment. Evaluate the current fish lift spare parts and restock as needed.
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) As a routine part of fishway operation continue a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel, 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 debris from entering and accumulating at the exit/entrance of the trough. After the "slick bar" is installed implement protocols/guidelines that utilize the hydro control room operator to spill trash by lowering the 10-ft rubber dam. 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.

Table 1

Summary of the daily number of fish passed by the Holtwood fish passage facility in 2005.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*15 May*
Hours of Operation - Tailrace:	*1.9*	*4.6*	*7.4*	*7.0*	*7.3*	*6.8*	*9.5*	*9.3*	*6.2*	*11.3*
Number of Lifts - Tailrace:	*3*	*6*	*10*	*8*	*9*	*9*	*12*	*12*	*6*	*12*
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):	*55.0*	*55.5*	*56.5*	*57.6*	*57.6*	*56.6*	*56.5*	*56.3*	*56.2*	*69.0*
American shad	0	77	52	7	7	188	142	233	23	3,422
Gizzard shad	107	460	1,368	776	1,265	1,140	885	1,175	907	3,337
Sea lamprey	0	0	1	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	1	0	0	0	0	1
Brown trout	0	1	0	0	0	0	0	0	0	1
Tiger muskie	0	0	0	0	1	0	0	0	0	0
Carp	0	1	1	2	1	5	2	1	0	10
Quillback	0	0	0	1	5	2	0	1	1	35
Shorthead redhorse	0	0	100	71	70	49	27	101	35	24
Channel catfish	1	2	3	7	5	0	6	2	0	3
Brown bullhead	0	0	0	0	0	0	0	0	0	0
White catfish	0	0	0	0	0	0	0	0	0	0
Rock bass	0	1	0	0	1	0	0	0	0	1
Redbreast sunfish	0	0	0	0	0	0	0	0	0	1
Green sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	2
Bluegill	0	0	1	0	0	0	0	0	0	10
Smallmouth bass	2	10	20	6	7	21	9	14	4	7
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	1		0	0	0	0	0	0
Walleye	0	21	22	27	27	16	8	27	8	40
Splake	0	0	0	0	0	0	0	0	0	0
Total	***110***	***573***	***1,569***	***898***	***1,390***	***1,421***	***1,079***	***1,554***	***978***	***6,894***

Table 1

Continued.

Date:	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*
Hours of Operation - Tailrace:	*11.0*	*10.5*	*11.3*	*10.5*	*9.4*	*11.0*	*10.6*	*10.4*	*10.3*	*10.3*
Number of Lifts - Tailrace:	*15*	*19*	*18*	*11*	*11*	*17*	*20*	*21*	*20*	*20*
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):	*68.9*	*68.5*	*68.0*	*68.6*	*68.8*	*67.3*	*67.0*	*67.0*	*66.7*	*65.2*
American shad	5,158	4,523	3,587	2,195	1,119	2,073	853	2,022	855	468
Gizzard shad	7,879	4,330	4,889	4,137	1,815	2,964	3,814	1,506	1,473	687
Sea lamprey	0	1	0	0	0	0	0	0	0	0
Rainbow trout	1	1	1	0	2	1	1	0	0	3
Brown trout	0	0	0	0	0	2	2	0	1	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	2	9	36	1	1	0	15	16	6	0
Quillback	13	24	6	11	1	8	14	9	15	11
Shorthead redhorse	11	26	8	8	4	0	17	8	1	14
Channel catfish	7	20	7	34	13	9	44	5	2	10
Brown bullhead	0	5	0	0	0	0	0	0	0	0
White catfish	0	0	0	0	0	0	0	2	0	0
Rock bass	0	6	0	2	0	2	1	0	0	1
Redbreast sunfish	0	0	0	0	0	0	1	0	0	0
Green sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	14	0	0	0	0	0	0
Bluegill	3	4	0	0	0	4	7	0	0	0
Smallmouth bass	6	11	4	8	7	4	6	2	4	0
Largemouth bass	1	1	0	1	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	1	0	0	0
Yellow perch	1	0	1	0	1	0	0	0	0	0
Walleye	31	82	45	69	38	39	86	45	18	12
Splake	0	0	0	0	0	0	0	0	0	0
Total	***13,113***	***9,043***	***8,584***	***6,480***	***3,001***	***5,106***	***4,862***	***3,615***	***2,375***	***1,206***

Table 1

Continued.

Date:	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*
Hours of Operation - Tailrace:	*1.5*	*6.2*	*10.0*	*10.5*	*10.0*	*10.0*	*10.8*	*10.0*	*10.0*	*9.2*
Number of Lifts - Tailrace:	*2*	*5*	*10*	*11*	*10*	*10*	*11*	*10*	*10*	*9*
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):	*64.7*	*65.5*	*66.0*	*66.4*	*66.2*	*66.8*	*69.3*	*69.6*	*70.8*	*70.0*
American shad	58	1,236	947	924	632	563	713	408	484	337
Gizzard shad	148	310	239	243	194	434	585	340	246	668
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	1	0	0	2	0	0	0	1
Brown trout	0	1	1	1	0	0	0	0	1	0
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	0	0	1	2	1	5	19	6	5	2
Quillback	0	14	0	0	3	24	104	49	10	48
Shorthead redhorse	0	32	6	16	4	6	35	13	25	26
Channel catfish	0	12	3	15	3	6	13	11	1	5
Brown bullhead	0	0	0	0	0	1	0	0	0	0
White catfish	0	0	0	0	0	0	0	0	0	0
Rock bass	0	0	1	2	0	1	0	2	0	1
Redbreast sunfish	0	0	0	3	0	0	0	5	0	1
Green sunfish	0	1	0	0	0	0	0	0	0	1
Pumpkinseed	0	0	0	0	0	0	0	5	0	0
Bluegill	0	3	2	2	0	6	6	3	0	1
Smallmouth bass	0	6	1	1	4	3	2	1	2	4
Largemouth bass	0	0	0	0	0	0	1	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	2	22	2	13	14	21	15	5	9	7
Splake	0	0	1	0	0	0	0	0	0	0
Total	***208***	***1,637***	***1,205***	***1,222***	***855***	***1,072***	***1,493***	***848***	***783***	***1,102***

Table 1

Continued.

Date:	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*9.2*	*8.7*	*9.3*	*7.8*	*9.0*	*9.0*	***317.8***
Number of Lifts - Tailrace:	*11*	*9*	*9*	*9*	*9*	*9*	***403***
Hours of Operation - Spillway:	*0.0*	*0.0*	*2.5*	*6.8*	*0.0*	*0.0*	***9.3***
Number of Lifts - Spillway:	*0*	*0*	*3*	*4*	*0*	*0*	***7***
Water Temperature (°F):	*71.2*	*73.7*	*73.9*	*74.5*	*77.2*	*78.6*	
American shad	257	152	155	181	105	33	***34,189***
Gizzard shad	238	197	1,509	1,880	337	226	***52,708***
Sea lamprey	0	1	0	0	0	0	***3***
Rainbow trout	0	2	0	0	0	0	***18***
Brown trout	0	0	1	0	0	0	***12***
Tiger muskie	0	0	0	0	0	0	***1***
Carp	7	8	28	32	18	29	***272***
Quillback	44	66	49	50	64	91	***773***
Shorthead redhorse	40	74	114	36	98	60	***1,159***
Channel catfish	3	0	5	22	12	5	***296***
Brown bullhead	0	0	0	0	0	0	***6***
White catfish	0	0	0	0	0	0	***2***
Rock bass	1	0	0	0	0	0	***23***
Redbreast sunfish	0	0	0	0	14	0	***25***
Green sunfish	0	0	0	0	0	1	***3***
Pumpkinseed	0	0	0	0	0	0	***21***
Bluegill	9	0	1	6	0	0	***68***
Smallmouth bass	3	3	36	16	9	15	***258***
Largemouth bass	0	0	0	0	0	0	***5***
White crappie	0	0	0	0	0	0	***1***
Yellow perch	0	0	1	0	0	0	***5***
Walleye	10	6	20	54	10	21	***892***
Splake	0	0	0	0	0	0	***1***
Total	***612***	***509***	***1,919***	***2,277***	***667***	***481***	***90,741***

Table 2

Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in 2005.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs)			Elevation (ft)		
					A	B*	C**	Tailrace	Spillway	Forebay
27 Apr	44,800	55.2	25	10	150			116		167
28 Apr	48,000	56.0	25	10	150			116-119		167-168
29 Apr	40,200	57.1	24	10	150			116.5		167
30 Apr	38,400	57.7	22	10	150			118		168
1 May	36,200	57.7	22	10	150			117		167
2 May	32,000	57.1	22	10	150			117		166.5
3 May	31,400	58.0	22	9	150			116		164
4 May	32,100	56.2	22	9-10	150			117.5		166.5
5 May	29,200	56.3	22	10	150			119		166
15 May	18,600	69.0	36	8-10	150			117		168.5
16 May	18,400	69.2	36	8-10	150			116		168
17 May	18,200	68.7	36	7-10	150			116.5		168.5
18 May	16,200	68.5	36	3,6,8	150			113		168
19 May	16,600	69.0	36	7-10	150			112		168
20 May	16,300	68.7	36	8-10	150			115		168.5
21 May	16,300	67.3	36	5-8	150			113		168
22 May	16,100	67.2	36	6-10	150			114		169
23 May	15,100	67.2	36	8-10	150			116		168
24 May	18,800	66.3	33	8-10	150			115		168
25 May	14,700	65.2	33	7-10	150			116.5		168
26 May	18,800	64.9	33	10	150			116		168
27 May	18,600	65.4	33	10	150			115		168
28 May	12,800	66.3	33	5-8	150			113.5		168
29 May	18,500	66.5	30	0,8,10	150			114		168
30 May	18,100	66.5	32	4,6,9	150			112		168
31 May	18,100	67.6	30	6-10	150			115		168

Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs)			Elevation (ft)		
					A	B	C	Tailrace	Spillway	Forebay
1 Jun	12,200	69.6	32	5-10	150			115		168
2 Jun	12,700	70.4	34	6-10	150			112		168.5
3 Jun	12,600	70.6	36	9	150			113		168.5
4 Jun	13,100	70.5	36	8-9	150			112		168
5 Jun	12,000	71.9	36	3-10	150			116		168
6 Jun	14,900	73.7	36	8-10	150			113.5		168.5
7 Jun	14,700	73.7	30-18	5,9,10	150		220	116	116	168.5
8 Jun	14,500	75.0	12	8	150		220	112	116	168.5
9 Jun	15,700	77.4	20-22	0,7,8,10	150			115		168.5
10 Jun	14,400	78.5	26	5,8,10	150			114		168

* Tailrace gate B not utilized in 2005 due to PFBC sound study.

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

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 2005.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*
Observation Time (Start):	*15:00*	*14:00*	*9:15*	*9:00*	*8:55*	*11:15*	*9:00*
Observation Time (End):	*17:00*	*18:00*	*17:00*	*16:30*	*16:30*	*18:00*	*17:35*
Military Time (hrs)							
0700 to 0759							
0800 to 0859							
0900 to 0959			6	2	1		3
1000 to 1059			24	2	1		3
1100 to 1159			6	0	0	0	7
1200 to 1259			2	0	1	74	11
1300 to 1359			0	0	2	32	20
1400 to 1459		18	4	0	0	16	41
1500 to 1559	0	30	6	3	2	41	31
1600 to 1659	0	20	4	0	0	12	21
1700 to 1759		9				13	5
1800 to 1859							
1900 to 1959							
2000 to 2059							
Total	**0**	**77**	**52**	**7**	**7**	**188**	**142**

Date:	*4 May*	*5 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
Observation Time (Start):	*9:05*	*10:45*	*13:45*	*8:30*	*8:00*	*8:30*	*7:35*
Observation Time (End):	*18:40*	*15:35*	*20:00*	*20:00*	*19:35*	*19:45*	*19:00*
Military Time (hrs)							
0700 to 0759							27
0800 to 0859				0	47	16	288
0900 to 0959	3			1,025	461	454	638
1000 to 1059	22	6		280	665	466	557
1100 to 1159	17	8		343	731	335	103
1200 to 1259	30	3		38	376	439	26
1300 to 1359	33	1	145	0	477	708	365
1400 to 1459	27	2	330	11	432	145	0
1500 to 1559	29	3	186	1,229	224	213	0
1600 to 1659	38		192	1,174	403	59	0
1700 to 1759	17		1,003	474	369	6	0
1800 to 1859	17		1,101	316	293	360	191
1900 to 1959			465	268	45	386	
2000 to 2059							
Total	**233**	**23**	**3,422**	**5,158**	**4,523**	**3,587**	**2,195**

Table 3

Continued.

Date:	20 May	21 May	22 May	23 May	24 May	25 May	26 May
Observation Time (Start):	*8:30*	*8:00*	*7:56*	*8:15*	*8:00*	*8:00*	*8:15*
Observation Time (End):	*18:23*	*19:00*	*18:45*	*18:57*	*18:30*	*18:25*	*10:00*
Military Time (hrs)							
0700 to 0759			0				
0800 to 0859	52	4	33	36	25	14	16
0900 to 0959	261	70	77	22	26	17	42
1000 to 1059	235	237	78	110	85	27	
1100 to 1159	376	159	137	219	86	60	
1200 to 1259	94	123	94	293	152	62	
1300 to 1359	0	214	26	342	135	38	
1400 to 1459	0	290	109	300	92	68	
1500 to 1559	10	377	118	290	107	38	
1600 to 1659	47	266	103	171	67	79	
1700 to 1759	25	237	47	120	62	50	
1800 to 1859	19	96	31	119	18	15	
1900 to 1959							
2000 to 2059							
Total	**1,119**	**2,073**	**853**	**2,022**	**855**	**468**	**58**

Date:	27 May	28 May	29 May	30 May	31 May	1 Jun	2 Jun
Observation Time (Start):	*13:30*	*8:00*	*8:00*	*8:15*	*8:00*	*8:00*	*8:15*
Observation Time (End):	*18:30*	*18:30*	*18:20*	*18:20*	*18:25*	*18:30*	*18:30*
Military Time (hrs)							
0700 to 0759							
0800 to 0859		0	3	10	2	14	9
0900 to 0959		7	51	78	12	19	67
1000 to 1059		61	226	25	44	82	22
1100 to 1159		146	292	33	48	53	25
1200 to 1259		159	71	43	89	139	51
1300 to 1359	2	151	57	17	37	97	44
1400 to 1459	458	128	59	202	88	120	87
1500 to 1559	264	89	68	127	126	88	46
1600 to 1659	203	138	37	59	49	34	22
1700 to 1759	204	44	45	36	47	50	23
1800 to 1859	105	24	15	2	21	17	12
1900 to 1959							
2000 to 2059							
Total	**1,236**	**947**	**924**	**632**	**563**	**713**	**408**

Table 3

Continued.

Date:	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*
Observation Time (Start):	*8:15*	*8:30*	*8:30*	*8:30*	*7:45*	*9:00*	*8:00*
Observation Time (End):	*18:30*	*17:20*	*18:00*	*17:30*	*17:25*	*17:00*	*17:20*
Military Time (hrs)							
0700 to 0759					0		
0800 to 0859	0	0	3	3	0		0
0900 to 0959	70	37	4	13	12	8	13
1000 to 1059	37	43	3	8	8	9	5
1100 to 1159	90	43	3	30	23	21	5
1200 to 1259	52	40	17	5	16	30	52
1300 to 1359	99	38	49	9	26	45	4
1400 to 1459	27	52	114	24	21	27	8
1500 to 1559	44	57	27	39	15	16	12
1600 to 1659	37	21	14	13	21	25	3
1700 to 1759	17	6	23	8	13		3
1800 to 1859	11						
1900 to 1959							
2000 to 2059							
Total	**484**	**337**	**257**	**152**	**155**	**181**	**105**

Date:	*10 Jun*	
Observation Time (Start):	*8:00*	
Observation Time (End):	*17:20*	*Total*
Military Time (hrs)		
0700 to 0759		*27*
0800 to 0859	2	*577*
0900 to 0959	0	***3,499***
1000 to 1059	4	***3,375***
1100 to 1159	0	***3,399***
1200 to 1259	9	***2,591***
1300 to 1359	7	***3,220***
1400 to 1459	4	***3,304***
1500 to 1559	2	***3,957***
1600 to 1659	5	***3,337***
1700 to 1759	0	***2,956***
1800 to 1859		***2,783***
1900 to 1959		***1,164***
2000 to 2059		
Total	**33**	***34,189***

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2005.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway*	Tailrace	Spillway
27-Apr	0	0		100%	0%
28-Apr	77	77		100%	0%
29-Apr	52	52		100%	0%
30-Apr	7	7		100%	0%
1-May	7	7		100%	0%
2-May	188	188		100%	0%
3-May	142	142		100%	0%
4-May	233	233		100%	0%
5-May	23	23		100%	0%
15-May	3422	3422		100%	0%
16-May	5158	5158		100%	0%
17-May	4523	4523		100%	0%
18-May	3,587	3,587		100%	0%
19-May	2,195	2,195		100%	0%
20-May	1119	1119		100%	0%
21-May	2073	2073		100%	0%
22-May	853	853		100%	0%
23-May	2022	2022		100%	0%
24-May	855	855		100%	0%
25-May	468	468		100%	0%
26-May	58	58		100%	0%
27-May	1,236	1,236		100%	0%
28-May	947	947		100%	0%
29-May	924	924		100%	0%
30-May	632	632		100%	0%
31-May	563	563		100%	0%
1-Jun	713	713		100%	0%
2-Jun	408	408		100%	0%
3-Jun	484	484		100%	0%
4-Jun	337	337		100%	0%
5-Jun	257	257		100%	0%
6-Jun	152	152		100%	0%
7-Jun	155	145	10	94%	6%
8-Jun	181	100	81	55%	45%
9-Jun	105	105		100%	0%
10-Jun	33	33		100%	0%
Total	***34,189***	***34,098***	***91***	***100%***	***0%***

* Spillway entrance gate severely damaged by Hurricane Ivan flooding in September, 2004.
Operation of Spillway lift on 7 and 8 June 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
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr	26 Apr	27 Apr
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun	03 Jun	10 Jun
Season duration (days)	58	47	40	40	43	55	36	39	45
Number of days of operation	55	41	40	36	42	35	34	39	36
American shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135	109,360	68,926
American shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254	3,428	34,189
River flow ≤40,000 cfs									
Number of days	48	22	34	19	40	19	15	2	33
Percent of season	87%	54%	85%	53%	95%	54%	44%	5%	92%
Number of American shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229	2	34,060
Daily average of American shad passed	546	341	1,002	1,037	2,733	543	1,348	1	1,032
Percent of total passage	93%	91%	98%	67%	99%	59%	80%	0%	99.6%
River flow 40,001 to 60,000 cfs									
Number of days	7	2	6	12	2	14	18	20	3
Percent of season	13%	5%	15%	33%	5%	40%	53%	51.30%	8.00%
Number of American shad passed	1,862	230	633	9,536	634	7,029	5,019	1,943	129
Daily average of American shad passed	266	115	106	795	317	502	279	97	43
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.80%	56.70%	0.40%
River flow >60,000 cfs									
Number of days	0	17	0	5	0	2	1	17	0
Percent of season	0%	41%	0%	14%	0%	6%	3%	43.60%	0.00%
Number of American shad passed	0	493	0	173	0	171	6	1,483	0
Daily average of American shad passed	0	29	0	35	0	86	6	87	0
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%	43.30%	0.00%

* Denotes seasons of high river flow.

Table 6

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2005.

	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	7.0%

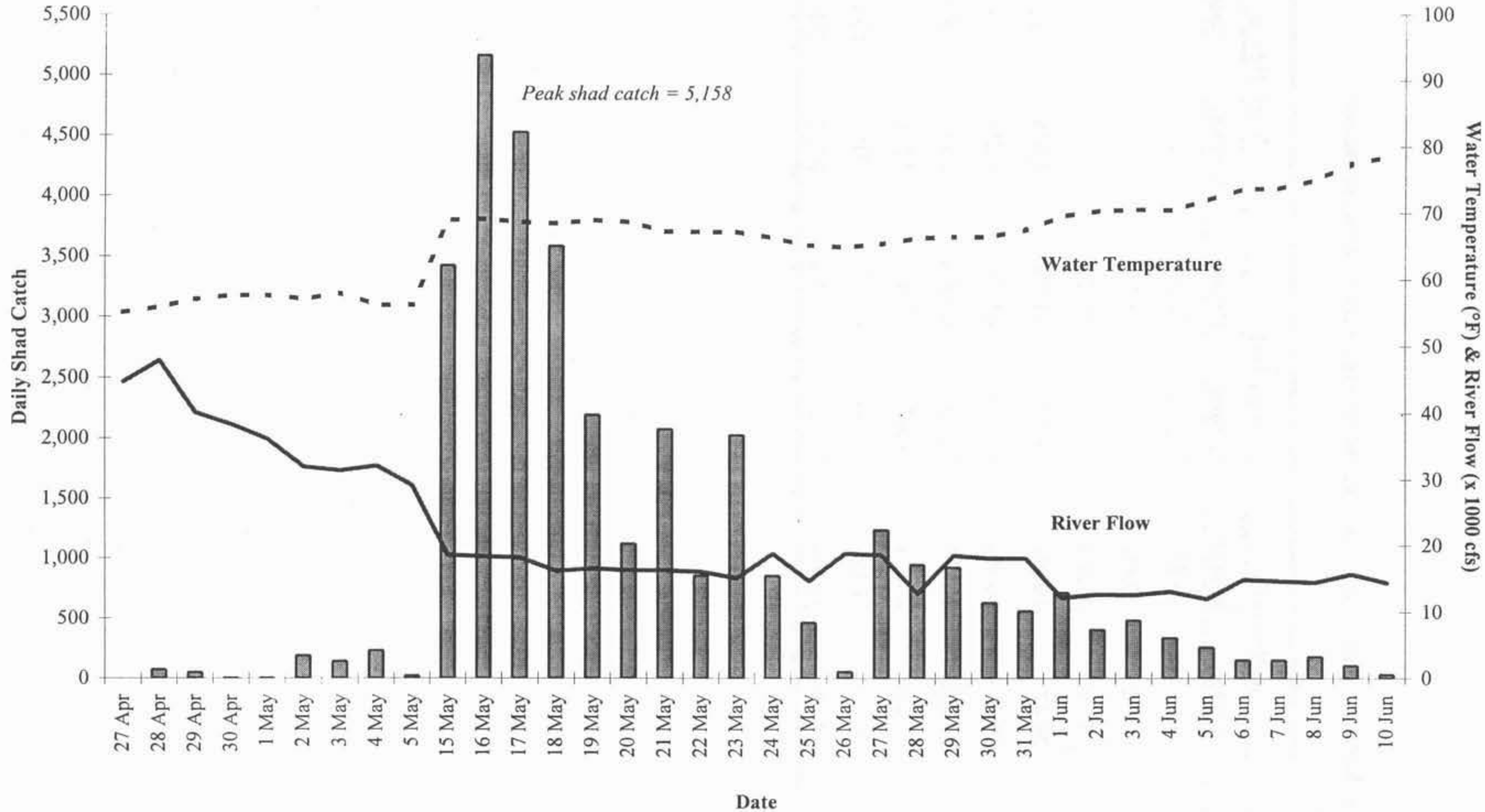

Figure 1

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 2005.

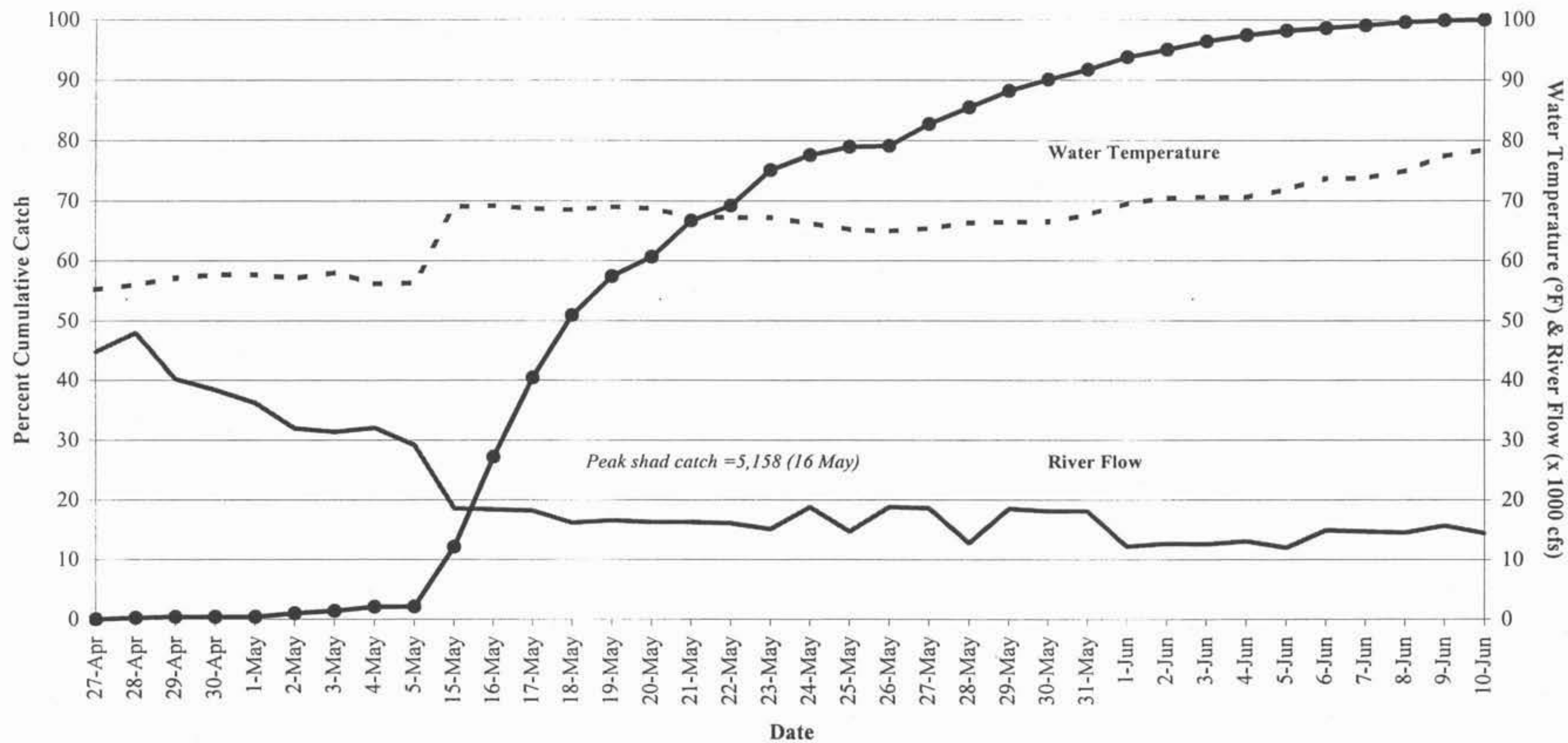

Figure 2

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 2005.

JOB I – PART 4
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 2005 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 became operational in 1986, which increased the hydraulic capacity to 110,000 cfs. Each unit is capable of passing approximately 8,500 cfs and 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 inches, 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 having horizontal, adjustable, propeller-shaped blades.

Fishway Design and Operation

Fishway Design

The fishway was sized to pass a design population of 2.5 million American shad and 5 million river herring. The design incorporated numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998). The Safe Harbor lift has three entrances (gates A, B, and C). The lift has a fish handling system that 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 was scheduled to commence after passage of approximately 500 American shad via the Holtwood Fishway, which occurred on May 1. The Safe Harbor fishway began operation on 2 May, with operations ending on 13 June. A shut down of the facility occurred from 11 to 15 May due to repairs at Holtwood Dam. Lift operations ended due to the dwindling fish catch and rising water temperatures; indications that the migration run was ending. Throughout the 2005 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishways major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

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

Fish Counts

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

RESULTS

Relative Abundance

The abundance of fishes collected and passed in 2005 by the Safe Harbor fishway is presented in Table 1. A total of 111,778 fish of 25 species passed upstream into Lake Clarke. Gizzard shad (44,387) was the dominant species passed and comprised nearly 39.7% of the catch. Some 25,425 American shad were passed upstream through the fishway. Other predominant fishes passed included quillback (29,062), channel catfish (5,345), shorthead redhorse (2,290), walleye (2,651), carp (1,742), and smallmouth bass (611). Peak passage occurred on 17 May, when 10,382 fish were passed.

American Shad Passage

The Safe Harbor fishway passed 25,425 American shad in 2005 during 37 days of operation (Table 1). Though collection and passage of shad varied daily, numbers were generally higher than in recent years. The Conowingo fishway passed 68,926 American shad, which was their lowest season total since 1998. Having lower numbers of shad in the system, and lower than normal river flow, Safe Harbor passed 74.4% of the shad Holtwood Dam passed (34,189). Moreover, the Safe Harbor fishway passed 37% of the American shad passed by Conowingo Dam. Peak shad passage occurred on 17 May when 3,529 shad were captured and passed in a little over 9 hours of operation. American shad were passed at water temperatures of 55°F to 82.3°F and river flows of 11,900 to 32,100 cfs (Table 2 and Figures 1and 2). Water temperature and river flow on those days when more than 100 American shad were passed averaged 67.3°F (55.5°F to 77.7°F) and 17,300 cfs (12,600 cfs to 29,200 cfs), respectively.

The number of American shad observed passing through the trough by hour is shown in Table 3. With the season's shad catch broken down based on hours of observation, passage rates were generally steady from 0800 to 1559 hr, with a sharp, then steady decrease in catch from 1600 to 1859 hr. The peak passage period was between 0900-1059 hr with a total of 6,722 American shad passed. The highest hourly passage (537) occurred between 1200 and 1259 hr on 18 May.

During the 2005 season, the Safe Harbor fishway passed a total of 24 tagged American shad that passed through the downstream fish lift facilities. These shad were captured, tagged and released downstream of Conowingo dam by the Maryland DNR. Safe Harbor observed the passage of twenty-two green floy tags, (2005), one pink floy tag, (2004), and one orange floy tag, (2003).

Other Alosids

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2005.

SUMMARY

Although shut down for 5 days, (May 11-15) to accommodate the repairs at Holtwood Dam, one day (June 7) due to mechanical problems with valve one, and one shortened day due to a lightning strike (May 28), the 2005 Safe Harbor fishway operating season was successful. A total of 25,425 American shad were passed into Lake Clarke, or 74% 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 nine 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. Report for Safe Harbor Water Power Corporation, Conestoga, PA.

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

Table 1

Number and disposition of fish passed by the Safe Harbor fishway in 2005.

Date:	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*16 May*
Hours of Operation:	*6.8*	*5.3*	*5.5*	*6.0*	*7.0*	*6.2*	*6.5*	*6.5*	*7.0*	*9.7*
Viewing Start Time:	*9:00*	*10:00*	*9:30*	*9:15*	*9:00*	*8:50*	*8:30*	*8:45*	*10:00*	*8:10*
Viewing End Time:	*15:30*	*15:15*	*16:00*	*15:20*	*15:15*	*14:30*	*15:25*	*15:15*	*15:30*	*17:00*
Numbers of Lifts:	*6*	*5*	*6*	*7*	*6*	*6*	*6*	*7*	*6*	*10*
Water Temp (F):	*55.5*	*55.0*	*55.0*	*55.0*	*55.0*	*56.0*	*56.0*	*58.3*	*59.0*	*68.0*
American shad	43	38	96	124	77	100	57	64	20	1,535
Gizzard shad	1,236	1,182	729	721	325	176	187	198	220	3,441
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	0	0	0	0	0	0	0	0	1
Brook Trout	0	0	0	0	0	0	0	0	0	0
Carp	11	66	73	19	8	49	38	66	294	210
Quillback	144	151	375	323	372	92	300	835	1,281	4,078
Shorthead redhorse	69	24	81	197	107	50	243	431	448	206
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	1	3	1	141
Channel catfish	23	1	2	1	0	0	0	0	0	0
Flathead catfish	0	0	0	0	0	0	0	0	2	0
Rock bass	1	0	2	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green Sunfish	0	0	0	0	0	0	0	1	1	1
Pumpkinseed	0	0	0	0	0	0	0	0	0	2
Bluegill	0	0	0	0	0	0	26	90	150	36
Smallmouth bass	33	18	9	11	13	25	0	0	0	1
Largemouth bass	0	0	0	0	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	1	0	0	1	2
Walleye	2	0	2	5	1	5	19	19	31	82
Striped Bass	0	0	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0	1	0
Total	**1,562**	**1,480**	**1,369**	**1,401**	**903**	**498**	**871**	**1,746**	**2,450**	**9,722**

Table 1

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*
Hours of Operation:	*9.3*	*10.8*	*10.0*	*10.0*	*9.5*	*9.5*	*9.3*	*9.3*	*8.3*	*9.0*
Viewing Start Time:	*8:30*	*8:00*	*8:00*	*8:05*	*8:45*	*8:45*	*8:00*	*8:05*	*8:30*	*8:15*
Viewing End Time:	*17:45*	*18:00*	*17:15*	*17:00*	*17:10*	*17:10*	*17:00*	*17:00*	*17:00*	*17:00*
Numbers of Lifts:	*14*	*16*	*14*	*11*	*12*	*11*	*12*	*14*	*13*	*9*
Water Temp (F):	*68.0*	*68.0*	*68.0*	*68.0*	*68.0*	*67.0*	*65.0*	*67.0*	*65.0*	*64.4*
American shad	3,529	3,038	2,025	1,310	1,453	1,330	1,065	1,358	1,022	607
Gizzard shad	4,422	3,939	5,300	2,549	2,506	4,604	2,462	569	584	1,653
Sea lamprey	0	1	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	1	0	0	0	0
Brown trout	0	0	1	0	0	0	0	0	0	0
Brook Trout	0	0	0	0	0	0	0	0	0	0
Carp	147	78	45	65	20	1	5	6	11	5
Quillback	1,628	1,487	955	1,322	754	1,511	676	814	632	243
Shorthead redhorse	52	10	11	10	0	0	3	3	2	5
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	317	31	61	516	379	1,043	144	106	146	59
Flathead catfish	0	1	0	0	0	0	0	0	0	0
Rock bass	29	3	0	1	0	0	0	1	1	0
Redbreast sunfish	0	1	0	0	0	4	0	0	0	0
Green Sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	7	3	1	3	0	0	0	0	0	0
Bluegill	0	1	0	1	0	0	0	0	0	0
Smallmouth bass	1	7	9	7	27	17	4	6	1	2
Largemouth bass	0	0	0	2	0	0	0	1	1	0
White crappie	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	1
Yellow perch	5	0	3	4	0	0	0	0	0	0
Walleye	245	86	96	171	288	518	71	72	63	42
Striped Bass	0	1	0	0	0	0	1	2	0	1
Muskellunge	0	0	1	0	0	0	0	0	0	0
Total	**10,382**	**8,687**	**8,508**	**5,961**	**5,427**	**9,029**	**4,431**	**2,938**	**2,463**	**2,618**

Table 1

Continued.

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*
Hours of Operation:	*7.4*	*7.7*	*10.2*	*8.9*	*9.0*	*8.5*	*9.7*	*7.4*	*8.9*	*7.2*
Viewing Start Time:	*8:30*	*8:30*	*8:45*	*8:40*	*8:00*	*8:00*	*8:00*	*8:40*	*9:00*	*8:40*
Viewing End Time:	*17:00*	*14:15*	*16:53*	*16:40*	*16:30*	*16:50*	*17:00*	*16:00*	*17:15*	*17:20*
Numbers of Lifts:	*10*	*5*	*9*	*9*	*8*	*9*	*10*	*8*	*9*	*9*
Water Temp (F):	*64.5*	*65.5*	*65.8*	*66.5*	*68.1*	*70.2*	*70.0*	*68.0*	*71.0*	*71.0*
American shad	557	663	937	964	424	531	513	201	573	469
Gizzard shad	447	89	749	718	296	356	414	119	307	728
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	1	1	0	0	0	0
Brown trout	0	0	0	0	0	0	0	0	0	0
Brook Trout	0	0	0	0	0	0	0	0	0	0
Carp	21	9	2	58	25	28	5	15	25	11
Quillback	591	292	580	1,462	522	282	387	341	743	438
Shorthead redhorse	17	7	1	3	13	6	20	15	19	5
Brown bullhead	0	0	0	0	0	1	0	0	0	0
Channel catfish	62	24	44	277	131	116	83	106	100	35
Flathead catfish	0	0	0	0	0	0	0	0	0	0
Rock bass	2	0	1	0	0	1	0	0	0	1
Redbreast sunfish	0	2	7	11	0	2	0	0	7	15
Green Sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	1	0	8	3	0	0
Bluegill	4	0	0	7	0	0	0	2	0	0
Smallmouth bass	2	0	2	6	1	2	0	4	6	3
Largemouth bass	0	0	0	0	0	0	0	0	0	0
White crappie	1	0	0	0	1	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0
Walleye	58	15	53	119	61	23	36	50	66	29
Striped Bass	0	0	0	0	1	0	0	0	0	1
Muskellunge	0	0	0	0	1	0	0	0	0	0
Total	**1,762**	**1,101**	**2,376**	**3,625**	**1,478**	**1,349**	**1,466**	**856**	**856**	**1,735**

Table 1

Continued.

Date:	*06 Jun*	*08 Jun*	*09 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	**Totals**
Hours of Operation:	*3.2*	*7.1*	*6.8*	*8.5*	*8.8*	*9.2*	*8.0*	**298.0**
Start Time:	*8:20*	*9:05*	*9:00*	*7:40*	*9:00*	*9:00*	*8:15*	--
End Time:	*11:00*	*17:00*	*16:45*	*15:50*	*15:40*	*15:45*	*15:50*	--
Numbers of Lifts:	*3*	*9*	*8*	*7*	*5*	*5*	*8*	**322.0**
Water Temp (F):	*73.0*	*74.6*	*77.7*	*77.7*	*77.0*	*77.7*	*82.3*	--
American shad	96	273	186	44	41	45	17	**25,425**
Gizzard shad	128	1,103	1,506	301	67	46	10	**44,387**
Sea lamprey	0	0	0	0	0	0	0	**1**
Rainbow trout	0	0	0	0	0	0	0	**3**
Brown trout	0	0	1	0	0	0	0	**3**
Brook Trout	0	0	0	0	0	0	0	**1**
Carp	2	151	81	21	37	33	1	**1,742**
Quillback	115	1,664	706	941	904	796	325	**29,062**
Shorthead redhorse	1	100	67	39	19	4	2	**2,290**
Brown bullhead	0	0	0	0	0	0	0	**1**
Channel catfish	31	738	286	222	26	28	61	**5,345**
Flathead catfish	0	0	0	0	0	0	0	**1**
Rock bass	0	5	0	0	0	0	1	**51**
Redbreast sunfish	1	9	0	0	2	2	4	**67**
Green Sunfish	0	0	0	1	0	0	0	**1**
Pumpkinseed	1	9	8	0	0	0	6	**50**
Bluegill	0	0	6	5	0	1	5	**34**
Smallmouth bass	1	9	12	12	17	15	27	**611**
Largemouth bass	0	0	1	0	0	0	1	**7**
White crappie	0	0	0	0	0	0	0	**2**
Black crappie	0	0	0	0	0	0	0	**2**
Yellow perch	0	0	1	0	0	0	0	**16**
Walleye	5	106	82	45	45	19	21	**2,651**
Striped Bass	0	0	0	3	1	3	6	**20**
Muskellunge	0	0	0	0	0	0	0	**2**
Total	**381**	**4,167**	**2,943**	**1,634**	**1,159**	**992**	**487**	**111,778**

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 2005. Safe Harbor fish lift did not operate from 11 to 15 May, due to repairs at Holtwood Dam.

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)
02 May	32.0	55.5	30	11	2 to 12	A & C	500	171.6	224.9
03 May	31.4	55.0	22	7	2 to 8	A & C	500	168.7	226.9
04 May	32.1	55.0	26	6	2 to 7	A & C	500	169.5	226.5
05 May	29.2	55.0	30	4	2 to 5	A & C	500	172.9	226.1
06 May	28.5	55.0	30	5	2,3, 5 to 7	A & C	500	170.7	225.0
07 May	27.5	56.0	30	5	3 to 7	A & C	500	168.9	225.0
08 May	25.7	56.0	30	4	3, 5 to 7	A & C	500	169.5	225.1
09 May	23.2	58.3	26	4	1, 5 to 7	A & C	500	169.0	225.2
10 May	21.9	59.0	30	4	1, 5 to 7	A & C	500	169.5	224.9
16 May	18.4	68.0	30	7	1, 3 to 8	A & C	500	169.9	226.4
17 May	18.2	68.0	28	6	1, 2 to 7	A & C	500	170.0	226.6
18 May	16.2	68.0	30	6	1,2 to 7	A & C	500	169.2	226.6
19 May	16.6	68.0	30	3	1, 5 & 6	A & C	500	168.8	227.4
20 May	16.3	68.0	22	8	1, 3 to 9	A & C	500	169.8	226.6
21 May	16.3	68.0	22	6	1,3, 5 to 7,10	A & C	500	168.2	226.7
22 May	16.1	67.0	22	3	1,3,7	A & C	500	171.2	226.5
23 May	15.1	65.0	22	3	1,3 & 9	A & C	500	169.7	226.5
24 May	18.8	67.0	26	5	1,3, 5 to 7	A & C	500	168.2	226.8
25 May	14.7	65.0	24	5	1,3, 5 to 7	A & C	500	169.9	226.3
26 May	18.8	64.4	20	5	1,2, 5 to 7	A & C	500	169.7	226.4
27 May	18.6	64.5	20	6	1 to 3, 5 to 7	A & C	500	170.7	226.4
28 May	12.8	65.5	32	3	2,8,9	A & C	500	168.4	226.2
29 May	18.5	65.8	24	8	1 to 3,5 to 9	A & C	500	168.4	226.5
30 May	18.1	66.5	32	8	1 to 3, 5 to 9	A & C	500	168.5	226.5
31 May	18.1	68.1	30	7	1 to 3,5,6,8,9	A & C	500	168.6	226.7
01 Jun	12.2	70.2	30	7	1,3, 5 to 9	A & C	500	168.8	226.5
02 Jun	12.7	70.0	22	1	1	A & C	500	169.1	226.6
03 Jun	12.6	68.0	20	3	1,2,6	A & C	500	169.1	226.8
04 Jun	13.1	71.0	30	7	1,3,5 to 9	A & C	500	169.1	227.0
05 Jun	12.0	71.0	30	7	1,3,5 to 7,9,10	A & C	500	169.9	226.7
06 Jun	14.9	73.0	30	4	1,2,8,9	A & C	500	169.6	226.9
08 Jun	14.5	74.6	24	2	1,2	A & C	500	168.8	226.5
09 Jun	15.7	77.7	28	6	1 to 3,5 to 7	A & C	500	171.1	225.6
10 Jun	14.4	77.7	30	1	1	A & C	500	169.3	226.1
11 Jun	13.1	77.7	32	7	1,3,5 to 9	A & C	500	168.4	226.1
12 Jun	11.9	77.7	30	3	1,3,5	A & C	500	168.6	226.7
13 Jun	12.2	82.3	30	7	1,3, 5 to 9	A & C	500	168.4	226.7

1 River flow and temperature measured at Holtwood Dam.

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2005.

Date:	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*16 May*
Observation Time (Start):	*9:00*	*10:00*	*9:30*	*9:15*	*9:00*	*8:50*	*8:30*	*8:45*	*10:00*	*8:10*
Observation Time (End):	*15:30*	*15:15*	*16:00*	*15:20*	*15:15*	*14:30*	*15:25*	*15:15*	*15:30*	*17:00*
Military time (hrs)										
0700 to 0759										
0800 to 0859							0	5	2	107
0900 to 0959	14	0	13	28	23	44	6	3	2	138
1000 to 1059	3	5	11	18	9	12	10	17	4	179
1100 to 1159	5	6	17	22	7	28	5	14	5	163
1200 to 1259	3	8	13	12	12	6	4	6	4	214
1300 to 1359	8	12	25	21	0	8	14	3	2	252
1400 to 1459	8	5	10	15	20	2	11	14	0	189
1500 to 1559	2	2	7	8	6	0	7	2	1	170
1600 to 1659							0	0	0	123
1700 to 1759							0	0	0	0
1800 to 1859										
1900 to 1959										
Total	**43**	**38**	**96**	**124**	**77**	**100**	**57**	**64**	**20**	**1,535**

Table 3

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*
Observation Time (Start):	*8:30*	*8:00*	*8:00*	*8:05*	*8:45*	*8:45*	*8:00*	*8:00*	*8:30*	*8:15*
Observation Time (End):	*17:45*	*18:00*	*17:15*	*17:00*	*17:10*	*17:10*	*17:00*	*17:00*	*17:00*	*17:00*
Military time (hrs)										
0700 to 0759										
0800 to 0859	266	186	607	173	117	99	113	218	156	44
0900 to 0959	484	163	365	155	181	194	194	92	106	49
1000 to 1059	393	417	251	88	211	159	126	197	161	80
1100 to 1159	290	330	212	101	191	141	108	203	76	45
1200 to 1259	256	537	134	112	140	105	61	240	92	14
1300 to 1359	323	348	169	131	200	146	135	31	161	108
1400 to 1459	473	312	108	154	212	131	126	160	144	59
1500 to 1559	486	323	110	174	82	235	66	146	75	17
1600 to 1659	312	200	61	222	72	120	136	71	51	191
1700 to 1759	246	222	8		47	0	0	0	0	
1800 to 1859										
1900 to 1959										
Total	**3,529**	**3,038**	**2,025**	**1,310**	**1,453**	**1,330**	**1,065**	**1,358**	**1,022**	**607**

Table 3

Continued.

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*
Observation Time (Start):	*8:30*	*8:30*	*8:45*	*8:40*	*8:00*	*8:00*	*8:00*	*8:40*	*9:00*	*8:40*
Observation Time (End):	*17:00*	*14:15*	*16:53*	*16:40*	*16:30*	*16:50*	*17:00*	*16:00*	*17:15*	*17:20*
Military time (hrs)										
0700 to 0759										
0800 to 0859		224	23	174	117	60	42	6	91	0
0900 to 0959	85	220	233	197	26	56	17	0	133	141
1000 to 1059	51	75	127	168	35	87	3	55	116	44
1100 to 1159	57	43	156	126	29	34	88	23	65	40
1200 to 1259	61	67	104	80	33	74	149	20	53	35
1300 to 1359	102	34	112	72	73	11	15	19	50	73
1400 to 1459	59	0	78	72	46	127	59	67	35	83
1500 to 1559	96	0	70	49	61	66	64	11	25	28
1600 to 1659	46	0	34	26	4	16	76	0	5	22
1700 to 1759						0		0	0	3
1800 to 1859										
1900 to 1959										
Total	**557**	**663**	**937**	**964**	**424**	**531**	**513**	**201**	**573**	**469**

Table 3

Continued.

Date:	*06 Jun*	*08 Jun*	*09 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	
Observation Time (Start):	*8:20*	*9:05*	9:00	*7:40*	*9:00*	*9:00*	*8:15*	**Season**
Observation Time (End):	*11:00*	*17:00*	*16:45*	*15:50*	*15:40*	*15:45*	*15:50*	***Total***
Military time (hrs)								
0700 to 0759		0		8	0	0	0	**8**
0800 to 0859	35	0		5	0	0	11	**2,881**
0900 to 0959	37	33	27	3	21	26	0	**3,509**
1000 to 1059	14	29	39	5	7	7	0	**3,213**
1100 to 1159	4	19	22	10	3	3	1	**2,692**
1200 to 1259	6	21	5	3	1	5	2	**2,692**
1300 to 1359	0	9	9	8	3	1	1	**2,689**
1400 to 1459	0	6	34	1	3	0	2	**2,825**
1500 to 1559	0	109	33	1	3	3	0	**2,538**
1600 to 1659	0	47	17	0	0	0	0	**1,852**
1700 to 1759	0							**526**
1800 to 1859								**0**
1900 to 1959								**0**
Total	**96**	**273**	**186**	**44**	**41**	**45**	**17**	**25,425**

Table 4

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2005.

	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%**

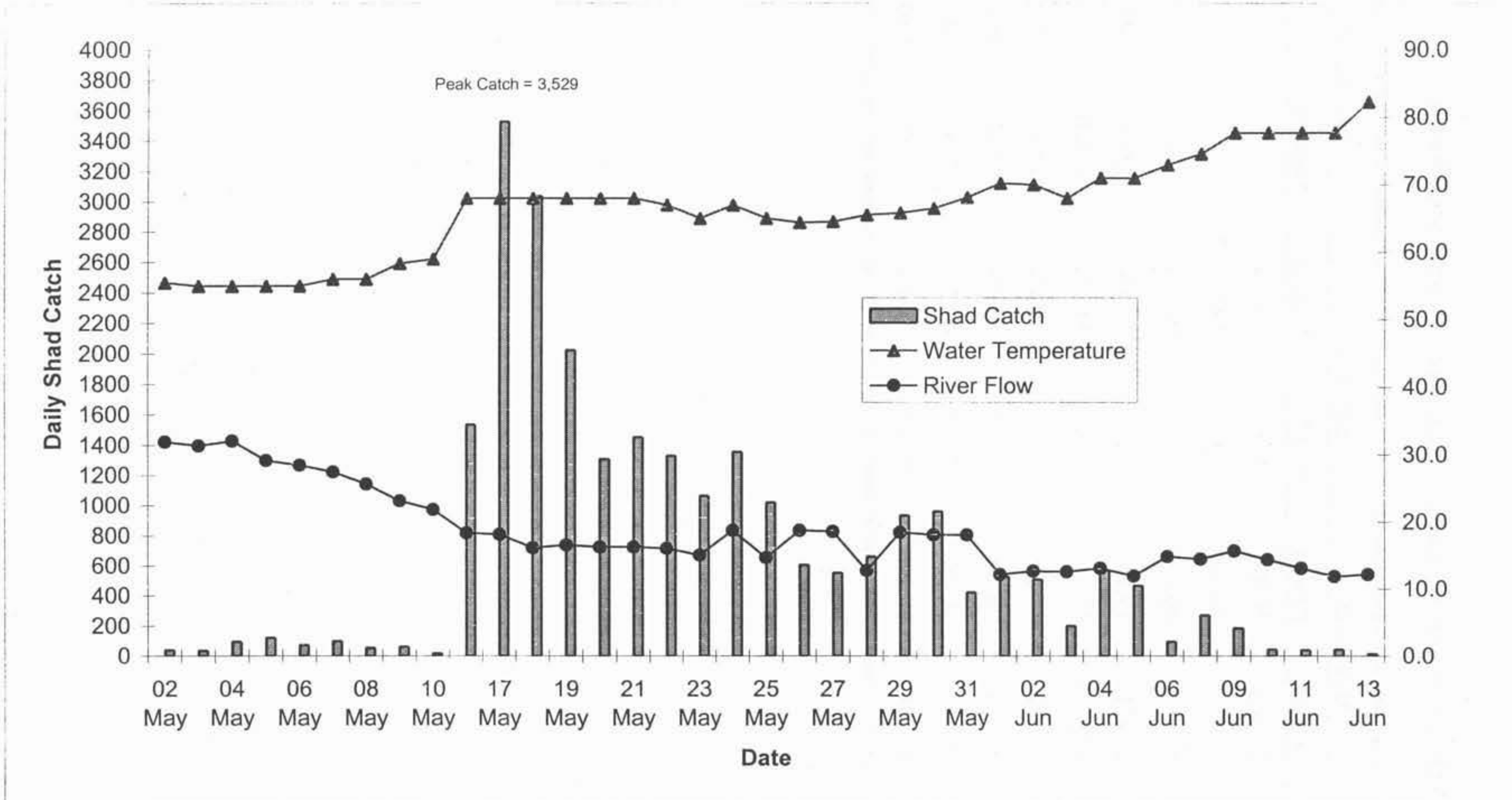
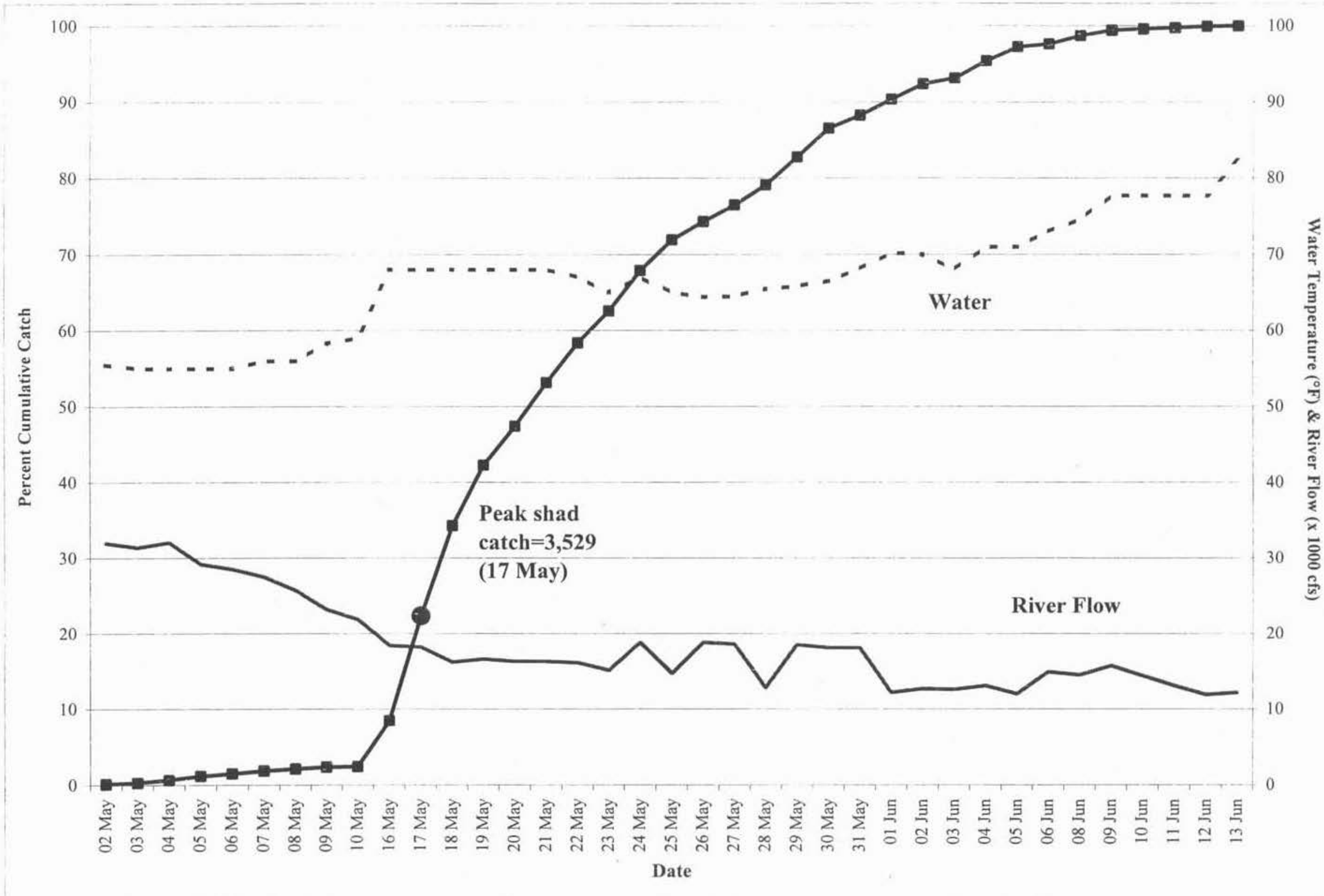


Figure 1

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 2005.


Percent Cumulative Catch
Water Temperature (°F) & River Flow (x 1000 cfs)
Peak shad catch=3,529 (17 May)
Water
River Flow
Date
02 May
03 May
04 May
05 May
06 May
07 May
08 May
09 May
10 May
16 May
17 May
18 May
19 May
20 May
21 May
22 May
23 May
24 May
25 May
26 May
27 May
28 May
29 May
30 May
31 May
01 Jun
02 Jun
03 Jun
04 Jun
05 Jun
06 Jun
08 Jun
09 Jun
10 Jun
11 Jun
12 Jun
13 Jun

FirstEnergy

Job I - Part 5

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

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EXECUTIVE SUMMARY

The York Haven fish ladder was opened on 21 April allowing volitional (unmanned) passage. Manned Fishway operation started on 5 May and ended on 17 June. During this 43 day period a total of 35,940 fish of 21 taxa were enumerated as they passed upstream though the ladder into Lake Frederic. Gizzard shad (12,882) was the dominant fish species passed and comprised over 35% of the fish passed. Passage varied daily and ranged from 91 fish on 5 May to 2,222 fish on 10 June. A total of 1,772 American shad were counted as they passed through the ladder. Some 1,060 shad passed in May while 712 shad passed in June.

American shad were passed at water temperatures of 52.5°F to 82.5°F, and river flows that ranged from 24,600 cfs to 10,600 cfs and East Channel flows of 2,100 cfs and 3,000 cfs (Tables 2 and 3, Figures 3 and 4). During the first 15 days of Fishway operation, 5 May to 19 May, 174 shad passed upstream. Peak passage occurred between 20 May and 2 June. During this two week period 1,100 shad (62% of season total) passed upstream; 642 shad passed in five days. Passage during this period occurred at water temperatures that varied from 63.0°F to 70.0°F and at river flows that declined from 14,200 cfs to 11,600 cfs. East Channel flows during this period were 2,100 cfs. Some 498 shad passed though the ladder between 3 June and 17 June. Passage varied daily during this period and ranged from 5 to 69 shad per day. River flows ranged from 8,500 cfs to 11,400 cfs during this period while water temperatures increased from 68.8°F to a season high of 82.5° F on 14 June. East Channel flows were 2,100 cfs during this period.

The peak hourly passage of shad (87) occurred on 28 May between 0801 hrs and 0859 hrs. Over 71% of the shad (1,274) passed before 1100 hrs; hourly passage varied from 220 to 701 shad. Some 247 shad passed from 1101 hrs to 1300 hrs. A total of 245 shad passed between 1301 hrs and 1600 hrs. Future changes to Fishway operation should to be based on information obtained during the radio telemetry study conducted this spring and experience gained during the first six years of Fishway operation.

INTRODUCTION

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

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

Following discussions at the January 28, 2005 FPTAC meeting, a consensus was reached on the operation of the York Haven Fishway (Fishway) for the spring migration season. 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 2005, the sixth year of Fishway operation, was to incorporate experience gained during the first five seasons, along with FPTAC recommendations from the January 28nd meeting. Objectives of 2005 operation were to monitor passage of migratory and resident fishes through the Fishway and continue to assess operation, including improvements to the Fishway and modification of springtime minimum flow releases.

YHPC continues to work with the FPTAC to determine what minimum spill/flow is necessary for optimizing fish passage at the Project. Modification of the Main Dam spill/flow regime that was outlined in the 1997 Settlement Agreement was agreed to by the FPTAC because: (1) experience with reduced Main Dam spill indicated shad passage increased in the ladder in 2001, and (2) the minimum 4,000/2,000 cfs spill/flow that was originally selected to entice shad to continue moving upstream past the powerhouse to the Fishway was based solely on professional judgment. As a result, in 2005 when river flow was less than 23,000 cfs, a nominal minimum spill of 1,000 cfs was released over the Main Dam. The 1,000 cfs release over the Main Dam was based on measurements made in the tailrace downstream of the Fishway that indicated that the surface elevation of the water downstream of the Fishway dropped just 3.6 inches (0.3 ft) when spill at the Main Dam was reduced to 1,000 cfs. A nominal 2,100 cfs flow was also released through the Fishway into the East Channel during the spawning migration.

Recommendations concerning minimum flows included in the 2005 Fishway Operation Procedure included:

- If and when river flow was less than 23,000 cfs, a nominal minimum spill of 1,000 cfs was to be maintained over the Main Dam during daily Fishway operation.
- As feasible, Main Dam spill was to be reduced in 1,000 cfs increments (pending river conditions). Prior to proceeding to the next level of flow reduction a Fish Passage tailrace level reading was to be recorded.
- When Main Dam spill reached 1,000 cfs, a tailrace level was to be recorded and evaluated prior to continuous operation at this flow condition.
    - A significant reduction in tailrace level could indicate a reduction in the volume of East Channel Flow, which could reduce attraction to the Fishway.

Therefore any significant decrease in tailrace level was to be reviewed with the FPTAC.

- If a significant reduction was not noted, this level of minimum flow release was to be maintained for the remainder of the Fish Passage season during low flow periods.

Project Operation

The hydroelectric station located in York Haven, PA built in 1904, is situated at 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

After the Fishway was closed at the end of the 2004 season it was inundated by high river flows in mid-September 2004 during Hurricane Ivan and again during the spring of 2005 on 4 April. Neither flood caused major damage to the Fishway, but the high river flows deposited a large volume of debris and sediment in the ladder and counting building. Fishway preparations for the 2005 season began during the second week of April. All preseason preparations, including the removal of the debris and sediment from the ladder, were completed on 21 April, enabling volitional fish passage (unmanned) through the ladder to occur that night.

Manned Fishway operation commenced on 5 May, 3 days after the Safe Harbor Fish Lift was placed in service and had passed 177 American shad. Fish were counted and allowed to pass upstream daily between 0800 hrs and 1600 hrs from 5 May to 17 June; a 43 day period. On 2 days, 21 May and 2 June, counting was extended 1 hour as the shad passage count during the previous hour (1500 hrs to 1600 hrs) exceeded five American shad. The decision to stop manned Fishway operation on 17 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 28 June. At this time, the South fixed wheel gate was closed. On 29 June, the fish ladder and North fixed wheel gate were set to deliver a minimum flow of 365 cfs into the East Channel. On September 9 the fish ladder was closed, the North wheel gate remained open until December 2, 2005.

Fish Counts

Fish that passed through the ladder were identified to species and enumerated as they passed the counting window by a biologist or technician. A description of the procedures used to count fish is described in prior annual operating reports (Kleinschmidt 2000 and 2002). Fish passage by the viewing window was controlled by opening or closing an aluminum grating gate with an electric hoist that was controlled from inside the viewing room. This gate was closed nightly between 1600 and 1700 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 12 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 2005 passage was conducted, as hourly shad passage never reached the minimum passage requirement of 1,000 shad per hour.

Results

Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 35,940 fish of 21 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (12,882) was the dominant fish species passed and comprised over 35% of the fish passed. Some 1,772 American shad were counted as they passed through the ladder. Other predominant fishes passed included quillback (8,832), channel catfish (6,199), and walleye (3,912). Passage varied daily and ranged from 91 fish on 5 May to 2,222 fish on 10 June. Six striped bass and one flathead catfish, a non-indigenous species, were observed passing through the ladder.

American Shad Passage

A total of 1,772 American shad passed upstream through the ladder in 2005 (Table 1). Peak shad passage occurred on 27 May when 160 shad were passed. Some 1,060 shad passed in May while 712 shad passed in June.

American shad were passed at water temperatures of 52.5° F to 82.5° F, and river flows that ranged from 24,600 cfs to 10,600 cfs and East Channel flows of 2,100 cfs and 3,000 cfs (Tables 2 and 3, Figures 3 and 4). During the first 15 days of Fishway operation, 5 May to 19 May, 174 shad passed upstream. Peak passage occurred between 20 May and 2 June. During this two week period 1,100 shad (62% of season total) passed upstream; 642 shad passed in five days. Passage during this period occurred at water temperatures that varied from 63.0° F to 70.0° F and at river flows that declined from 14,200 cfs to 11,600 cfs. East Channel flows during this period were 2,100 cfs. Some 498 shad passed though the ladder between 3 and 17 June. Passage varied daily during this period and ranged from 5 to 69 shad per day. River flows ranged from 8,500 cfs to 11,400 cfs during this period while water temperatures increased from 68.8°F to a season high of 82.5° F on 14 June. East Channel flows were 2,100 cfs during this period.

The hourly passage of American shad through the fish ladder is given in Table 3. Over 71% of the shad (1,274) passed before 1100 hrs; hourly passage varied from 220 to 701 shad. Some 247 shad passed from 1101 hrs to 1300 hrs. A total of 245 shad passed between 1301 hrs and 1600 hrs. Six shad passed between 1600 hrs and 1700 hrs on the two days the ladder was open. The peak hourly passage of shad (87) occurred on 28 May between 0800 hrs and 0859 hrs. No blueback herring or alewives were observed during the 2005 passage season.

Observations

Visual observations of fish activity were made on a random basis below the Main Dam once each day. On two occasions several carp, quillback and gizzard shad were observed trying to swim over the Main Dam. No shad or other alosines 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. Although no fish were observed passing through this portion of the Fishway three radio tagged shad did use the "weir cut" to pass upstream of the East Channel Dam.

Summary

Although the Fishway was flooded twice prior to the start of this season, no problems were encountered with any equipment after the Fishway was opened and all the equipment functioned as designed. The ladder was opened on 21 April allowing unmanned passage. Manned Fishway operation started on 5 May and ended on 17 June. During this 43 day period a total of 35,940 fish of 21 taxa were enumerated as they passed upstream though the ladder into Lake Frederic.

A total of 1,772 shad were observed as they passed upstream through the ladder. American shad were passed at water temperatures of 52.5° F to 82.5° F, and river flows that that ranged from 24,600 cfs to 10,600 cfs and East Channel flows of 2,100 cfs and 3,000 cfs. Collection and passage of shad varied daily with 62% of the total shad (1,772) passing between 20 May and 2 June. During this 14 day period, 642 shad passed upstream in five days. Most shad (1,274) passed through the ladder between 0801 hrs and 1100 hrs.

YHPC will continue working with members of the FPTAC to develop and implement practical changes to Fishway operation that are geared toward improving passage through the

Fishway. Future changes to Fishway operation should to be based on information obtained during the radio telemetry study conducted this spring and experience gained during the first six years of Fishway operation.

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 and 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 July, 2005. This observation process will continue in 2006.

Juvenile Passage

The Juvenile Downstream Passage Protocol provides for:

- Monitoring the forebay to determine when outmigrating juveniles arrive at the project
- Starting "Downstream Operation" when juveniles arrive at York Haven; Downstream Operation begins each evening at sunset and continue until about 11:30 p.m. Downstream Operation includes:
    - ➢ Turning on temporary lighting at the trash sluiceway and opening the sluiceway
    - ➢ Operating only Units 1-6 when river flow is insufficient for operation of any of the remaining units
    - ➢ Operating Units 7-20 only when river flow exceeds the hydraulic capacity of available Units 1-6; the operating priority for Units 7-20 is Unit 7, Unit 8, Unit 9, etc.

- Monitoring and sampling in the forebay as river water temperatures drop and/or river flows increase to determine when the juvenile shad emigration has ended for the season
- Ceasing "Downstream Operation" at the end of the run, in consultation with members of the FPTAC.

In accordance with the protocol, monitoring of the York Haven forebay for the presence of fish began on 29 September when water temperature was 69° F and river flow at Harrisburg was 3,820 cfs. Between 29 September and 9 October, detection of fish activity was noted as being generally non-existent or extremely light by station personnel that monitored the forebay nightly for fish activity. An increase in fish activity was noted on 9 October. Seven juvenile shad were collected with a cast net on 10 October confirming that juvenile shad had started migrating downstream. Downstream Operation at the station began on 11 October and continued through 3 November (24 days), in accordance with the protocol.

During the 24 day period, river flows ranged from 15,600 cfs to 114,000 cfs (Figure 5). Flows decreased from 23,700 cfs to 15,600 cfs between 10 and 14 October. The flows increased to 31,500 cfs on 17 October and declined to 16,000 cfs on 23 October. Heavy rain in late October caused river flows to increase again; flows peaked at 114,000 cfs on 28 October.

Observations and cast netting was conducted on 1 and 3 November following the high flow event. Since no juvenile shad were collected and fish activity was non-existent YHPC and the SRAFRC coordinator jointly agreed that there was no need to continue the procedure. Downstream Operation ended for the season following nightly operation on 3 November.

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, PA. 21 pp.

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

White. D.K., and J. Larson. 1998. Model study of the fish passage facility at the East Channel Dam York Haven Project. Alden Research Laboratory. 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 2005.

Date	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May
Observation Time	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Water Temperature (°F)	55.5	55.0	52.5	56.0	61.0	64.0	68.5	67.5	60.5	65.0
AMERICAN SHAD	0	0	1	0	10	10	8	3	5	5
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	36	67	59	27	85	130	196	390	181	105
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	1	0	1	0	1	1	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	1	0	0	0	1
BROWN TROUT	0	0	1	0	0	0	1	0	1	0
BROOK TROUT	0	0	0	0	0	0	3	0	0	0
MUSKELLUNGE	0	0	0	0	0	1	1	0	0	0
CARP	1	4	6	0	28	13	7	21	8	2
QUILLBACK	9	32	54	19	115	116	104	354	264	158
WHITE SUCKER	0	0	3	2	14	20	15	10	11	1
SHORTHEAD REDHORSE	11	38	28	19	95	67	37	58	0	50
CHANNEL CATFISH	0	0	3	20	38	32	93	110	41	26
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	25	50	24	15	95	62	42	40	32	24
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	1
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	8	15	16	20	44	32	31	46	55	100
FALL FISH	1	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**91**	**206**	**196**	**122**	**525**	**484**	**539**	**1,033**	**598**	**473**

Table 1. Continued

Date	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May
Observation Time	8.0	8.0	8.0	8.0	8.0	8.0	9.0	8.0	8.0	8.0
Water Temperature (°F)	66.5	66.0	65.0	66.0	67.0	64.0	64.0	64.5	65.3	64.0
AMERICAN SHAD	3	4	35	36	54	126	62	45	88	59
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	187	128	253	330	593	533	874	728	938	499
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	1	0	0	0	0	0	0	0	0	0
BROWN TROUT	1	0	1	0	0	0	0	0	0	0
BROOK TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	1	0	0	0	3	0
CARP	15	33	5	1	3	4	4	2	1	0
QUILLBACK	393	134	57	45	61	121	19	41	69	44
WHITE SUCKER	2	4	2	1	0	1	0	0	3	1
SHORTHEAD REDHORSE	79	40	20	9	3	4	0	2	3	6
CHANNEL CATFISH	101	64	57	8	12	11	46	41	54	2
ROCK BASS	3	2	2	0	0	0	0	3	0	0
PUMKINSEED	1	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	42	0	7	5	4	7	1	2	12	4
LARGEMOUTH BASS	1	0	1	0	0	0	0	0	0	0
BLACK CRAPPIE	0	1	0	0	0	0	0	0	0	0
YELLOW PERCH	0	1	0	0	0	0	0	0	0	1
WALLEYE	196	150	140	106	149	123	131	74	98	70
FALL FISH	0	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**1,026**	**562**	**580**	**541**	**880**	**930**	**1,137**	**938**	**1,269**	**686**

Table 1. Continued

Date	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun
Observation Time	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	9.0	8.0
Water Temperature (°F)	63.0	63.0	66.0	67.0	66.5	67.0	65.0	68.5	70.0	69.0
AMERICAN SHAD	25	29	160	142	37	42	71	105	109	31
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	393	256	347	455	315	205	125	159	152	83
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	1	1
BROWN TROUT	0	0	0	1	2	1	1	3	6	6
BROOK TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	2	0	0	0	0	0	0	0
CARP	1	0	13	18	13	9	5	12	11	6
QUILLBACK	29	13	146	274	128	169	146	619	316	451
WHITE SUCKER	1	0	2	2	6	4	4	8	14	0
SHORTHEAD REDHORSE	2	2	3	4	1	3	3	13	28	10
CHANNEL CATFISH	13	18	43	91	168	180	57	87	92	59
ROCK BASS	0	0	0	0	0	0	0	0	2	0
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	0	0	4	10	21	10	13	12	12	14
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	2	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	81	134	133	106	158	225	99	104	121	121
FALL FISH	0	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**545**	**452**	**853**	**1103**	**849**	**848**	**524**	**1122**	**866**	**782**

Table 1. Continued

Date	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	12-Jun	13-Jun
Observation Time	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Water Temperature (°F)	68.8	71.0	75.5	74.0	78.5	80.0	79.5	81.0	80.5	81.5
AMERICAN SHAD	21	31	69	46	21	21	55	37	37	45
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	105	81	195	286	286	371	531	714	648	394
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	1	6	1	0	0	0	0	0	0
BROWN TROUT	10	4	13	9	2	0	0	0	0	0
BROOK TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	1	0	0	1	0	0	0
CARP	1	4	27	27	27	36	37	16	8	1
QUILLBACK	265	145	151	519	472	369	720	380	373	308
WHITE SUCKER	7	11	13	18	9	17	21	9	7	0
SHORTHEAD REDHORSE	4	10	7	2	0	2	4	4	3	0
CHANNEL CATFISH	51	38	82	95	89	228	725	442	579	537
ROCK BASS	0	1	2	0	0	0	0	0	0	0
PUMKINSEED	0	0	2	0	0	0	2	4	0	0
SMALLMOUTH BASS	5	9	9	19	24	24	16	27	24	18
LARGEMOUTH BASS	0	0	0	0	0	0	0	2	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	108	64	55	92	82	112	110	109	102	51
FALL FISH	0	0	0	0	0	0	0	0	0	0
FLATHEAD CATFISH	0	0	0	0	0	0	0	0	0	0
Total	**577**	**399**	**631**	**1115**	**1012**	**1180**	**2222**	**1744**	**1781**	**1354**

Table 1. Continued

Date	14-Jun	15-Jun	16-Jun	17-Jun	Total
Observation Time	8.0	8.0	8.0	8.0	**354**
Water Temperature (°F)	82.5	81.0	78.0	74.0	
AMERICAN SHAD	55	12	12	5	**1772**
ALEWIFE	0	0	0	0	**0**
BLUEBACK HERRING	0	0	0	0	**0**
GIZZARD SHAD	255	68	94	25	**12882**
HICKORY SHAD	0	0	0	0	**0**
STRIPED BASS	0	0	0	0	**6**
WHITE PERCH	0	0	0	0	**0**
AMERICAN EEL	0	0	0	0	**0**
RAINBOW TROUT	0	0	0	0	**13**
BROWN TROUT	0	0	0	0	**63**
BROOK TROUT	0	0	0	0	**3**
MUSKELLUNGE	0	0	0	0	**10**
CARP	6	2	6	1	**445**
QUILLBACK	336	149	105	40	**8832**
WHITE SUCKER	5	0	0	0	**248**
SHORTHEAD REDHORSE	5	1	1	8	**689**
CHANNEL CATFISH	1306	249	158	53	**6199**
ROCK BASS	0	0	0	0	**15**
PUMKINSEED	0	0	0	0	**9**
SMALLMOUTH BASS	21	7	21	17	**830**
LARGEMOUTH BASS	0	0	0	0	**7**
BLACK CRAPPIE	0	0	0	0	**1**
YELLOW PERCH	0	0	0	0	**2**
WALLEYE	67	32	25	17	**3912**
FALL FISH	0	0	0	0	**1**
FLATHEAD CATFISH	1	0	0	0	**1**
Total	**2057**	**520**	**422**	**166**	**35,940**

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

Date	River Flow (cfs)	East Channel Flow (cfs)	Main Dam Flow (cfs)	Water Temp. (°F)	Secchi (in) Avg.	Secchi (in) Min.	Secchi (in) Max.	Stop log Gate	Elevation (ft) Head Pond Avg.	Head Pond Min.	Head Pond Max.	Tailwater Avg	Tailwater Min.	Tailwater Max.
5-May	27,500	3,000	24,500	55.0	24.0	24.0	24.0	CLOSED	279.00	279	279	274.0	274	274.0
6-May	25,700	2,800	22,900	55.0	24.0	24.0	24.0	CLOSED	278.95	278.9	279	273.9	273.9	273.9
7-May	24,600	3,000	21,600	52.5	24.0	24.0	24.0	CLOSED	279.00	278.9	279.1	273.9	273.8	274.0
8-May	22,400	2,100	20,300	56.0	15.0	6.0	24.0	CLOSED	278.90	278.8	279	273.9	273.8	273.9
9-May	21,100	2,100	19,000	61.0	24.0	24.0	24.0	CLOSED	278.65	278.6	278.7	274.3	273.8	274.8
10-May	20,100	2,100	18,000	64.0	25.0	24.0	26.0	CLOSED	278.50	278.5	278.5	273.8	273.7	273.8
11-May	19,000	2,100	16,900	68.5	24.0	24.0	24.0	CLOSED	278.35	278.3	278.4	273.8	273.8	273.8
12-May	18,100	2,100	16,000	67.5	16.0	12.0	20.0	CLOSED	278.25	278.2	278.3	273.8	273.6	273.9
13-May	17,200	2,100	15,100	60.5	24.0	24.0	24.0	CLOSED	278.20	278.2	278.2	273.6	273.5	273.6
14-May	16,400	2,100	14,300	65.0	17.0	10.0	24.0	CLOSED	278.10	278.1	278.1	273.5	273.5	273.5
15-May	16,800	2,100	14,700	66.5	24.0	24.0	24.0	CLOSED	278.40	278.4	278.4	273.5	273.5	273.5
16-May	16,600	2,100	14,500	66.0	22.0	20.0	24.0	CLOSED	278.00	278	278	273.6	273.6	273.6
17-May	15,800	2,100	13,700	65.0	18.0	12.0	24.0	CLOSED	277.95	277.9	278.0	273.6	273.5	273.6
18-May	15,200	2,100	13,100	66.0	22.0	20.0	24.0	CLOSED	278.00	278.0	278.0	273.5	273.5	273.5
19-May	14,400	2,100	12,300	67.0	20.0	16.0	24.0	CLOSED	277.95	277.9	278.0	273.5	273.5	273.5
20-May	14,200	2,100	12,100	64.0	20.0	20.0	20.0	CLOSED	278.00	278.0	278.0	273.6	273.5	273.6
21-May	14,100	2,100	12,000	64.0	15.0	10.0	20.0	CLOSED	278.00	278.0	278.0	273.5	273.4	273.5
22-May	14,000	2,100	11,900	64.5	19.0	18.0	20.0	CLOSED	277.95	277.9	278	273.5	273.5	273.5
23-May	13,600	2,100	11,500	65.3	20.0	20.0	20.0	CLOSED	277.90	277.9	277.9	273.5	273.5	273.5
24-May	12,900	2,100	10,800	64.0	22.0	20.0	24.0	CLOSED	277.85	277.8	277.9	273.5	273.5	273.5
25-May	12,700	2,100	10,600	63.0	12.5	10.0	15.0	CLOSED	277.80	277.8	277.8	273.5	273.4	273.5
26-May	12,700	2,100	10,600	63.0	10.0	10.0	10.0	CLOSED	277.90	277.9	277.9	273.5	273.5	273.5
27-May	12,500	2,100	10,400	66.0	17.5	15.0	20.0	CLOSED	277.90	277.9	277.9	273.5	273.5	273.5
28-May	12,100	2,100	10,000	67.0	19.5	15.0	24.0	CLOSED	277.70	277.7	277.7	273.4	273.4	273.4
29-May	12,100	2,100	10,000	66.5	22.0	20.0	24.0	CLOSED	277.70	277.7	277.7	273.5	273.5	273.5
30-May	12,000	2,100	9,900	67.0	16.0	12.0	20.0	CLOSED	277.80	277.8	277.8	273.5	273.5	273.5
31-May	12,000	2,100	9,900	65.0	17.5	15.0	20.0	CLOSED	277.80	277.8	277.8	273.5	273.5	273.5
1-Jun	12,000	2,100	9,900	68.5	17.5	15.0	20.0	CLOSED	277.85	277.8	277.9	273.5	273.5	273.5
2-Jun	11,600	2,100	9,500	70.0	21.0	18.0	24.0	CLOSED	277.75	277.7	277.8	273.4	273.4	273.4
3-Jun	11,300	2,100	9,200	69.0	19.0	18.0	20.0	CLOSED	277.65	277.6	277.7	273.5	273.4	273.5
4-Jun	11,300	2,100	9,200	68.8	22.0	20.0	24.0	CLOSED	277.80	277.8	277.8	273.5	237.5	273.5
5-Jun	11,200	2,100	9,100	71.0	19.5	15.0	24.0	CLOSED	277.80	277.8	277.8	273.5	273.4	273.5
6-Jun	11,100	2,100	9,000	75.5	24.0	24.0	24.0	CLOSED	277.70	277.7	277.7	273.5	273.5	273.5
7-Jun	11,700	2,100	9,600	74.0	24.0	24.0	24.0	CLOSED	277.75	277.7	277.8	273.6	273.6	273.6
8-Jun	13,300	2,100	11,200	78.5	20.0	20.0	20.0	CLOSED	277.85	277.8	277.9	273.6	273.5	273.6
9-Jun	13,500	2,100	11,400	80.0	24.0	24.0	24.0	CLOSED	277.90	277.9	277.9	273.5	273.5	273.5
10-Jun	12,100	2,100	10,000	79.5	21.0	18.0	24.0	CLOSED	277.70	277.7	277.7	273.5	273.4	273.5
11-Jun	11,200	2,100	9,100	81.0	22.0	20.0	24.0	CLOSED	277.65	277.6	277.7	273.5	273.5	273.5
12-Jun	10,900	2,100	8,800	80.5	17.5	15.0	20.0	CLOSED	277.75	277.7	277.8	273.4	273.4	273.4
13-Jun	10,800	2,100	8,700	81.5	12.0	12.0	12.0	CLOSED	277.70	277.7	277.7	273.4	273.4	273.4
14-Jun	11,400	2,100	9,300	82.5	13.5	12.0	15.0	CLOSED	277.85	277.8	277.9	273.5	273.5	273.5
15-Jun	12,900	2,100	10,800	81.0	14.0	14.0	14.0	CLOSED	278.10	278.1	278.1	273.6	273.6	273.6
16-Jun	11,000	2,100	8,900	78.0	14.0	12.0	16.0	CLOSED	277.70	277.7	277.7	273.4	273.4	273.4
17-Jun	10,600	2,100	8,500	74.0	13.5	12.0	15.0	CLOSED	277.70	277.7	277.7	273.5	273.5	273.5

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2005.

Date	River Flow (cfs)	Elevation (ft) Head Pond Avg.	Head Pond Min.	Head Pond Max.	Tailwater Avg	Tailwater Min.	Tailwater Max.	Inside Fishway Avg	Inside Fishway Min.	Inside Fishway Max.	Inside Weir Avg	Inside Weir Min.	Inside Weir Max.	Above Counting Room Avg	Above Counting Room Min.	Above Counting Room Max.	Below Fixed Wheel Gate Avg	Below Fixed Wheel Gate Min.	Below Fixed Wheel Gate Max.	Counting Room Avg	Counting Room Min.	Counting Room Ma
5-May	27,500	279.00	279	279	274.00	274	274	274.70	274.7	274.7	277.50	277.5	277.5	279.0	279	279	277.30	277.3	277.3	278.80	278.8	278
6-May	25,700	278.95	278.9	279	273.90	273.9	273.9	274.65	274.6	274.7	277.50	277.5	277.5	278.9	278.9	279	277.30	277.3	277.3	278.70	278.7	278
7-May	24,600	279.00	278.9	279.1	273.90	273.8	274	274.70	274.7	274.4	277.45	277.4	277.5	278.8	278.8	278.9	277.40	277.4	277.4	278.70	278.7	278
8-May	22,400	278.90	278.8	279	273.85	273.8	273.9	274.45	274.4	274.5	277.35	277.3	277.4	278.7	278.7	278.8	277.35	277.3	277.4	278.65	278.6	278
9-May	21,100	278.65	278.6	278.7	274.30	273.8	274.8	274.45	274.4	274.5	277.35	277.3	277.4	278.4	278.2	278.7	277.20	277.2	277.2	278.50	278.5	278
10-May	20,100	278.50	278.5	278.5	273.75	273.7	273.8	274.40	274.4	274.4	277.25	277.2	277.3	278.5	278.5	278.5	277.15	277.1	277.2	278.45	278.4	278
11-May	19,000	278.35	278.3	278.4	273.80	273.8	273.8	274.85	274.8	274.9	277.30	277.3	277.3	278.3	278.3	278.4	277.15	277.1	277.2	278.35	278.3	278
12-May	18,100	278.25	278.2	278.3	273.75	273.6	273.9	274.40	274.4	274.4	277.15	277.1	277.2	278.2	278.2	278.3	277.00	277	277	278.25	278.2	278
13-May	17,200	278.20	278.2	278.2	273.55	273.5	273.6	274.40	274.4	274.4	277.10	277	277.2	278.2	278.2	278.2	276.95	276.9	277	278.20	278.2	278
14-May	16,400	278.10	278.1	278.1	273.50	273.5	273.5	274.40	274.4	274.4	277.05	277	277.1	278.2	278.2	278.2	276.95	276.9	277	278.10	278.1	278
15-May	16,800	278.40	278.4	278.4	273.50	273.5	273.5	275.30	275.3	275.3	277.20	277.2	277.2	278.1	278.1	278.1	277.90	277.9	277.9	278.00	278	27
16-May	16,600	278.00	278	278	273.60	273.6	273.6	274.40	274.4	274.4	277.10	277.1	277.1	278.1	278.1	278.2	277.05	277	277.1	278.00	278	27
17-May	15,800	277.95	277.9	278.0	273.55	273.5	273.6	274.40	274.4	274.4	277.05	277.0	277.1	278.0	278.0	278.1	276.90	276.9	276.9	277.95	277.9	278
18-May	15,200	278.00	278.0	278.0	273.50	273.5	273.5	274.30	274.3	274.3	276.95	276.9	277.0	278.0	278.0	278.0	276.95	276.9	277.0	278.00	278.0	278
19-May	14,400	277.95	277.9	278.0	273.50	273.5	273.5	274.30	274.3	274.3	276.95	276.9	277.0	277.9	277.9	278.0	276.90	276.9	276.9	277.95	277.9	278
20-May	14,200	278.00	278.0	278.0	273.55	273.5	273.6	274.30	274.3	274.3	276.95	276.9	277.0	278.0	278.0	278.0	276.95	276.9	277.0	278.00	278.0	278
21-May	14,100	278.00	278.0	278.0	273.45	273.4	273.5	274.35	274.3	274.4	277.00	277.0	277.0	278.1	278.1	278.1	276.90	276.9	276.9	278.00	278.0	278
22-May	14,000	277.95	277.9	278	273.50	273.5	273.5	274.35	274.3	274.4	279.95	276.9	277.0	278.0	278.0	278.0	276.85	276.8	276.9	277.95	277.9	278
23-May	13,600	277.90	277.9	277.9	273.50	273.5	273.5	274.30	274.3	274.3	276.85	276.8	276.9	277.9	277.9	277.9	277.30	276.8	277.8	277.90	277.9	277
24-May	12,900	277.85	277.8	277.9	273.50	273.5	273.5	274.35	274.3	274.4	276.90	276.9	276.9	277.9	277.9	278.0	276.80	276.8	276.8	277.85	277.8	277
25-May	12,700	277.80	277.8	277.8	273.45	273.4	273.5	274.20	274.2	274.2	276.85	276.8	276.9	277.8	277.8	277.8	276.80	276.8	276.8	277.80	277.8	277
26-May	12,700	277.90	277.9	277.9	273.50	273.5	273.5	274.30	274.3	274.3	276.90	276.9	276.9	277.9	277.9	277.9	276.80	276.8	276.8	277.90	277.9	277
27-May	12,500	277.90	277.9	277.9	273.50	273.5	273.5	274.30	274.3	274.3	276.90	276.9	276.9	277.9	277.9	277.9	276.80	276.8	276.8	277.90	277.9	277
28-May	12,100	277.70	277.7	277.7	273.40	273.4	273.4	274.30	274.3	274.3	276.85	276.8	276.9	277.8	277.8	277.8	276.70	276.7	276.7	277.70	277.7	277
29-May	12,100	277.70	277.7	277.7	273.50	273.5	273.5	274.30	274.3	274.3	276.85	276.8	276.9	277.8	277.8	277.8	276.75	276.7	276.8	277.70	277.7	277
30-May	12,000	277.80	277.8	277.8	273.50	273.5	273.5	274.30	274.3	274.3	276.80	276.8	276.8	277.8	277.8	277.8	276.70	276.7	276.7	277.80	277.8	277
31-May	12,000	277.80	277.8	277.8	273.50	273.5	273.5	274.30	274.3	274.3	276.80	276.8	276.8	277.8	277.8	277.8	276.80	276.8	276.8	277.80	277.8	277
1-Jun	12,000	277.85	277.8	277.9	273.50	273.5	273.5	274.30	274.3	274.3	276.80	276.8	276.8	277.8	277.8	277.8	277.40	276.8	278.0	277.80	277.8	277
2-Jun	11,600	277.75	277.7	277.8	273.40	273.4	273.4	274.45	274.4	274.5	276.85	276.8	276.9	277.8	277.8	277.8	276.80	276.8	276.8	277.75	277.7	277
3-Jun	11,300	277.65	277.6	277.7	273.45	273.4	273.5	274.30	274.3	274.3	276.85	276.8	276.9	277.6	277.6	277.7	276.75	276.7	276.8	277.65	277.6	277
4-Jun	11,300	277.80	277.8	277.8	273.50	237.5	273.5	274.30	274.3	274.3	276.90	276.9	276.9	277.8	277.8	277.8	276.90	276.9	276.9	277.80	277.8	277
5-Jun	11,200	277.80	277.8	277.8	273.45	273.4	273.5	274.30	274.3	274.3	276.90	276.9	276.9	277.9	277.9	277.9	276.85	276.8	276.9	277.80	277.8	277
6-Jun	11,100	277.70	277.7	277.7	273.50	273.5	273.5	274.40	274.4	274.4	276.90	276.9	276.9	277.8	277.8	277.8	276.85	276.8	276.9	277.70	277.7	277
7-Jun	11,700	277.75	277.7	277.8	273.60	273.6	273.6	274.25	274.2	274.3	276.90	276.9	276.9	277.7	277.7	277.8	276.85	276.8	276.9	277.75	277.7	277
8-Jun	13,300	277.85	277.8	277.9	273.55	273.5	273.6	274.30	274.3	274.3	276.90	276.9	276.9	277.8	277.8	277.9	276.85	276.8	276.9	277.85	277.8	277
9-Jun	13,500	277.90	277.9	277.9	273.50	273.5	273.5	274.30	274.3	274.3	276.95	276.9	277.0	277.9	277.9	277.9	276.80	276.8	276.8	277.80	277.8	277
10-Jun	12,100	277.70	277.7	277.7	273.45	273.4	273.5	274.40	274.4	274.4	276.85	276.8	276.9	277.8	277.8	277.8	276.75	276.7	276.8	277.65	277.6	277
11-Jun	11,200	277.65	277.6	277.7	273.50	273.5	273.5	274.35	274.3	274.4	276.85	276.8	276.9	277.7	277.7	277.8	276.70	276.7	276.7	277.65	277.6	277
12-Jun	10,900	277.75	277.7	277.8	273.40	273.4	273.4	274.40	274.4	274.4	276.90	276.9	276.9	277.8	277.8	277.9	276.80	276.8	276.8	277.75	277.7	277
13-Jun	10,800	277.70	277.7	277.7	273.40	273.4	273.4	274.40	274.4	274.4	276.90	276.9	276.9	277.8	277.8	277.8	276.80	276.8	276.8	277.70	277.7	277
14-Jun	11,400	277.85	277.8	277.9	273.50	273.5	273.5	274.40	274.4	274.4	376.95	276.9	277.0	277.9	277.8	278.0	276.85	276.8	276.9	277.85	277.8	27
15-Jun	12,900	278.10	278.1	278.1	273.60	273.6	273.6	274.45	274.4	274.5	277.10	277.1	277.1	278.1	278.1	278.1	277.00	277.0	277.0	278.10	278.1	27
16-Jun	11,000	277.70	277.7	277.7	273.40	273.4	273.4	274.25	274.2	274.3	276.85	276.8	276.9	277.7	277.7	277.7	276.50	276.7	276.7	277.70	277.7	27
17-Jun	10,600	277.70	277.7	277.7	273.50	273.5	273.5	274.80	274.8	274.8	276.80	276.8	276.8	277.7	277.7	277.7	276.20	276.2	276.2	277.70	277.7	27

Table 4. Hourly summary of American shad passage through the sepentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2005.

Date	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)										
0801 - 0900	0	0	0	0	1	3	3	0	2	0
0901 - 1000	0	0	0	0	3	1	2	0	0	2
1001 - 1100	0	0	0	0	0	0	0	1	0	0
1101 - 1200	0	0	0	0	0	1	0	0	0	0
1201 - 1300	0	0	0	0	1	0	1	2	2	0
1301 - 1400	0	0	0	0	1	5	0	0	0	0
1401 - 1500	0	0	1	0	4		1	0	0	1
1501 - 1600	0	0	0	0	0	0	1	0	1	2
1601 - 1700	0	0	0	0	0	0	0	0	0	0
Total Catch	**0**	**0**	**1**	**0**	**10**	**10**	**8**	**3**	**5**	**5**

Table 4. *(continued)*

Date	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1700	1600	1600	1600
Military Time (Hours)										
0801 - 0900	2	0	20	20	35	58	29	18	32	31
0901 - 1000	0	0	7	8	5	25	12	8	22	4
1001 - 1100	0	0	3	5	5	14	3	9	12	9
1101 - 1200	0	1	1	1	1	12	4	2	5	5
1201 - 1300	0	1	0	1	3	2	4	4	7	2
1301 - 1400	0	0	1	0	2	5	0	2	3	2
1401 - 1500	1	2	3	1	1	9	2	1	5	2
1501 - 1600	0	0	0	0	2	1	7	1	2	4
1601 - 1700	0	0	0	0	0	0	1	0	0	0
Total Catch	**3**	**4**	**35**	**36**	**54**	**126**	**62**	**45**	**88**	**59**

Table 4. *(continued)*

Date	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1700	1600
Military Time (Hours)										
0801 - 0900	5	9	29	87	15	12	39	36	60	13
0901 - 1000	4	6	46	26	4	6	14	31	17	6
1001 - 1100	4	2	22	6	1	8	6	9	8	5
1101 - 1200	4	1	12	7	1	5	3	18	3	3
1201 - 1300	3	4	31	6	2	2	4	1	3	4
1301 - 1400	4	4	11	5	1	7	3	6	2	0
1401 - 1500	0	2	7	1	9	1	0	2	5	0
1501 - 1600	1	1	2	4	4	1	2	2	10	0
1601 - 1700	0	0	0	0	0	0	0	0	1	0
Total Catch	**25**	**29**	**160**	**142**	**37**	**42**	**71**	**105**	**109**	**31**

Table 4. *(continued)*

Date	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	12-Jun	13-Jun
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600
Military Time (Hours)										
0801 - 0900	7	7	27	20	4	4	19	11	5	12
0901 - 1000	6	8	4	11	9	6	7	2	4	11
1001 - 1100	4	2	4	2	2	1	17	8	17	15
1101 - 1200	2	1	5	4	2	8	3	7	3	4
1201 - 1300	0	3	10	3	1	0	2	0	6	0
1301 - 1400	0	3	14	3	0	2	3	2	0	3
1401 - 1500	2	3	5	2	2	0	2	4	2	0
1501 - 1600	0	4	0	1	1	0	2	3	0	0
1601 - 1700	0	0	0	0	0	0	0	0	0	0
Total Catch	**21**	**31**	**69**	**46**	**21**	**21**	**55**	**37**	**37**	**45**

Table 4. *(continued)*

Date	14-Jun	15-Jun	16-Jun	17-Jun		
Observation Time (Start)	0800	0800	0800	0800		
Observation Time (End)	1600	1600	1600	1600	**Total**	**%**
Military Time (Hours)						
801 - 0900	24	5	4	2	701	39.6
901 - 1000	16	3	6	0	353	19.9
1001 - 1100	8	0	0	1	220	12.4
1101 - 1200	1	2	1	1	134	7.6
1201 - 1300	2	0	0	1	113	6.4
1301 - 1400	1	0	0	0	95	5.4
1401 - 1500	1	2	1	0	86	4.9
1501 - 1600	2	0	0	0	64	3.6
1601 - 1700	0	0	0	0	6	0.3
Total Catch	**55**	**12**	**12**	**5**	**1772**	**100.0**

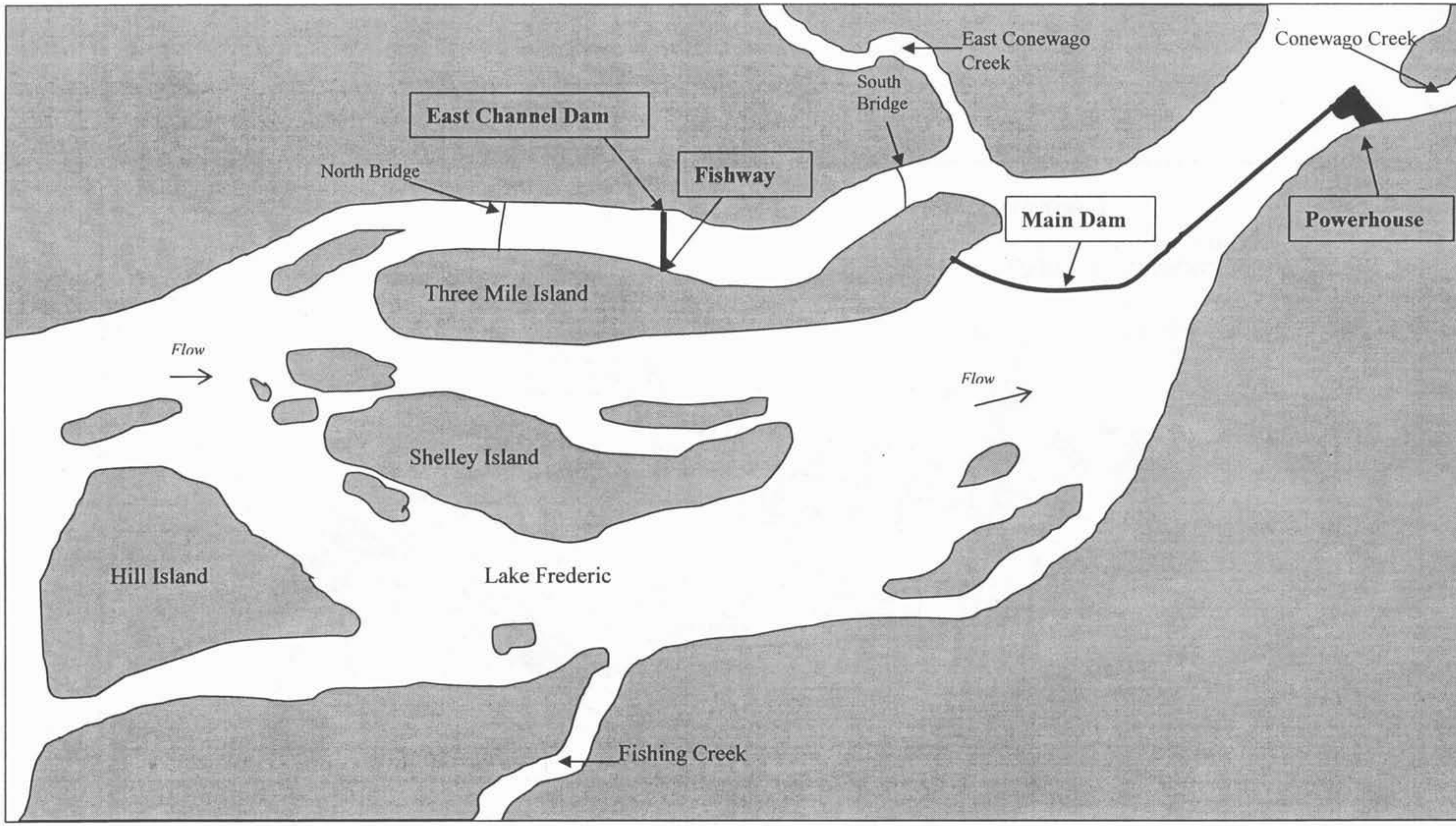
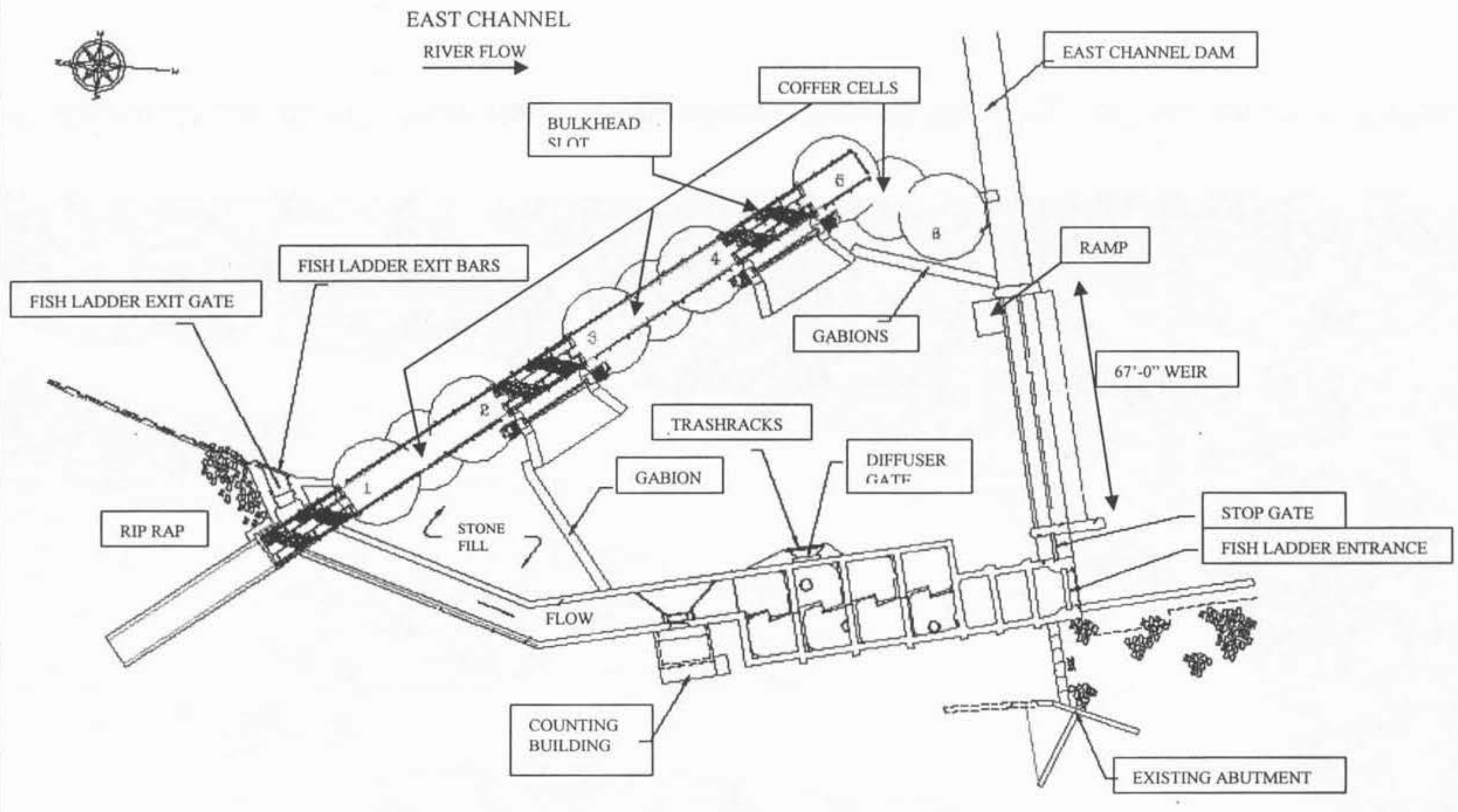


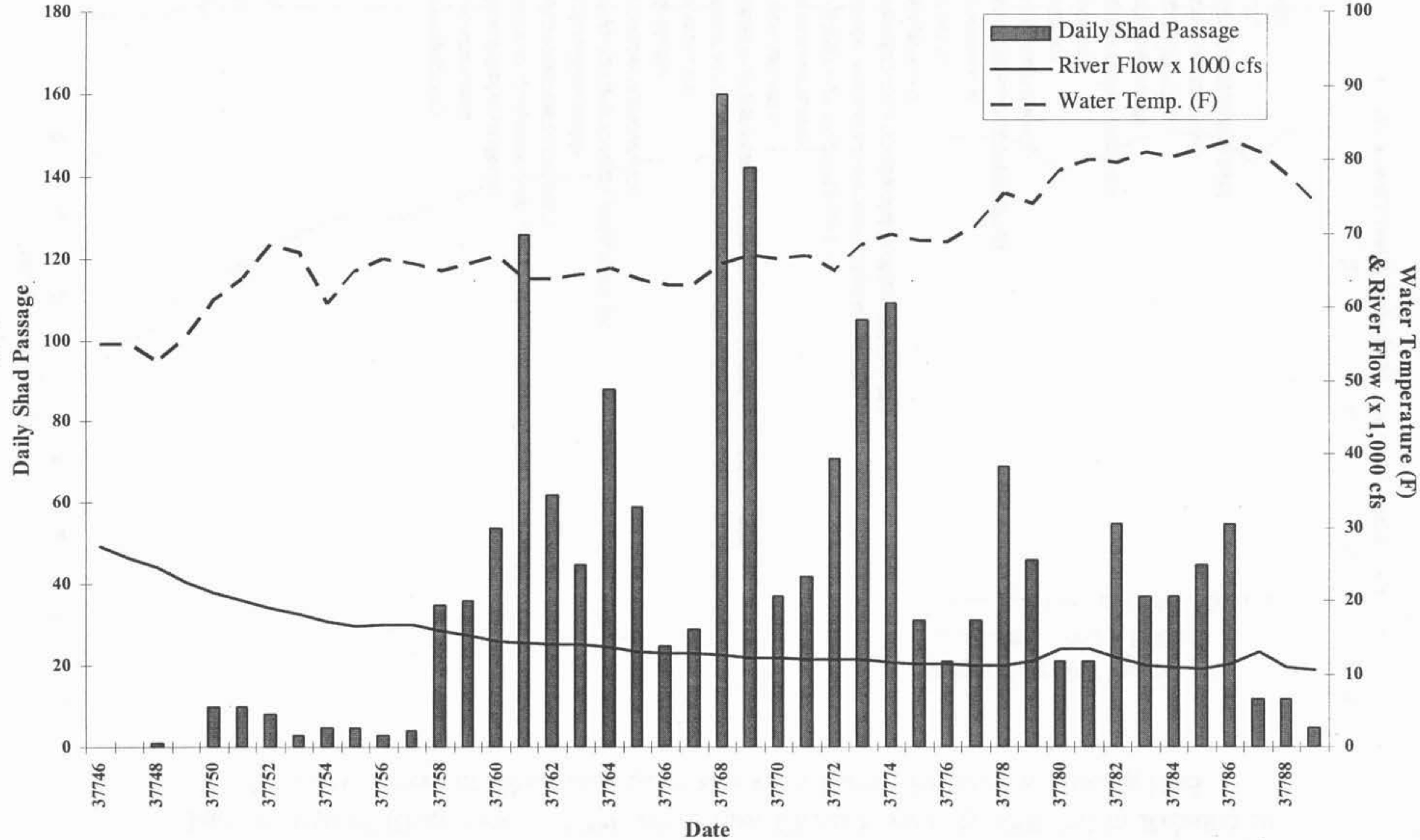
Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



GENERAL ARRANGEMENT
YORK HAVEN FISHWAY

FIGURE 2

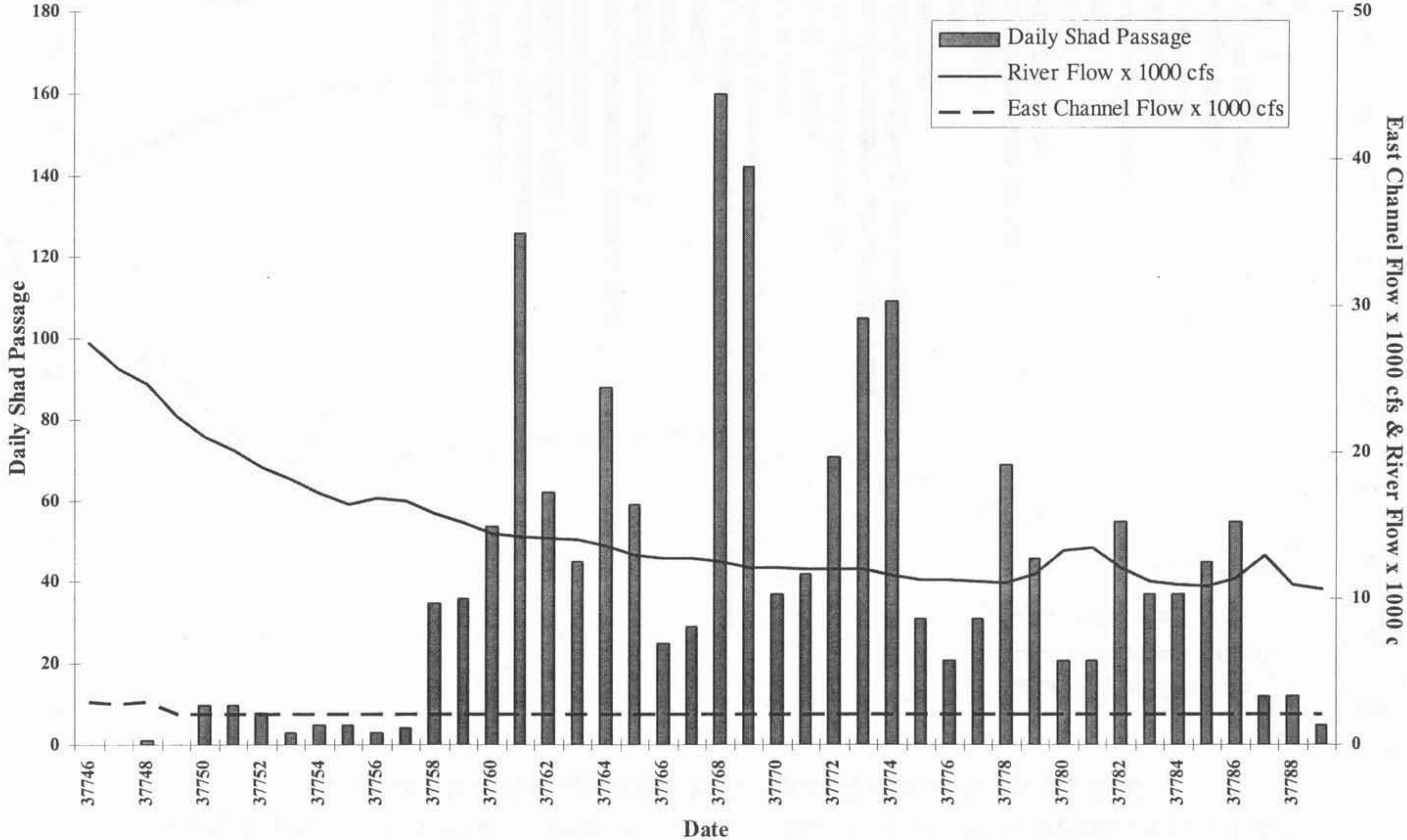
Figure 3. Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2005



1-93

Initial Doc.

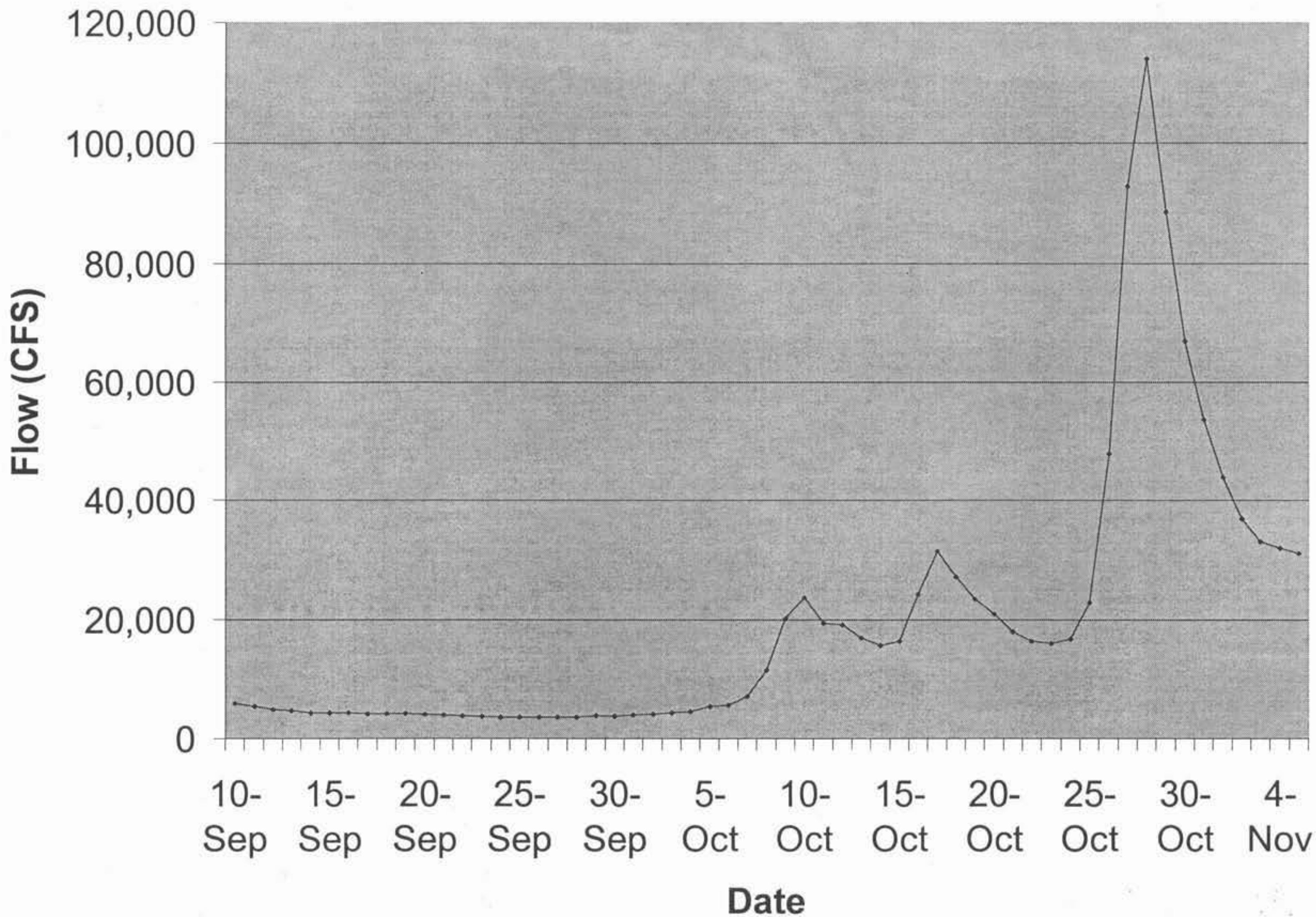
Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2005



1-94

Initial Doc.

Figure 5. Plot of River Flow (cfs) at the USGS Harrisburg Station (#01570500) on the Susquehanna River, 10 September to 5 November, 2005



Job II – Part 1

AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2005

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ABSTRACT

The Pennsylvania Fish and Boat Commission (PFBC) cooperates with other state and federal agencies and hydro-power companies to restore the American shad (*Alosa sapidissima*) to the Susquehanna River. The restoration effort is coordinated through the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). One component of that effort is production of hatchery-reared American shad larvae for stocking in the Susquehanna River. Fertilized American shad eggs obtained from several rivers initiate hatchery activities. The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. (Lancaster, Pennsylvania) was contracted to capture ripe adult shad, on the spawning grounds, during spawning activity, artificially fertilize the eggs and deliver them to the hatchery. The objective was to deliver up to 20 million fertilized American shad eggs with a viability of 60-70 percent.

Egg collection began on 19 May 2005 and ended on 5 June 2005. Sampling occurred on 13 dates and included 24 boat-days of gill netting. A total of 2.9 million eggs were collected and delivered to the Van Dyke Hatchery. The number of eggs collected was significantly less than 2004 when 9.39 million eggs were taken and slightly less than 1993 when 2.97 million eggs were taken. This is attributed in part to a late start resulting from permitting delays. Egg viability averaged 72.4%, within the 60-70% goal of the PFBC. All eggs were collected by gill net from the Coxsackie and Lower Schodack sites.

INTRODUCTION

The Pennsylvania Fish and Boat Commission (PFBC) is cooperating with other state and federal agencies and hydro-power companies to restore the American shad (*Alosa sapidissima*) to the Susquehanna River. The restoration effort is coordinated through the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). One component of that effort is production of hatchery-reared American shad larvae at the Commission's Van Dyke Hatchery for stocking in the Susquehanna River. Fertilized American shad eggs are required to initiate the hatchery activities.

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. was contracted to capture ripe adult shad on the spawning grounds during spawning activity, artificially fertilize the eggs, and deliver them to the hatchery. The objective in 2005 was to deliver 10 to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Since 1980 more than 500 million eggs have been obtained as part of the Susquehanna River anadromous fish restoration program. Annual production has ranged from 11 to 52 million eggs per year. The highest production was from the Columbia River, Oregon, which was discontinued in 1989. All subsequent egg collection efforts have been made on the East Coast. Since 1989, the primary rivers used have been the Delaware and Hudson rivers (Table 1).

COLLECTING METHODS AND SCHEDULE

Water temperatures and local conditions were monitored, and PFBC Project Officer was consulted to determine the start date for egg collection operations. The Wyatt Group used procedures employed since 1989. This included regular contact with commercial fishermen and resource agency personnel beginning on April 1. After this date, contact was made once a week until April 15 and then every two days until conditions indicated that spawning activity had reached a point where egg collection efforts should yield the desired 5-liter minimum for shipment.

Water temperature data from USGS stations at Coxsackie (Hudson RM125) and Stuyvesant (Hudson RM 127) was monitored for indications that water temperatures were approaching 55°F. Commercial fisherman began gill netting for shad during the last week of April. As the commercial shad fishing season progressed, commercial fishers were asked about the size of catches and spawning conditions of shad. Data obtained from lower river locations were used as an indication that the shad spawning migration had begun. Information from the Cheviot/Rogers Island reach (river miles 106 to 114), a few miles below the area where The Wyatt Group would net shad, was an important trigger for initiating egg collection activities.

The Wyatt Group provided two field crews to capture ripe American shad and to strip, fertilize and pack eggs for shipment and delivery to the Van Dyke Hatchery. Both crews operated from boats that were fully equipped to capture shad by gill net. A driver was provided to deliver shad eggs to the Van Dyke Hatchery in Thompsontown, Pennsylvania.

The Wyatt Group obtained a "License to Collect or Possess" Hudson River American shad from the NYDEC. The permit required by the NYDEC to collect American shad eggs from the Hudson River was obtained later than scheduled, but had less impact on collections than anticipated due to cool weather and a late spring. The project complied with all regulations and requirements imposed by the State of New York. Disposal of carcasses was according to conditions of the permit.

Gill net operations were conducted in areas of the river where ripe shad have been captured with consistency. Gill netting was not conducted from Fridays at 6:00 PM to Saturdays at 6:00 PM, in observance of a NYDEC designated lift day; which is day when no commercial fishing is allowed. The project was terminated when eggs were no longer being taken regularly in a quantity (5 liters or more) which justified shipment to the Van Dyke Hatchery.

Monofilament gill nets were of 5.5 inch stretch mesh, up to 600 feet long and 8 feet deep. Each crew set some 900 to 1,200 feet of net. Gill nets were primarily anchored and tended regularly after being set, or occasionally drifted and tended after an approximately 30-45 minute drift. Collection sites in 2005 included Coxsackie (RM 125) and Lower Schodack (RM135). Fishing commenced just before dusk and continued until ripe shad were no longer caught. Generally, the entire operation was conducted between 6:00 PM and 1:00 AM.

All netting was conducted in tidal areas. The impact of tidal conditions, although mostly affecting netting efficiency at certain sites, influenced the availability of ripe shad. On the Hudson River, spawning shad were especially vulnerable to gill netting on the flats and along the shore during the period when the tide changed from ebb to flood. Tide tables were used to decide when gill netting would be most effective at selected sites. At Coxsackie, the water depth is variable (4-10 feet) and gill nets could be set at any tide stage.

PROCESSING AND DELIVERY OF SHAD EGGS

The proper handling of shad and eggs in the field is crucial to egg viability. All processing was done on board each boat and only running ripe females were used. Eggs from 4-6 ripe shad were squeezed into a dry collecting pan. Sperm was taken only when eggs were ready to be fertilized. Eggs were fertilized with sperm from up to six males; but preferably, a ratio of one male to three female shad was used in the fertilization process. Eggs and sperm were taken from fewer fish, if the preferred number was not available, to assure that only live fish were used.

Sperm and eggs were dry mixed for about one minute followed by addition of a small amount of water to activate the sperm and ensure fertilization. After several minutes, eggs were washed repeatedly to remove excess sperm, unfertilized and broken eggs, scales, and blood. Eggs were then placed in large plastic buckets with at least 10 gallons of clean river water and allowed to harden for at least two hours before packaging. Hardened eggs were filtered into doubled plastic bags, five liters of eggs with five liters of clean river water. At least two liters of pure oxygen was injected into the bags, which were then secured with castrating rings. When ready for shipment, the bags were placed into coolers and labeled with river location, date of collection, quantity of eggs and water temperature.

When the volume of eggs was five liters or more, eggs were delivered by automobile to the Van Dyke Hatchery. The goal was to have the eggs arrive at the hatchery between 8:00 and 10:30 AM with all shipments arriving before 11:00 AM the next day. Daily reports were filed by voice message on a telephone answering machine monitored by the PFBC Project Officer and hatchery staff. The report included the approximate total of eggs collected in liters, time of departure and estimated time of arrival of eggs, river temperature and conditions and observations that might affect egg collection efforts the following night.

RESULTS AND DISCUSSION

The project commenced when permits were obtained from NYDEC. Two crews began collections on May 19. Boat 2 ended collection efforts on June 2, while boat 1 ended on June 5 when water temperature reached 67°F. Sampling occurred on 13 dates during this period, including 24 boat-days of gill netting.

A total of 2.9 million eggs were shipped to the Van Dyke Hatchery (Table 2). The number of eggs collected was significantly less than 2004 when 9.39 million eggs and the lowest since annual Hudson River egg collections were initiated in 1989. Eggs were collected from the Coxsackie and Lower Schodack sites. Eggs were available on a consistent basis at Coxsackie. The goal of 60-70% viability was exceeded with an average of 72.4% and a range from 33.8% to 83.9% in individual shipments.

TABLE 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson Rivers and delivered to the Van Dyke Hatchery, 1983-2005.

Year	Delaware	Hudson	Total
1983	2.40	1.17	3.57
1984	2.64	-	2.64
1985	6.16	-	6.16
1986	5.86	-	5.86
1987	5.01	-	5.01
1988	2.91	-	2.91
1989	5.96	11.18	17.14
1990	13.15	14.53	27.68
1991	10.74	17.66	28.40
1992	9.60	3.00	12.60
1993	9.30	2.97	12.27
1994	10.27	6.29	16.56
1995	10.75	11.85	22.60
1996	8.31	5.69	14.00
1997	11.76	11.08	22.84
1998	10.34	15.72	26.06
1999	5.49	21.00	26.49
2000	3.83	16.40	20.23
2001	6.35	3.90	10.25
2002	2.04	18.51	20.55
2003	3.47	17.27	20.74
2004	2.41	9.39	11.80
2005	6.21	2.92	9.13
Total	154.96	190.53	345.49

TABLE 2. Collection data for American shad eggs, Hudson River, 2005.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability
19-May	Coxsackie	12.8	403,737	24	62	78.1
21-May	Coxsackie	3.5	130,888	27	59	81.3
22-May	Coxsackie	4.9	149,534	28	59	77.3
23-May	Coxsackie	3.6	133,239	30		76.1
24-May	Coxsackie	3.9	119,017	33		80.7
28-May	Coxsackie	6.1	192,406	37	59	62.9
29-May	Coxsackie	9.1	299,787	38		83.7
30-May	Coxsackie	3.6	126,443	39	60	61.5
31-May	Lower Schodack	8.7	385,985	40	60	78.3
1-Jun	Lower Schodack	11.6	465,976	44	62	83.9
2-Jun	Lower Schodack	1.7	133,109	46	63	33.8
4-Jun	Lower Schodack	7.2	322,568	48	66	62.2
5-Jun	Lower Schodack	1.5	60,866	49	67	76.2
Total		78.2	2,923,555			

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2005

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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 2005, 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 PA Fish and Boat Commission (PFBC) Area Fisheries Manager and his staff stationed at Bushkill, PA. In 2000 through 2005, 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 the assistance of Ecology III. In 2005, fourteen 200-foot gill nets were set per night with the exception of the first night, May 9, when nine nets were set. 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. Eggs were then gently scooped into large, double-lined plastic bags – about 3 liters of eggs and 3 to 5 liters of fresh water. Medical-grade oxygen was bubbled into the bags to super-saturation and they were sealed with rubber castration rings. Bags were then placed into coolers and transported by truck 150 miles to the 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.

Results and Discussion

Table 1 summarizes daily Delaware River shad egg collections during May 2005. American shad spawning operations commenced on May 9, when river flow was 4,900 cfs (USGS gauge at Montague, NJ), and river temperature was 14.4° C (58° F). Egg take ended on June 2, when river flow was 1,880 cfs and temperature was 21° C (69.8° F). The 2005 egg-take operation was conducted during a window of decreasing flow and rapidly increasing temperature conditions (Figure 1, Table 1). All of the successful egg collections occurred when flow was near or below 62-year median flows (Figure 1). Egg collections were negatively impacted by rapidly increasing water temperatures which contracted the spawning period and reduced egg viability.

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 - 3 each; 4.75 - 1 each; 5.00 - 2-5 each; 5.25 - 1 each; 5.50 - 1 each; 5.75 - 1 each; and 6.00 - 1-2 each.

A total of 905 adult American shad were caught (Table 1). Nightly catches ranged from 23 to 103 shad. Sex ratio (male to female) was 0.65:1. Some 145.6 L (6.2 million) fertilized eggs were collected and shipped to the Van Dyke Hatchery. A total of 669,000 American shad larvae were stocked in the Lehigh River, 799,000 were stocked in the Schuylkill River, and 170,000 were stocked in the Delaware River at Smithfield Beach to replenish the Delaware for the adults used for egg-take. From 1983 to 2005, 155 million American shad eggs were collected from the Delaware River. From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 15.2 million in the Lehigh River, 5.0 million in the Schuylkill River, and 0.2 million in the Delaware River. The increased numbers of adult shad collected in 2005, and a sharp increase in catch/effort (Figure 3) are thought to be reflective of an increase in the abundance of adult shad in 2005.

Summary

Shad eggs were collected and shipped on all 15 nights that were fished from 9 May through 2 June 2005. During this time, 905 adult shad were captured and 145.6 liters of eggs were shipped for a hatchery count of 6.2 million eggs. Overall, the viability for Delaware River American shad eggs was 32%.

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Figure 1. American shad egg collections and flow, Delaware River, 2005.

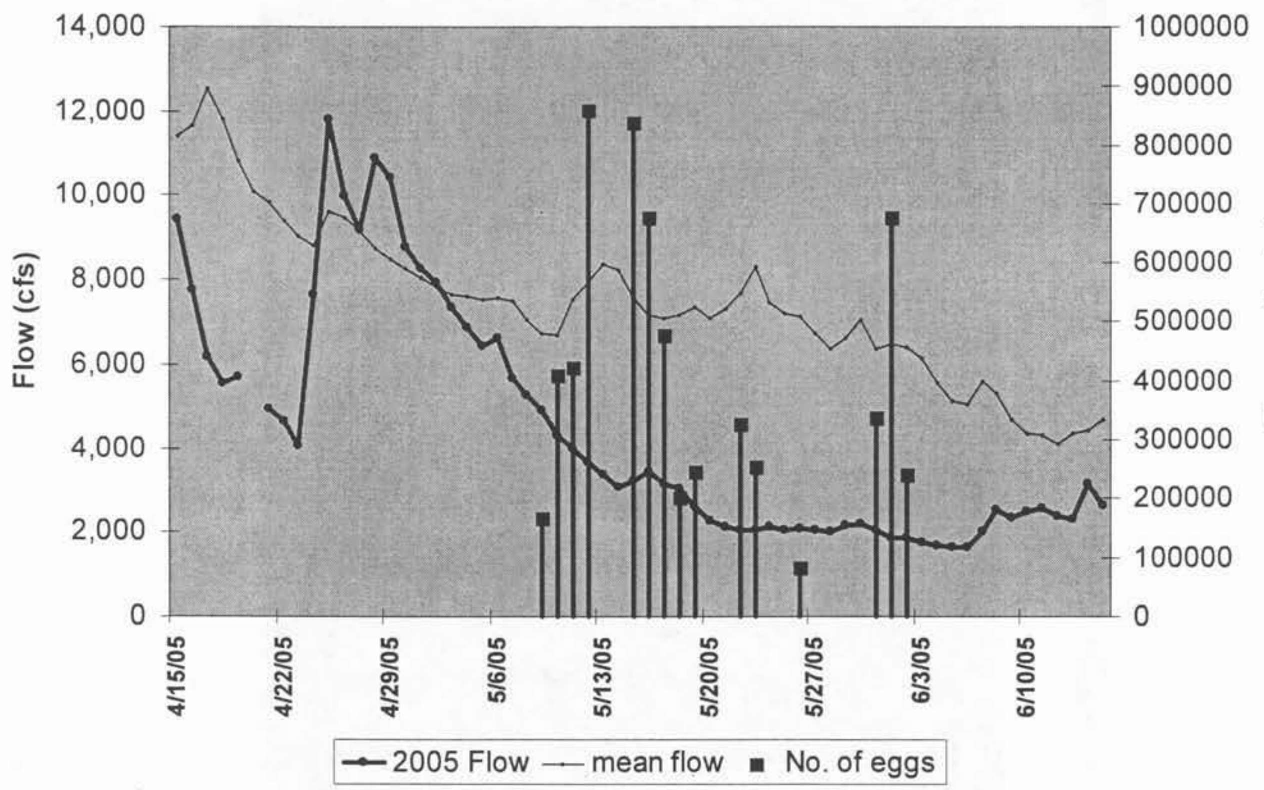
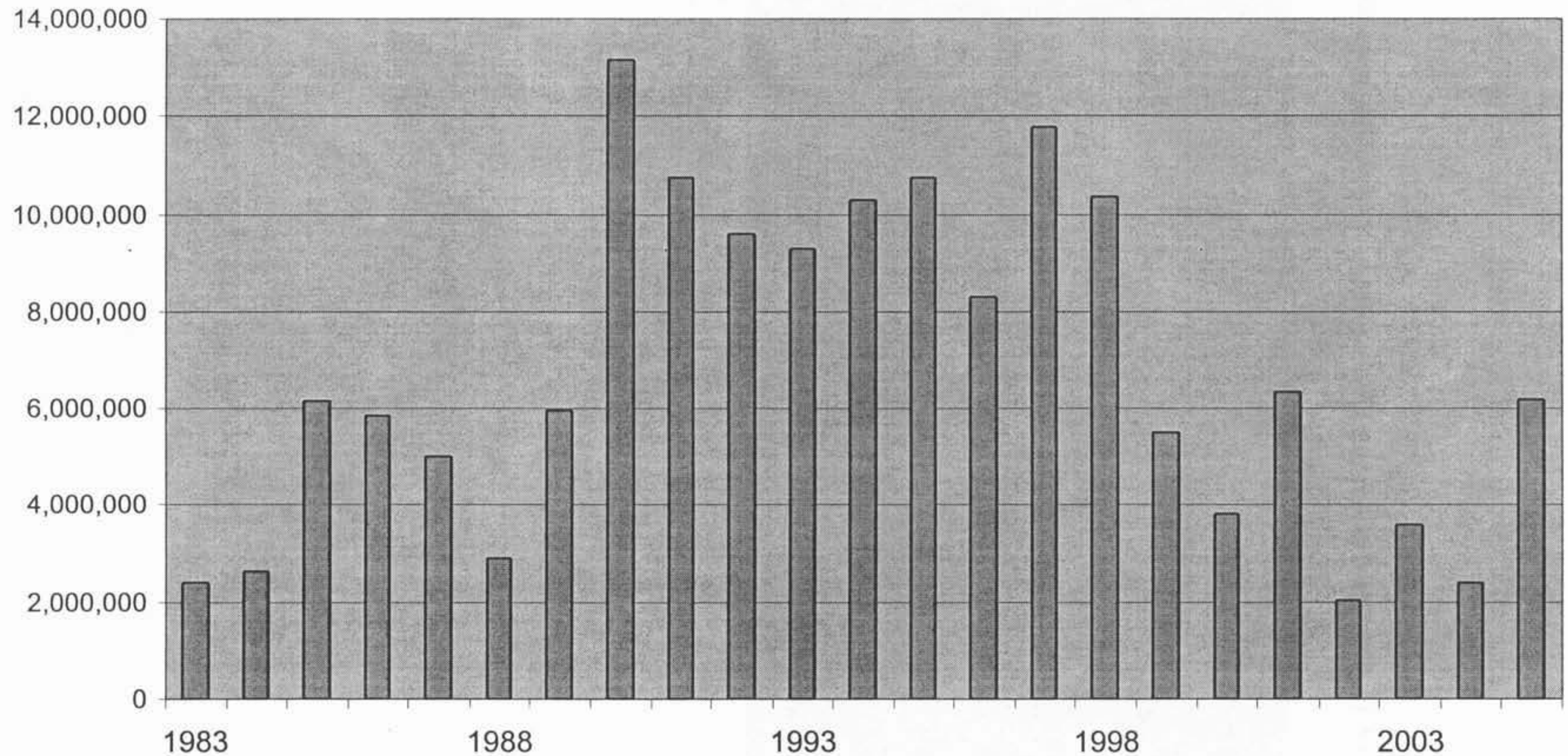


Figure 2. American shad eggs collected from the Delaware River.



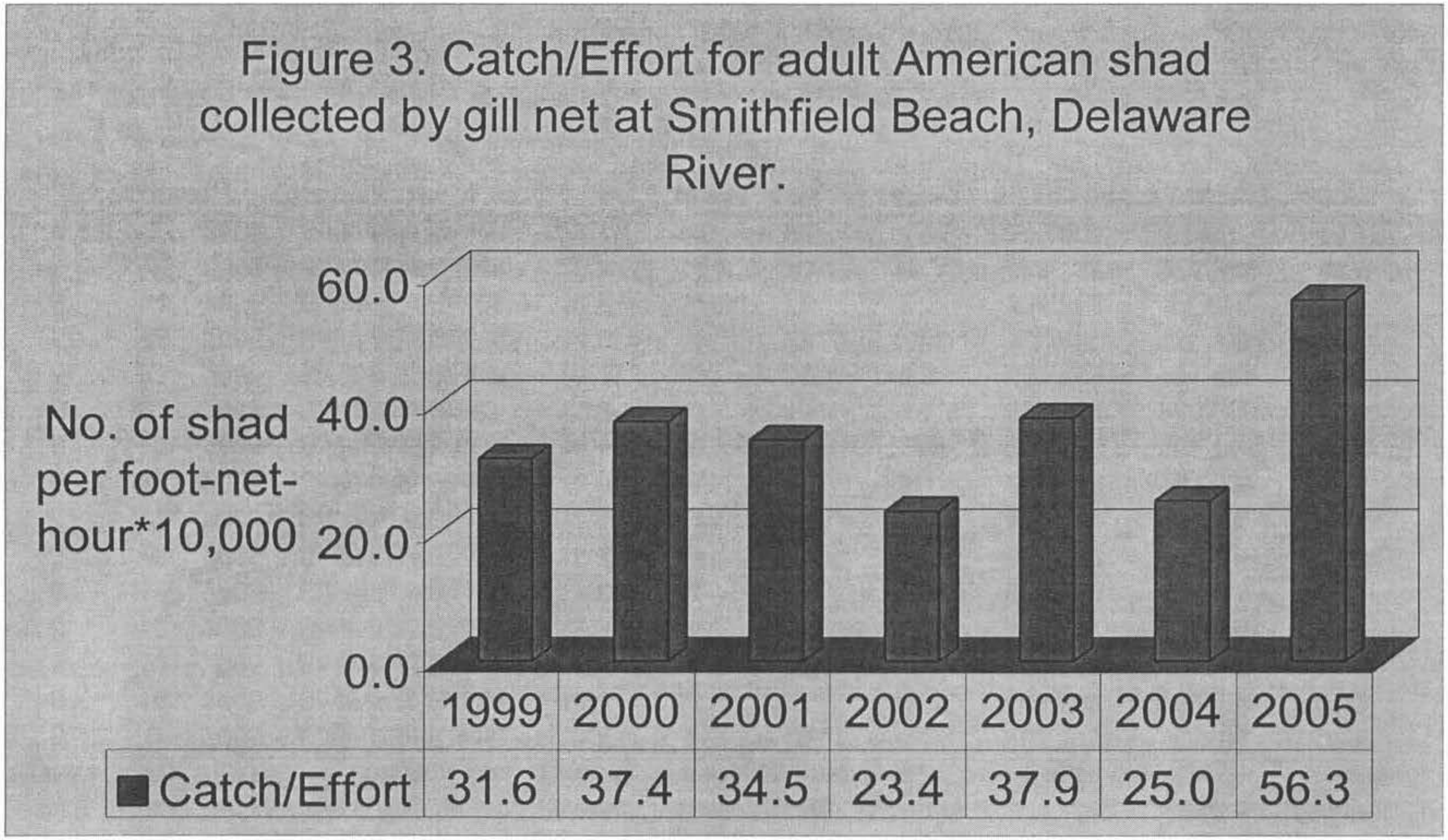


Figure 3. Catch/Effort for adult American shad collected by gill net at Smithfield Beach, Delaware River.

Table 1. Delaware River American shad egg collection, 2005.

MONTH	DAY	YEAR	Location	Water Temp C	No. of Nets	No. of shad captured	Volume (L)	Eggs	Viable Eggs	Percent Viable
5	9	2005	Smithfield Beach	14.4	9	40	5.3	167,172	97,461	58.5
5	10	2005	Smithfield Beach	16.4	14	77	13.7	408,897	250,594	61.3
5	11	2005	Smithfield Beach	18	14	74	9	423,167	93,740	22.2
5	12	2005	Smithfield Beach	18.3	14	102	14.4	860,197	32,386	3.8
5	15	2005	Smithfield Beach	18.8	14	103	18.9	838,520	52,534	6.3
5	16	2005	Smithfield Beach	18.6	14	77	17	676,022	349,439	51.7
5	17	2005	Smithfield Beach	18.8	14	65	10.9	478,881	8,733	1.8
5	18	2005	Smithfield Beach	18.3	14	35	5.1	200,758	101,627	50.6
5	19	2005	Smithfield Beach	18.4	14	34	6.75	244,673	153,758	62.8
5	22	2005	Smithfield Beach	16.2	14	45	10	325,894	260,966	80.1
5	23	2005	Smithfield Beach	16.3	14	38	7.3	253,699	161,679	63.7
5	26	2005	Smithfield Beach	14.3	14	23	2.24	82,905	28,608	34.5
5	31	2005	Smithfield Beach	19.5	14	72	7.1	336,862	71,976	21.4
6	1	2005	Smithfield Beach	20.4	14	70	13.2	675,738	274,504	40.6
6	2	2005	Smithfield Beach	21.1	14	50	4.7	240,604	37,867	15.7
					Total	905	145.59	6,213,989	1,975,872	31.8%

JOB II – PART 3
REPORT ON HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN AND HICKORY SHAD AT CONOWINGO DAM, SPRING 2005

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BACKGROUND

For over a decade, 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 Susquehanna River shad stocks have continued their growth and the contribution of hatchery fish has ranged from 30 to 75%.

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 2002-2005. Option 3 was included in the Annual Work Plan in 2003 and continued in 2004 and 2005. Beginning in 2004, hormone induced spawning of hickory shad collected from Susquehanna River anglers was also included.

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 use of a fleet of transport trucks to carry American shad and other alosines 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 has been operated under contract as (1) a source of fishes for special on-site spawning studies and for induced spawning at Maryland Department of Natural Resources' Manning Hatchery, and, (2) collection of biological information from American shad. In past years, the West Fish lift 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 daily from 11 AM to 7 PM from late April through early June, typically captures about 10,000 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 in two to three 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 Lapidum-Deer Creek area.

METHODS AND MATERIALS

Cooperating anglers at Conowingo Dam and at the mouth of Deer Creek plus the elecrofishing efforts by DNR and USFWS personnel at Lapidum provided the source for the pre-spawn hickory shad for the 2005 trials at Conowingo Dam. Hickory shad spawning trials began on April 15 to coincide with the mid-April start up for the Van Dyke Hatchery and were terminated on April 27 when the angler catch of hickory shad was on the decline and the American shad catch outnumbered the hickory shad catch. 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 in 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 spawning trials conducted at the dam in 2005.

The 2005 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 2004. The 10-ft and 12-ft diameter fiberglass tanks used for spawning trials in 2005 were the same tanks that were used from 2002 to 2004. 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 25-40 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 tanks were 6,400 and 9,200 liters respectively. An egg sock fastened to the discharge from the spawning tank prevented shad eggs from exiting the egg tank via the standpipe drain that maintained the water level in the egg tank.

The stocking rate for hickory shad was 60 and 100 fish for the small and large tanks respectively with a 3:2 (M/F) sex ratio, if available. Each of the eight hickory shad trials were single tank trials. The stocking rate for the larger American shad was 50 and 75 fish for the small and large tanks with the same 3:2 sex ratio as hickory shad. Seven of the 11 American shad trials were double tank (10 and 12-ft tank) trials and the remaining four were single tank trials. All on-site spawning trials in 2005 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.

The egg sock was examined daily during each spawning trial. If eggs were present, they were transferred into a 10 gallon plastic bucket, sieved through a colander with 0.25-in holes to remove scales and placed 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 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 8) 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 were collected in a day they were released below the dam. Following the initial egg pulse, (usually within 48 hours following injection with LHRH) the tanks were drained, mortalities, if any, recorded and the fish were 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 15 and concluded on April 27, 2005. During this interval, 8 spawning trials (2 pellet, 5 liquid $LHRH_a$ and one mixed) were conducted with 712 adult hickory shad (Appendix Table A-1). Four of the trials were conducted in the 10-ft tank and four in the 12-ft tank. Each trial ran from two to four days but the largest pulse of eggs was produced on the second day. A total of 73.5 liters of eggs was collected from the hickory shad trials and shipped to the Van Dyke Hatchery (Table 1). The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 61.4% (Mike Hendricks, personal communication). Water temperature in the spawning tanks ranged from 12 to 17°C and dissolved oxygen levels ranged from 4.0 to 10.2 ppm. Adult mortality rate for hickory shad during the spawning trials was 2.2%.

A total of 11 on-site spawning trials with 1,135 American shad from April 27 to June 6 produced 160.5 liters of eggs (Table 2 and Appendix Table A-2). A total of 148.6 liters was shipped to the Van Dyke Hatchery and 11.9 liters were released into the river below Conowingo Dam. Ten of the trials were conducted with pelletized implants and one with liquid injections. The 3:2 sex ratio in favor of males was achieved in most trials as well as the stocking density of 1 fish per 125 liters of water. Both sexes received an identical 150 ug dosage of $LHRH_a$. The total volume of eggs produced per female in individual 2005 trials (0.0-0.418 liters) was above the average of 0.373 observed for the previous four years, (Figure 2). When adjusted for viability, the volume of viable eggs produced per female in the 2005 trials was greater than 0.01 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 Van Dyke was 23.9% (Mike Hendricks, personal communication). Mortality rate for adult American shad during the 2005 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 2005 showed a dramatic improvement in quality and quantity from the past two seasons (Table 3). The estimated overall egg viability of 61.4% is higher than the 44 and 46% viability estimates for on-site spawning trials with hickory shad in 2003 and 2004 respectively. The increased volume of hickory shad eggs collected in 2005 (73.5 liters) was primarily due to the larger number (721) of brood stock available.

This was the fifth year of hormone induced American shad spawning trials at the Conowingo West Fish Lift. The results of the 2005 spawning trials were an improvement over last year's results (Table 4) but they 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 to surpass the 2004 trials.

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, 2005.

Trial #	Liquid/ Pellet	Start/Stop Date	S-1 M/F	S-2 M/F	S-1 Liters	S-2 Liters	No. Liters Shipped	Eggs	No. Viable Eggs	Percent Viable
1 and 2	Pellet	4/15-4/17	60/40	36/24	10.5	2.7	13.2	4,564,292	965,330	21.1%
3	Liquid	4/18-4/20		44/29		9.1	9.1	3,930,022	1,271,828	32.4%
4	Liquid	4/19-4/21	61/48		15.6		15	7,167,301	5,928,416	82.7%
5	Liquid	4/21-4/23		50/20		7.4	7.4	3,169,575	2,655,880	83.8%
6	Liquid	4/21-4/23	74/34		8.5		8.5	3,492,347	2,519,746	72.2%
7	L+P	4/25-4/27		40/32		6.9	6.9	2,302,173	1,797,424	78.1%
8	Liquid	4/25-4/27	75/45		13.1		13.1	4,101,701	2,506,627	61.1%
Totals			**270/167**	**170/105**	**47.7**	**26.1**	**73.5**	**28,727,411**	**17,645,251**	**61.4%**

Total Males =440
Total Females =272
Total Fish =712
Mean liters/trial. = 9.25 liters

Mean No. of Eggs/ Liter = 388,208
Mean No. of Eggs/Female (All Trials) = 105,615
Mean No, of Viable Eggs/ Female (All Trials) = 64,872
Mean Egg Viability (All Trials) = 61.4%

Table 2

Summary of egg production data for hormone-induced spawning trials conducted with American shad in a 10 ft diameter (S-2) and 12 ft diameter (S-1) tank at Conowingo Dam, Spring, 2005.

Trial #	Liquid/ Pellet	Start/Stop Date	S-1 M/F	S-2 M/F	S-1 Liters	S-2 Liters	Total Liters Shipped	No. eggs	No. Viable	Viabil.
1	Pellet	4/27-4/29	45/30		2.9		2.9	198,939	19,000	9.6%
2	Pellet	4/28-5/2		30/20		12.0	8.3	536,355	189,383	35.3%
3	Pellet	5/4-5/8	45/30	30/20	16.9	13.9	26.6	1,533,390	528,602	34.5%
4	Pellet	5/8-5/10	45/30	30/20	5.8	12.0	17.8	861,227	144,907	16.8%
5	Pellet	5/10-5/12	45/30	30/20	9.7	14.7	24.4	1,191,802	396,072	33.2%
6	Pellet	5/13-5/15	45/30	30/20	9	9.9	18.9	736,445	124,538	16.9%
7	Pellet	5/16-5/18	45/30	30/20	6.9	5.9	12.8	631,143	95,935	15.2%
8	Pellet	5/19-5/22	45/30	30/20	8.9	9.7	18.6	1,147,437	158,606	13.8%
9	Pellet	5/22-5/24	45/30	30/20	2.4	7.9	10.3	671,352	160,615	23.9%
10	Pellet	5/26-5/30		30/20		8.0	8	490,687	96,143	19.6%
11	Liquid	6/3-6/6	41/44		4		0			
Totals			**401/284**	**270/180**	**66.5**	**94.0**	**148.6**	**7,998,778**	**1,913,801**	**23.9%**

Total Males = 671
Total Females = 464
Total Fish = 1135

Mean vol. / trial =14.6 liters
Mean No. of Eggs / Liter (10 Trials) = 53,828
Mean No. of Eggs/Female (10 Trials) = 17,239
Mean No, of Viable Eggs/ Female (10 Trials) = 4,125
Mean Egg Viability (10 Trials) = 23.9%

Table 3

Summary of hormone induced spawning trials with hickory shad at Conowingo Dam, 2003-05

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

Table 4

Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-2005.

Year	**2001**	**2002**	**2003**	**2004**	**2005**
Start/Finish date	4-30/6-4	4-24/6-6	4-28/6-5	4-27/5-27	4-27/6-6
Tank diameter	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
Number of trials	10	10	12	10	11
Total fish	599	1000	1504	1055	1135
Males/Females per trial	36/24	66/34	75/50	75/50	75/50
Stocking density (fish/liters	1/153	1/156	1/125	1/125	1/125
Male:Female ratio	1.5:1	2:1	3:2	3:2	3:2
Hormone injected	LHRHa	SGnRHa	LHRHa	LHRHa	LHRHa
Liquid, Pellet	P	P	L+P	L+P	L+P
Dose (ug) Male/Female	75/150	150/150	150/150	150/150	150/150
Eggs collected (liters)	103	146.8	234	90.4	160.5
Liters of eggs /Female	0.429	0.432	0.387	0.244	0.418
No. eggs/liter	63,140	51,235	51,187	59,775	53,828
Total number of eggs	6,503,420	7,521,346	11,970,764	5,403,660	7,998,778
Viability (%)	33.2	10.1	17.7	20	23.9
Total number of viable eggs	2,159,135	760,935	2,118,852	1,080,732	1,913,801
Total liters of viable eggs	34.20	14.85	41.42	18.1	35.6
Adult mortality rate (%)	6.0	3.6	2.0	11.5*	3.3

* Does not include total loss of fish in trial 7 due to power loss.

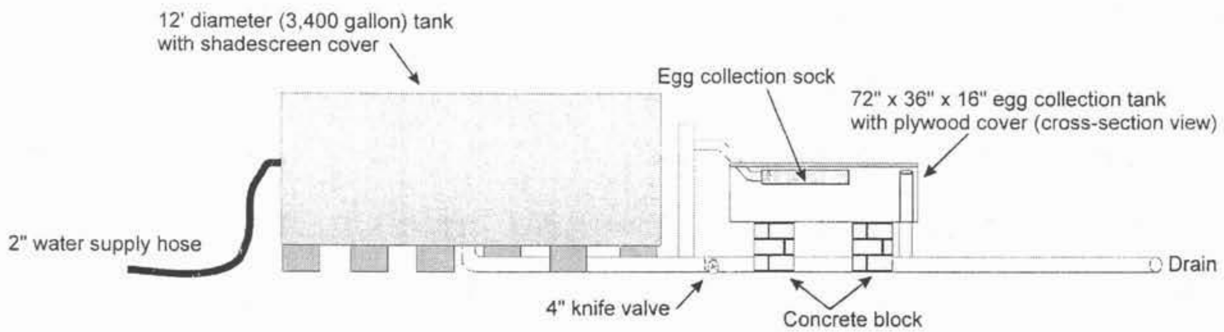

Figure 1

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

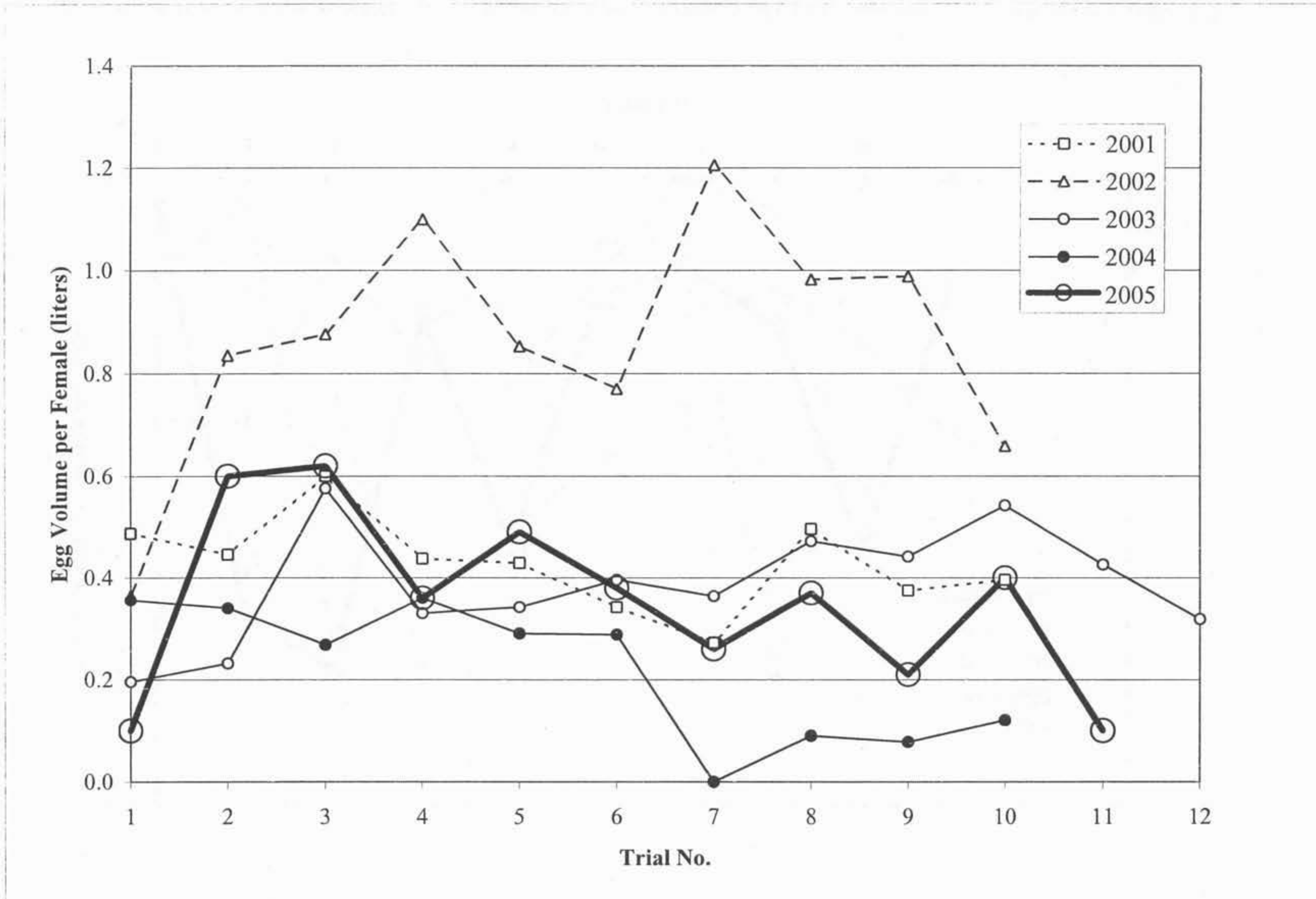

Figure 2 Comparison of American shad egg production per female by trial number and year at Conowingo Dam, 2001-2005

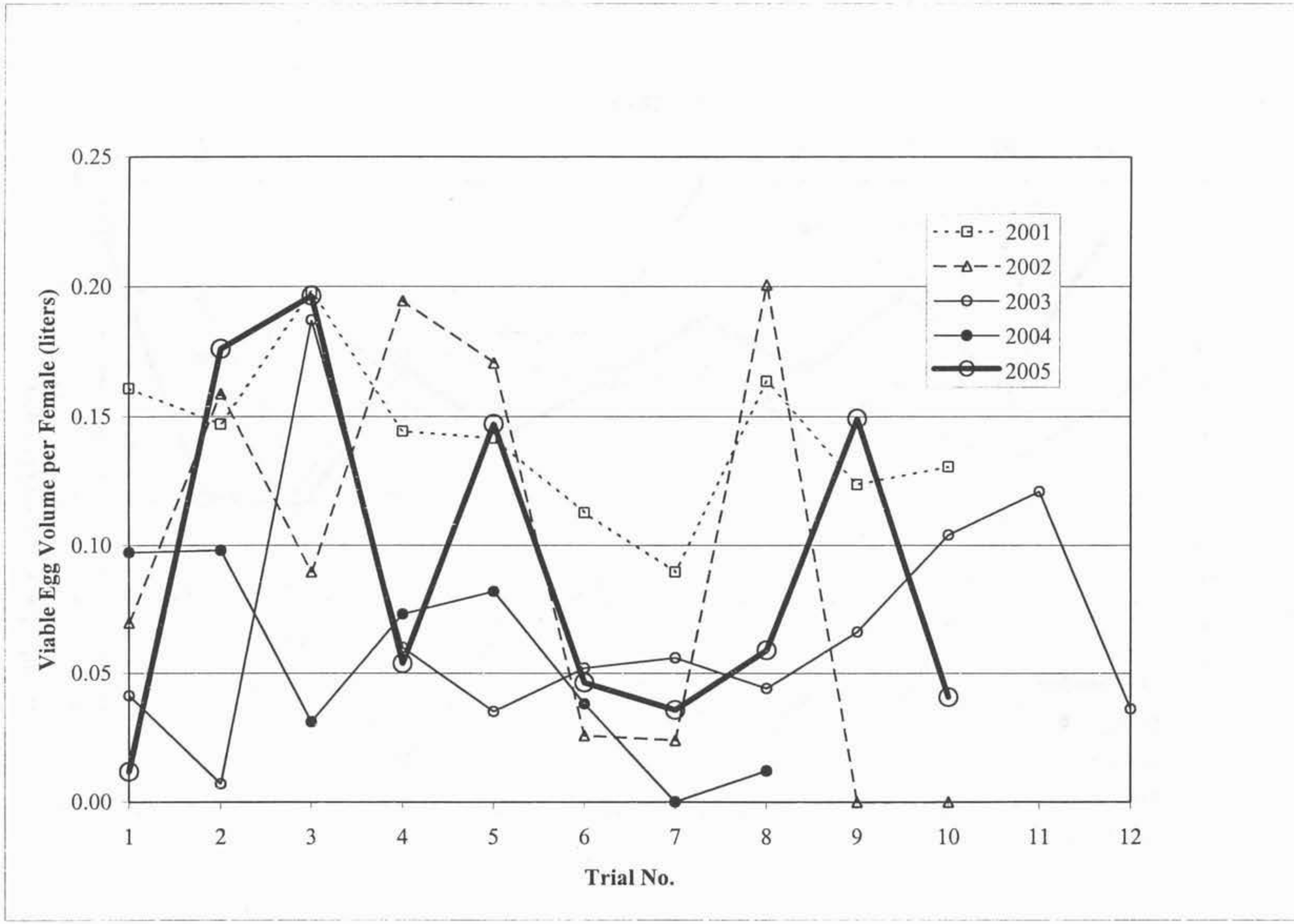

Figure 3 Comparison of viable American shad eggs produced per female by trial number and year at Conowingo Dam, 2001-2005

Appendix Table A-1

Hormone Induced Hickory Shad Spawning Trials Conducted at Conowingo Dam West Fish Lift in a 12 Ft Diam. tank (S-1) and 10 ft Diam. tank (S-2), Spring 2005.

Trial No.	1	Dose/fish	50 ug LHRH	pellet
Tank	S-1			
M/F Ratio	60/40			
Start Date	4/15/2005	1530		
End Date	4/17/2005	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/15/2005	1705	13.5	9.5				
4/16/2005	1630	14.5	10				
4/17/2005	0730	12	4	10.5	10.5		4

Trial No.	2	Dose/fish	50 ug LHRH	pellet
Tank	S-2			
M/F Ratio	36/24			
Start Date	4/15/2005	1630		
End Date	4/17/2005	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/15/2005	1705	13.2	9.8				
4/16/2005	1630	14.5	9.9				
4/17/2005	0730	12	4.7				
4/17/2005	0800			2.7	2.7		6

Trial No.	3	Dose/fish	50 ug LHRH	liquid
Tank	S-2			
M/F Ratio	44/29			
Start Date	4/18/2005	1430		
End Date	4/20/2005	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/18/2005	1500	15.8	10				
4/19/2005	0815	14.2	10.2				
4/20/2005	0805	15	10.1				
4/20/2005	0900			9.1	9.1		

Appendix Table A-1

Continued.

Trial No.	**4**	Dose/fish	50 ug LHRH	liquid
Tank	S-1			
M/F Ratio	61/48			
Start Date	4/19/2005	1330		
End Date	4/21/2005	1430		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/19/2005	1405	15	9.9				
4/20/2005	0805	15	10.2				
4/20/2005	1030			15.3	15.3		
4/21/2005	1430			0.3		0.3	1

Trial No.	**5**	Dose/fish	50 ug LHRH	liquid
Tank	S-2			
M/F Ratio	50/20			
Start Date	4/21/2005	1500		
End Date	4/23/2005	1000		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/21/2005	1600	15.6	10.1				
4/22/2005	0945	13	10.2				
4/22/2005	1200			3.3	3.3		
4/23/2005	0830	15.8	10.1	2.2	2.2		4

Trial No.	**6**	Dose/fish	50 ug LHRH	liquid
Tank	S-1			
M/F Ratio	74/34			
Start Date	4/21/2005	1530		
End Date	4/23/2005	1030		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/21/2005	1610	15.6	9.8				
4/22/2005	0945	16	10.3	4.1	4.1		
4/23/2005	0900	15.8	10.0	6.3	6.3		1

Appendix Table A-1

Continued.

Trial No.	**7**	Dose/fish	50 ug LHRH		pellet-58 fish
Tank	S-2				liquid-14 fish
M/F Ratio	40/32				
Start Date	4/25/2005	1345			
End Date	4/27/2005	0900			

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/2005	1540	17.0	9.5				
4/26/2005	0830	15.6	9.2				
4/26/2005	1230			2.7	2.7		
4/26/2005	1448	15.7	9.2				
4/27/2005	0850	15.2	10.2	5.5	5.5		

Trial No.	**8**	Dose/fish	50 ug LHRH		liquid
Tank	S-1				
M/F Ratio	75/45				
Start Date	4/25/2005	1530			
End Date	4/27/2005	0930			

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/2005	1545	17	8.8				
4/26/2005	0830	15.6	8.8				
4/26/2005	1300			4.2	4.2		
4/26/2005	1450	15.7	9.4				
4/27/2005	0915	15.1	10.2	7.6	7.6		

Appendix Table A-2

Hormone Induced American Shad Spawning Trials Conducted at Conowingo Dam West Fish Lift in a 10 (S-2) and 12 ft (S-1) Diam. Tank with a 3:2 (M/F) Sex Ratio. Spring 2005.

Trial No.	**1**		LHRH 150 ug	pellet
Tank	S-1			
M/F	45/30			
Start Date	4/27/2005	1115		
End Date	4/29/2005	1300		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/27/2005	1635	16	9.4				
4/28/2005	1600	14.9	10.2				
4/29/2005	0833	14.2	9.9				
4/29/2005	1200			2.9	2.9		

Trial No.	**2**		LHRH 150 ug	pellet
Tank	S-2			
M/F	30/20			
Start Date	4/28/2005	0930		
End Date	5/2/2005	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/28/2005	1610	15	10.1				
4/29/2005	0830	14.2	9.8				
4/30/2005	0850	14	9.8	8.3	8.3		
5/2/2005	0830	15.5	9.2	3.7		3.7	2f

Trial No.	**3**	LHRH 150 ug		pellet
Tank	S-1			
M/F	45/30			
Start Date	5/4/2005	1310		
End Date	5/8/2005	0800		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/2005	1735	15.1	9.4				
5/5/2005	1651	14.9	9.1				
5/6/2005	0955	15.2	9.2				
5/6/2005	1200			14.1	14.1		
5/6/2005	1650	14.6	9.7				
5/7/2005	0815	14.5	10.2	2.8		2.8	

Appendix Table A-2

Continued.

Trial **3** continued

Tank	S-2	
M/F	30/20	
Start Date	5/4/2005	1430
End Date	5/8/2005	0800

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/2005	1730	15.1	9.2				
5/5/2005	1649	14.9	9.2				
5/6/2005	0955	15.1	9.5				
5/6/2005	1230			12.5	12.5		
5/6/2005	1650	15.1	10.5				
5/7/2005	0815	14.4	10.5	1.4		1.4	

Trial No.	**4**	LHRH 150 ug	pellet
Tank	S-1		
M/F	45/30		
Start Date	5/8/2005	0900	
End Date	5/10/058	1000	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/2005	1455	15.6	10.1				
5/9/2005	1719	16.1	8.7				
5/10/2005	1000	15.5	9.9	5.8	5.8		1f

Tank	S-2	
M/F	30/20	
Start Date	5/8/2005	0945
End Date	5/10/2005	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/2005	1455	15.6	9.1				
5/9/2005	1717	16.1	8.9				
5/10/2005	1030	15.5	10.1	12	12		1f

Appendix Table A-2

Continued.

Trial No.	**5**	LHRH 150 ug		pellet			
Tank	S-1						
M/F	45/30						
Start Date	5/10/2005	1130					
End Date	5/12/2005	1000					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2005	1645	16.6	10.3				
5/11/2005	1021	16.1	10.3				
5/11/2005	1645	17	9.4				
5/12/2005	0930	18.1	9.4	9.7	9.7		0

Tank	S-2	
M/F	30/20	
Start Date	5/10/2005	1030
End Date	5/12/2005	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2005	1645	16.6	9.9				
5/11/2005	1020	16.0	10.4				
5/11/2005	1644	16.9	9.1				
5/12/2005	1000	18.1	9.5	14.7	14.7		0

Trial No.	**6**	LHRH 150 ug		pellet			
Tank	S-1						
M/F	45/30						
Start Date	5/13/2005	1000					
End Date	5/15/2005	1200					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/13/2005	1530	17.9	9				
5/15/2005	930	18.2	8.2	9	9		1m,2f

Tank	S-2	
M/F	30/20	
Start Date	5/13/2005	915
End Date	5/15/2005	1200

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/13/2005	1530	18	8.6				
5/15/2005	0900	18.2	8.7	9.9	9.9		5f

Appendix Table A-2

Continued.

Trial No.	**7**	LHRH 150 ug	pellet
Tank	S-1		
M/F	45/30		
Start Date	5/16/2005	0945	
End Date	5/18/2005	1000	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/16/2005	1615	21	6.9				
5/17/2005	1015	20.9	5.9				
5/17/2005	1700	21.2	6.2				
5/18/2005	0930			6.9	6.9		1m,2f

Tank	S-2	
M/F	30/20	
Start Date	5/16/2005	1015
End Date	5/18/2005	0930

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/16/2005	1615	21	6.4				
5/17/2005	1014	20.9	6.2				
5/17/2005	1700	21.2	6.4				
5/18/2005	0900			5.9	5.9		5f

Trial No.	**8**	LHRH 150 ug	pellet
Tank	S-1		
M/F	45/30		
Start Date	5/19/2005	1000	
End Date	5/22/2005	1030	

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/19/2005	1649	21.4	6.1				
5/20/2005	0913	20	5.8				
5/20/2005	1530	20	5.8				
5/20/2005	1730			6.2			
5/21/2005	0845	20	6.2	2.7	8.9		
5/22/2005	0817	20	5.2				6f

Appendix Table A-2

Continued.

Trial no. 8 continued

Tank	S-2	
M/F	30/20	
Start Date	5/19/2005	0930
End Date	5/22/2005	0845

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/19/2005	1647	21.2	6.4				
5/20/2005	0915	20	6.2				
5/20/2005	1530	20	6.2				
5/20/2005	1730			6			
5/21/2005	0830	20	6.5	3.7	9.7		
5/22/2005	0816	20	5.2				1m,1f

Trial No.	9	LHRH 150 ug		pellet
Tank	S-1			
M/F	45/30			
Start Date	5/22/2005	1300	aerated with oxygen after 5/23	
End Date	5/24/2005	1100		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/22/2005	1500	20.3	5				
5/23/2005	1030	20.1	4.6				
5/23/2005	1615	20.7	5.8				
5/24/2005	0810	20.6	5.8	2.4	2.4		3f

Tank	S-2	
M/F	30/20	
Start Date	5/22/2005	1230
End Date	5/24/2005	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/22/2005	1500	20.5	5.4				
5/23/2005	1030	20.1	4.2				
5/23/2005	1612	20.7	8.1				
5/24/2005	0810	20.7	8.2	7.9	7.9		

Appendix Table A-2

Continued.

Trial No.	**10**	LHRH 150 ug		pellet
Tank	S-2			
M/F	30/20			
Start Date	5/26/2005	1340	with oxygen	
End Date	5/30/2005	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/26/2005	1548	20.3	7				
5/28/2005	0830	20.1	7.6	8	8		
5/30/2005	0900	20.1	7				1m,1f

Trial No.	**11**	LHRH 150 ug		liquid
Tank	S-1			
M/F	41/44			
Start Date	6/3/2005	1600	with oxygen	
End Date	6/6/2005	1100		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/3/2005	1610	21.3	5.4				
6/3/2005	1720	21.3	6.2				
6/4/2005	1620	22.3	7.2				
6/5/2005	0900	22.1	6	4		4	
6/6/2005	1100						1m,3f

Job II - Part 4

American Shad Egg Collection from the Lower Susquehanna River

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INTRODUCTION

For many years, the hatchery component of the Susquehanna River shad restoration program has relied on delivery of fertile shad eggs taken by strip-spawning of broodfish from the Hudson and Delaware rivers. Although Hudson River shad eggs have been extremely beneficial to the program with large numbers and very good viability, this is a costly project which involves hiring a private contractor and maintaining two netting crews over about a 30-day period each spring. Since the Susquehanna River adult shad population has grown substantially in recent years, SRAFRC is interested in using this egg source to eventually replace that of the Hudson River. This will reduce overall cost of egg collections while providing a genetically superior strain - fish with a demonstrated urge to return to the Susquehanna to spawn.

From the 1890s through about 1920, tens of millions of shad eggs were collected by commercial fishermen and delivered to U. S. Fish Commission culture operations at the head of the Chesapeake Bay near Havre de Grace, MD. Newly hatched larvae were released into nearby and distant waters but it was eventually determined that these stockings were not enhancing shad populations. In fact, Chesapeake Bay shad harvest levels declined sharply from the mid-1890's until about 1910. Maryland harvest stabilized at 1-2 million pounds per year during the 1920s through the early 1970s followed by a precipitous decline which led to Maryland's closure of all Bay fisheries in 1980.

Immediately prior to the recent crash of shad fisheries in the upper Bay, shad eggs were once again collected from the lower Susquehanna River near Lapidum, MD. In 1971-1973, over 20 million eggs were taken from this area and released into hatching boxes upstream of all Susquehanna dams. As this egg source declined it was replaced by other populations, including those of the Mattaponi, Pamunkey, Potomac, James and Columbia rivers which supplied eggs to the Susquehanna program through the early 1980s. The Hudson and Delaware rivers have been the program's primary egg producers since 1990.

The purpose of this effort in 2005 was to expand on initial investigations in 2003-2004 which provided almost 700,000 viable shad eggs to the Van Dyke hatchery. The U. S. Fish and Wildlife Service (Harrisburg, PA and Annapolis, MD) assumed responsibility for this work.

METHODS

As was the case in the prior two years, commercial fisherman Gary "Rooster" Potter from Perryville, MD was hired on a daily rate basis to assist in brood fish collection, and to supply nets, storage facility and boat docks for the Service vessel. The USFWS Maryland Fishery Resources Office supplied a boat and 2-man crew and the Susquehanna River Coordinator provided most minor equipment (buckets, tubs, coolers, etc.) and directed daily operations. The plan called for netting shad three nights per week for up to 4 weeks during May, with eggs being delivered to Conowingo Dam nightly. Normandeau Associates, under separate contract to operate the tank spawning system at the dam, was responsible for delivery of eggs to Van Dyke. Normandeau also provided bottled oxygen from their supply at the dam.

Gear and Location

The primary gear employed for this effort included two multi-filament nets (mono is not allowed in MD) measuring 700' in length and 12' deep with 5½" mesh and 500' x 12' with 5" mesh. The 5½" gear is the same as that used by Mr. Potter and his father for commercial shad fishing during the 1970s. Nets mentioned above used fairly lightweight rings on the leadline to allow them to easily break away from snags. Another 700' x 12' net with 5.25" mesh with heavyweight rings was also occasionally deployed to fish deeper water from the bottom up.

Similar to past years, several netting attempts were initiated in the vicinity of the Lapidum boat landing in 12-15-ft of water approximately on the Harford-Cecil county line (Fig. 1). Length of drift time was limited by natural river flow, Conowingo operation, and placement of anchored catfish pots which had to be avoided to reduce gear damage. Sets at this location typically lasted for about 30 minutes, covered 1.0-1.5 km, and terminated off St. Catherine Island. Waters near the Port Deposit marina were also sampled, as were shallower areas around the islands upstream. In these latter cases the 12 ft. deep nets were purposely hung-up on the bottom in 8-10' depths and fished for about 45-60 minutes. In a few instances, deeper waters (15-20') below Lapidum were sampled using nets with heavyweight leadlines.

Effort

Netting and spawning operations occurred on eight nights from May 3-23. Spring 2005 was characterized as having lower than average river flow and cool, gradually rising water temperature (58-70° F). Fourteen net sets (1-2 per night) were completed (Table 1) with first sets each evening laid out about 8:15 – 8:30 p.m., fished for 30-45 minutes, and reset. Operations usually ceased by about 11 p.m.

Egg Processing

Male and female shad pulled from nets were placed into separate wash tubs. Egg take proceeded immediately following capture using the dry pan method described by Wyatt Group and successfully employed in their Hudson River operation. After all eggs were taken from each individual set, sperm was squeezed from one to several ripe males, gametes were gently stirred and allowed to sit for 1-2 minutes. Clean river water was added to initiate fertilization and after a few minutes, the eggs were washed with clean water and placed into a large water-filled container to harden. Water-hardening lasted at least one hour.

Hardened eggs were strained through cheesecloth and packaged into double plastic bags at up to 5 liters of eggs with 5 liters of clean water. Bags were injected with oxygen, secured with rubber bands and placed into coolers for drop off at Conowingo Dam.

Other information collected

The 2005 SRAFRC work plan called for removal and freezing of up to 200 shad heads from Lapidum collections for otolith and genetic analysis. All fish from which heads were taken were also sexed, weighed and measured (TL) and had a scale sample removed. Fin tissue samples were taken from 12 random fish and sent to the Genetics Lab at Lamar (USFWS) to aid in developing microsatellite DNA markers. Fish were numbered LAP-05-001; -002, etc.

RESULTS

A total of 169 American shad were netted on eight nights in May 2005. Males were poorly represented in the catch every night with only 12 being taken, compared to 157 females (sex ratio 13 to 1). Both total catch and especially sex ratios (SR) compared poorly to prior year results. In 2003, 219 shad were taken in 7 nights of netting with a SR of 6:1 favoring females; and in 2004 we took 242 shad – also in 7 nights – with a SR of 2:1.

Of the 157 females in 2005 collections only 17 were ripe and provided some eggs, 110 were hard and 30 were spent (Table 1). All males were ripe. Small amounts of fertile eggs, 2 liters or less, were taken each of the first few collecting nights and these were dumped back into the river at Perryville. No eggs were delivered to Conowingo or shipped to Van Dyke in 2005.

Heads and scales were taken from 162 shad and these fish were measured and weighed. Fish averaged 533 mm total length and 1680 g with ranges of 434-622 mm and 851-2470 g. One fish carried a green Maryland DNR Floy tag (#05264) having been released in the Conowingo tailrace this season. Other fish in collections in 2005 included several hundred gizzard shad, 8 striped bass, 43 channel catfish, 14 hickory shad, 11 bluebacks, a few carp and suckers, and one each of walleye, smallmouth bass and Atlantic needlefish.

DISCUSSION

Daily river flows during the May 2005 collecting period were considerably below average ranging between about 14,000 and 28,000 cfs as measured at York Haven. Water temperatures were generally cool and, unlike 2004, increased gradually throughout the season from 58°F on May 3rd to 71°F on May 23rd. Conowingo Dam maintained minimum flow conditions (7,500 cfs) each night during May.

Catch per effort in terms of number of American shad per net set was highest on the first night (May 3) at 30.0 and dropped off thereafter, averaging 11.7 during the week of May 10, 7.0 during the week of May 17, and 4.0 on the last collecting night – May 23. As mentioned earlier, only 17 ripe fish were among the 157 females taken in 2005 and males were scarce throughout the season (12 total) which precluded effective egg take.

Abundance of gizzard shad in all collections in the lower Susquehanna interfered with the speed of net retrieval and limited the number of net sets each night. As was the case in 2003 and 2004, American shad were collected in every one of the 14 net sets during this operation, though numbers were noticeably fewer. Use of the 5-inch mesh net and the heavy-weighted net did not improve catch rates, nor did relocation to Port Deposit or rocky areas above Lapidum. Shad abundance in the lower Susquehanna in 2005 appeared lower than past years, as was confirmed by passage count at Conowingo.

American shad egg collection has been attempted in the lower Susquehanna River near Lapidum and Port Deposit for three consecutive years under differing flow and temperature conditions. Fishing effort amounted to a combined 22 nights and 44 net sets that produced 630 shad (CPUE 14.3 shad/set).

Of those, 130 were males and 500 were females for an overall SR of 3.85 F:M. A total of 36.4 liters of eggs (1.3 million) with viability of 52.7% was delivered to Van Dyke Hatchery in 2003-2004. None were delivered in 2005. Susquehanna strip spawning has been a low cost effort with USFWS providing free labor. Unfortunately it has been relatively unproductive compared to the well-developed Hudson and Delaware River efforts.

RECOMMENDATIONS

1. SRAFRC should discontinue this project until the shad run size increases.

2. However, if and when this project is reinstituted:

   (a) Expand effort to four days per week for four weeks, beginning when water temperature reaches the high 50s and terminating when shad numbers drop off sharply. Fridays and weekends should be avoided due to high boat traffic near Lapidum.

   (b) Lapidum should remain the primary netting site, but new areas such as between the I-95 and US 40 bridges and the Susquehanna Flats (north and south channel) should be more thoroughly investigated, perhaps by a second boat crew.

   (c) Use of monofilament nets should be investigated. These may be less visible to shad under clear water or full moon conditions – but they may also take increased numbers of gizzard shad, and picking fish from the nets could be more difficult.

   (d) Because of poor availability of buck shad throughout the efforts in 2003-2005 consider use of experimental nets with panels of variable mesh sizes, 4.5 to 5.5 inches.

   (e) Continue using the dry method of fertilization as well as traditional water-hardening and packaging techniques, but investigate used of bottled oxygen during water hardening.

Table 1. Shad Egg Collections from lower Susquehanna River at Lapidum, MD - 2005

Date	No. sets	Gear	Water temp. (°F)	Shad catch males	ripe roe	hard roe	spent	Eggs taken
May 3	2	700' x 5.5"	58	4	4	46	6	2 liters
May 10	2	700' x 5.5" 500' x 5"	59	2	2	12	3	2 liters
May 11	2	700' x 5.5" 700 x 5.25"	61	2	4	14	4	1 liter
May 12	2	700' x 5.5"	63	2	1	24	0	0
May 17	2	700' x 5.5" 500' x 5"	68	1	1	2	3	0
May 18	2	700' x 5.25" 500' x 5"	69	0	3	8	6	0
May 19	1	700' x 5.25"	69	0	2	3	6	0
May 23	1	700' x 5.5"	71	1	0	1	2	0
Totals	14			12	17	110	30	5 L (dumped)

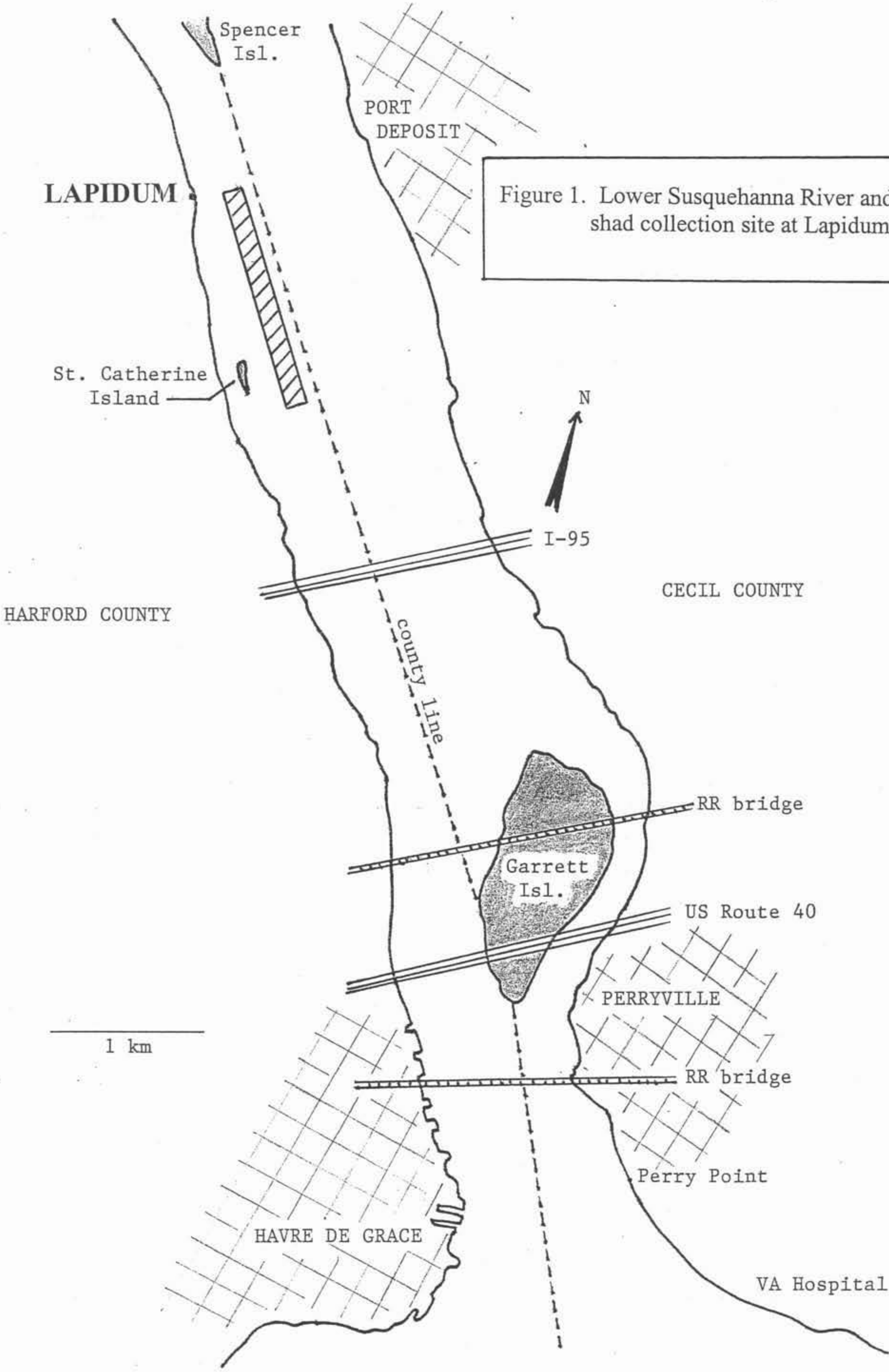

Figure 1. Lower Susquehanna River and shad collection site at Lapidum

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2005

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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 facility in 2000, upstream hydroelectric project owners were no longer responsible for funding the hatchery effort. Funding was provided by the Pennsylvania Fish and Boat Commission.

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

As is previous years, production goals for American shad for 2005 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.

EGG SHIPMENTS

Hickory shad

A total of 28.7 million hickory shad eggs (73.5 L) were received in seven shipments from tank-spawning operations at Conowingo Dam (Table 1). Some 17.6 million (61.4%) of the hickory shad eggs were viable.

American shad

A total of 17.1 million American shad eggs (372 L) were received in 42 shipments in 2005 (Table 1). This was the second lowest quantity of eggs received since 1982 (Table 2). Egg collections were reduced as a result of a late start on the Hudson River. Egg collection was delayed 7 to 10 days while the contractor resolved permit reporting issues from 2004. Overall American shad egg viability (which we define as the percentage which ultimately hatches) was 36.6%.

Thirteen Hudson River egg shipments (2.9 million eggs) were received from May 19 to June 5, 2005. Overall viability was 72.4%. By comparison, in 2003, 23 shipments were received from the Hudson River for a total of 17.1 million eggs. Hudson River eggs were collected from sites at Coxsackie and Lower Schodack Island.

Delaware River egg shipments were received from May 9 to June 2. A total of 18 shipments were received (6.2 million eggs) with a viability of 31.8%. By comparison, in 2004, the Delaware River produced 2.4 million eggs.

The U.S. Fish and Wildlife Service attempted to obtain eggs by strip-spawning ripe adult shad collected by gill net in the lower Susquehanna River near Lapidum, MD. This effort resulted in insufficient eggs to justify a shipment to the hatchery.

Normandeau Associates, under contract with the PFBC, attempted to obtain eggs by strip-spawning ripe adult shad collected by gill net in the upper portion of Conowingo Reservoir. Few ripe shad were collected and no eggs were shipped.

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 8.0 million eggs, in 11 shipments, were delivered to the Van

Dyke Hatchery, with a viability of 23.9%. By comparison, 4.7 million eggs, in 7 shipments, were received from this source in 2004.

SURVIVAL

Overall survival of American shad larvae was 87% compared to a range of 19% to 94% for the period 1984 through 2004. The 27% increase in survival from 2004 (60%) was due, in part, to stocking larvae earlier. In 2004, we reared the larvae longer, while waiting for river flows and turbidity to decrease. Average age at stocking was 15.2 days in 2005, compared to 23.4 days in 2004.

Survival of individual tanks followed patterns similar to those observed in the past. Four tanks, reared from 20 to 26 days of age, exhibited 20-d survival of 83.6% (Figure 1). Nine tanks, reared from 14 to 17 days of age, exhibited 14-d survival of 88.9%. Eleven tanks, reared from 10 to 13 days of age, exhibited 10-d survival of 94.1%. High mortality episodes occurred only in low density tanks (15,000 to 57,000 larvae), with the lowest survival in the lowest density tanks. The cause of the low survival in low density tanks is unknown. Feed rates were adjusted to feed as if 100,000 larvae were in each tank to ensure that the larvae could find the feed. Tank I41 was a result of pair spawning Delaware River brood fish for a genetics study conducted by the Northeast Fishery Center at Lamar. These fish were not tagged with tetracycline and were not stocked.

LARVAL PRODUCTION

Hickory shad larvae (5.4 million) were stocked in the lower Susquehanna River at Muddy Creek Access in the Conowingo Reservoir. Some 11.8 million hickory shad were also stocked in the Delaware River (3.2 million) and its tributaries Pennypack Creek (8.0 million) and Ridley Creek (600 thousand).

Production and stocking of American shad larvae, summarized in Tables 2, 3 and 4, totaled 5.21 million. A total of 2.2 million was released in the Juniata River, 1.0 million in the Susquehanna River near Montgomery Ferry, and 335 thousand in the West Branch Susquehanna River. Due to the poor egg production, no larvae were stocked in the North Branch Susquehanna River (PA or NY), the Chemung River, the Raritan River, or the four lower river tributaries. Delaware River egg collections were sufficient to nearly meet the goals for the Delaware River Basin. Larvae were stocked in the Lehigh River (669 thousand), the Schuylkill River (799 thousand), and the Delaware River (170 thousand). Larvae stocked in the Delaware River were allocated to replenish the Delaware for the brood stock taken there. Larvae stocked during the second of two trips to the Delaware (6/28/05) were observed to be heavily preyed upon by indigenous shad, 1 to 1 ½ inches in length.

TETRACYCLINE MARKING

All American and hickory shad larvae stocked received marks produced by immersion in tetracycline (Table 5). 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 3, 6 and 12 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 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, 9, 12, 15, and 18 days of age.

A single tank of larvae (A32) was given an experimental mark at 3, 6, 9 and 12 days of age and stocked in the Schuylkill River. Marks on days 3 and 9 were standard marks at 256-ppm OTC, using Terramycin 343 from Pfizer under INAD 8512. The day 6 and 12 marks utilized generic oxytetracycline hydrochloride from Am Tech at 171-ppm and 342-ppm, respectively. This product is approved by FDA for marking skeletal tissue of fish and has fewer record-keeping and reporting requirements.

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.

Mark retention was 100% for all American shad production marks sampled (Table 5). Mark retention could not be evaluated for the day 9, 12, 15 mark (larvae stocked in the Lehigh River) because none of the larvae stocked in the raceway survived. The experimental mark (Tank A32) using Amtech oxytetracycline HCL was not successful. Marks produced by immersion in 256-ppm Terramycin 343 on days 3 and 9 exhibited 100% retention with good or excellent mark ratings on all 18 specimens examined. Marks produced by immersion in 171-ppm Amtech Oxytetracycline hydrochloride on day 6 exhibited 61% retention with a single good mark, ten poor marks, and 7 unmarked specimens, of the 18 examined. Marks produced by immersion in 342-ppm Amtech Oxytetracycline hydrochloride on day 12 exhibited 83% retention with eight excellent marks, six good marks, one poor mark, and 3 unmarked specimens, of the 18 examined.

Fingerlings grown out in raceways and marked with 88g Amtech oxytetracycline HCL per kg of food exhibited mark retention of five percent. In previous years, feed marks using the same concentration of Terramycin 343 exhibited mark retention of 100% (Hendricks 1998, 1999, 2002). The cause of the poor performance of Amtech Oxytetracycline hydrochloride as an immersion and feed marking agent is not known. Analysis of survival of each uniquely marked group is discussed in Appendix I.

SUMMARY

Seven shipments of hickory shad eggs (28.7 million eggs) were received at Van Dyke in 2005. Egg viability was 61.4% and 17.6 million hickory shad larvae were stocked in a tributary to Conowingo Reservoir and in the Delaware River and its tributaries, Pennypack Creek and Ridley Creek.

A total of 42 shipments of American shad eggs (17.1 million eggs) was received at Van Dyke in 2005. Total egg viability was 37% and survival of viable eggs to stocking was 87%, resulting in production of 5.2 million larvae. Larvae were stocked in the Juniata River (2.2 million), Susquehanna River near Montgomery Ferry (1.0 million), the West Branch Susquehanna River (335 thousand), the Lehigh River (669 thousand), the

Schuylkill River (799 thousand) and the Delaware River (170 thousand). Scheduled releases in the North Branch Susquehanna River, the Chemung River, and the four lower river tributaries were cancelled due to lack of eggs.

Overall survival of larvae was 87%. No episodes of major mortality occurred as a result of larvae lying on the bottom of the tank or any other cause. Van Dyke jars with foam bottoms were used only twice 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 all groups analyzed. Hickory shad were marked at 512 ppm on day three. Mark retention for hickory shad was 100%. A single tank of larvae (A32) was given an experimental mark at 3, 6, 9 and 12 days of age. The day 6 and 12 marks utilized generic Oxytetracycline hydrochloride from Am Tech at 171-ppm and 342-ppm, respectively. Mark retention was 61% for the 171-ppm concentration and 83% for the 342-ppm concentration. Marks produced by this product were not as bright at those produced by Pfizer Terramycin 343.

RECOMMENDATIONS FOR 2006

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 leftover 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. Initiate a program 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 6). 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.

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Figure 1. Survival of American shad larvae at Van Dyke, 2005.

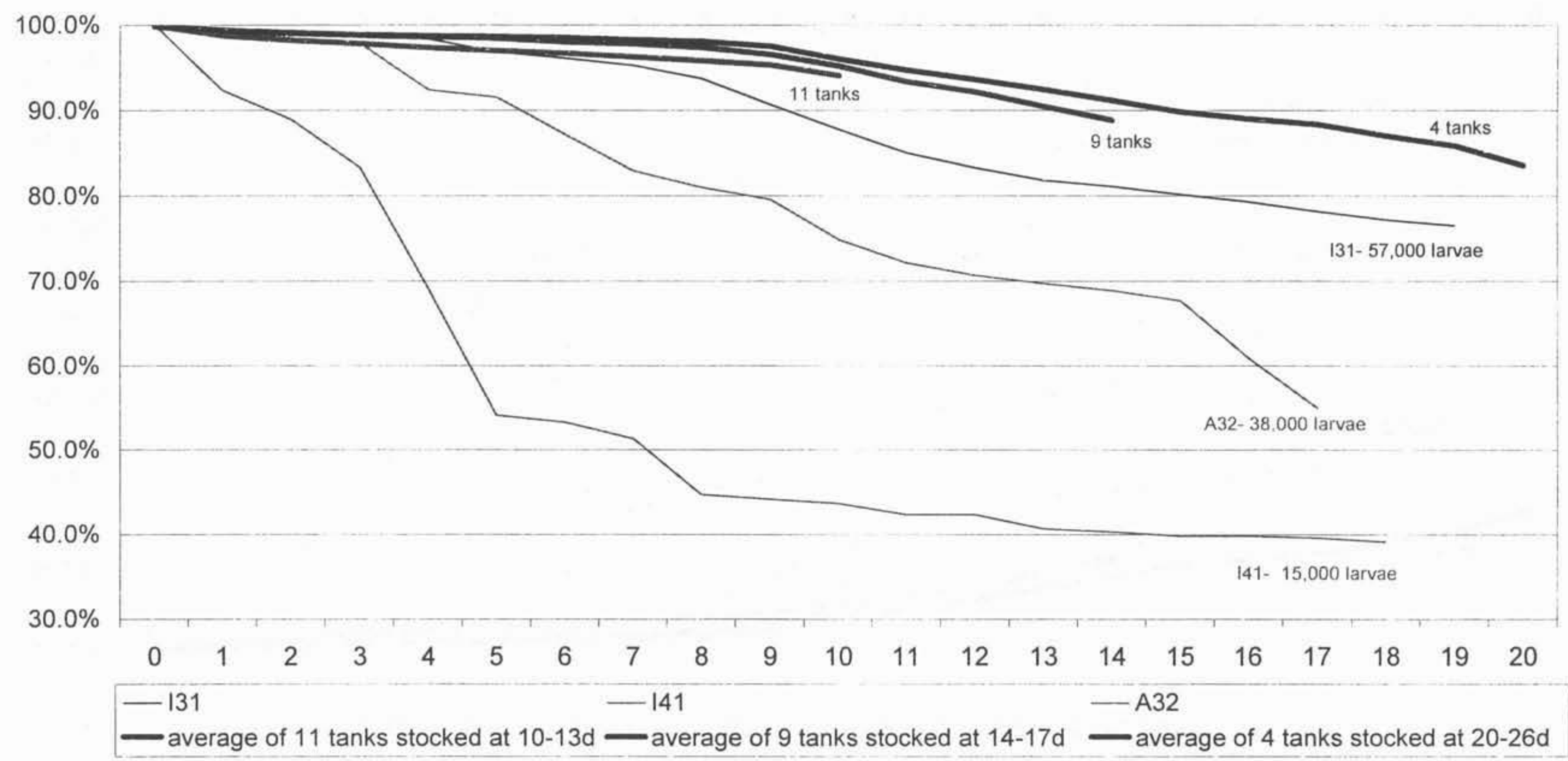

Figure 1. Survival of American shad larvae at Van Dyke, 2005.

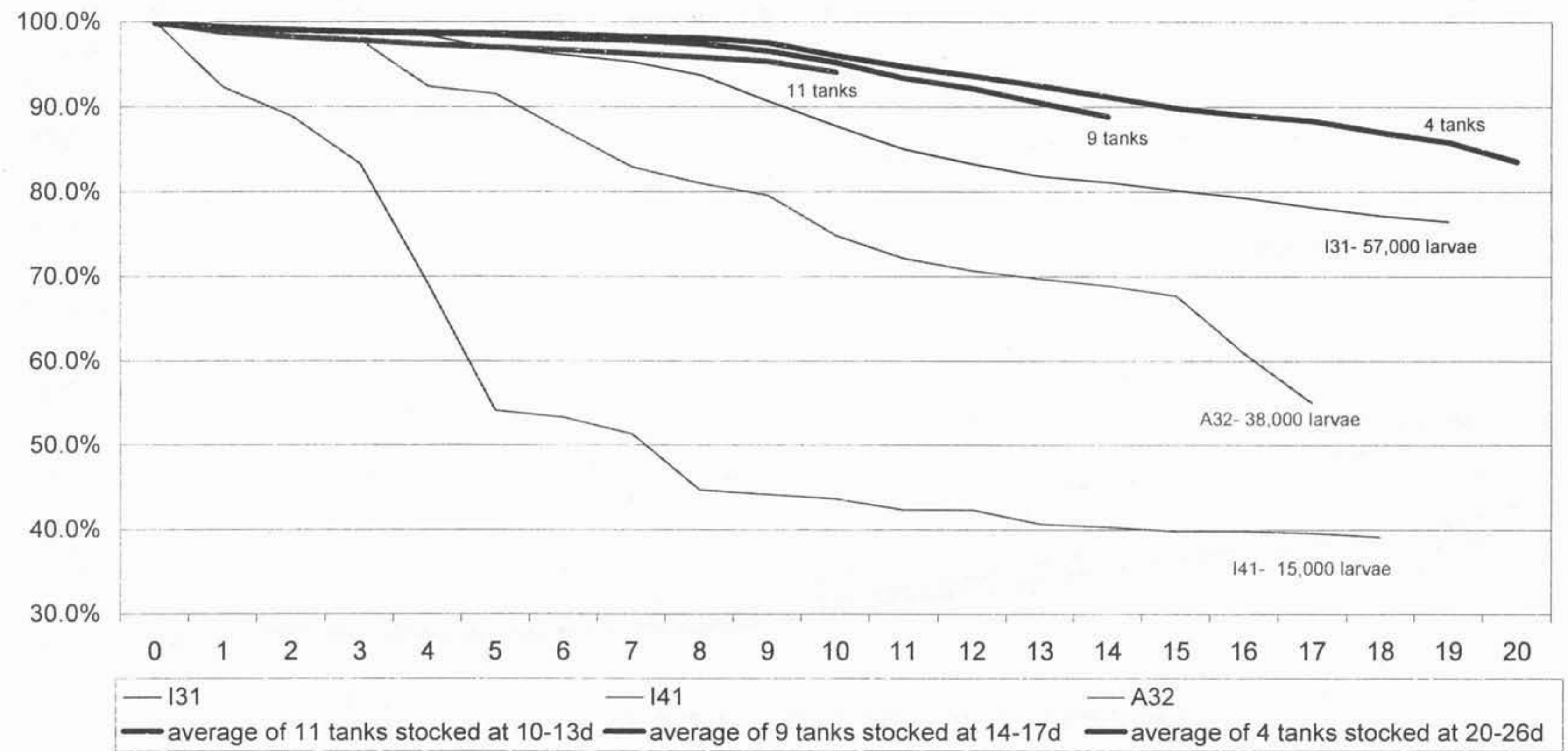

Table 1. Egg shipments received at Van Dyke, 2005.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	Hickory shad	Susq.-Conowingo	4/16/05	4/17/05	13.2	4,564,292	965,330	21.1%
2	Hickory shad	Susq.-Conowingo	4/19/05	4/20/04	9.1	3,930,022	1,271,828	32.4%
3	Hickory shad	Susq.-Conowingo	4/19/05	4/20/05	15.3	7,167,301	5,928,416	82.7%
4	Hickory shad	Susq.-Conowingo	4/21/05	4/22/05	7.4	3,169,575	2,655,880	83.8%
5	Hickory shad	Susq.-Conowingo	4/22/05	4/23/05	8.5	3,492,347	2,519,746	72.2%
6	Hickory shad	Susq.-Conowingo	4/26/05	4/26/05	6.9	2,302,173	1,797,424	78.1%
7	Hickory shad	Susq.-Conowingo	4/27/05	4/27/05	13.1	4,101,701	2,506,627	61.1%
8	American shad	Susq.-Conowingo	4/29/05	4/29/05	2.9	198,939	19,000	9.6%
9	American shad	Susq.-Conowingo	4/30/05	4/30/05	8.3	536,355	189,383	35.3%
10	American shad	Susq.-Conowingo	5/6/05	5/6/05	26.6	1,533,390	528,602	34.5%
11	American shad	Delaware	5/9/05	5/10/05	5.3	167,172	97,461	58.3%
12	American shad	Susq.-Conowingo	5/10/05	5/10/05	17.8	861,227	144,907	16.8%
13	American shad	Delaware	5/10/05	5/11/05	13.7	408,897	250,594	61.3%
14	American shad	Delaware	5/11/05	5/12/05	9	423,167	93,740	22.2%
15	American shad	Susq.-Conowingo	5/12/05	5/12/05	24.4	1,191,802	396,072	33.2%
16	American shad	Delaware	5/12/05	5/13/05	14.4	860,197	32,386	3.8%
17	American shad	Susq.-Conowingo	5/15/05	5/15/05	18.9	736,445	124,538	16.9%
18	American shad	Delaware	5/15/05	5/16/05	18.9	838,520	52,543	6.3%
19	American shad	Delaware	5/16/05	5/17/05	17	676,022	349,439	51.7%
20	American shad	Delaware	5/17/05	5/18/05	10.9	478,881	8,733	1.8%
21	American shad	Susq.-Conowingo	5/18/05	5/18/05	12.8	631,143	95,935	15.2%
22	American shad	Delaware	5/18/05	5/19/05	5.1	200,758	101,627	50.6%
23	American shad	Delaware	5/19/05	5/20/05	6.75	244,673	153,758	62.8%
24	American shad	Hudson-Coxsackie	5/19/05	5/20/05	12.8	403,737	315,300	78.1%
25	American shad	Susq.-Conowingo	5/21/05	5/21/05	6.4	324,587	108,210	33.3%
26	American shad	Susq.-Conowingo	5/20/05	5/21/05	12.2	822,850	50,396	6.1%
27	American shad	Husdon-Coxsackie	5/21/05	5/22/05	3.5	130,888	106,395	81.3%
28	American shad	Hudson-Coxsackie	5/22/05	5/23/05	4.9	149,534	115,540	77.3%
29	American shad	Delaware	5/22/05	5/23/05	10	325,894	260,966	80.1%
30	American shad	Hudson-Coxsackie	5/23/05	5/24/05	3.6	133,239	101,424	76.1%
31	American shad	Delaware	5/23/05	5/24/05	7.3	253,699	161,679	63.7%
32	American shad	Susq.-Conowingo	5/24/05	5/24/05	10.3	671,352	160,615	23.9%
33	American shad	Hudson-Coxsackie	5/24/05	1/0/00	3.9	119,017	87,313	73.4%
34	American shad	Delaware	5/26/05	5/27/05	1.8	66,620	27,156	40.8%
35	American shad	Delaware	5/26/05	5/27/05	0.44	16,285	1,452	8.9%
36	American Shad	Susq.-Conowingo	5/28/05	5/28/05	8	490,687	96,143	19.6%
37	American Shad	Hudson-Coxsackie	5/28/05	5/29/05	6.1	192,406	121,090	62.9%
38	American Shad	Hudson-Coxsackie	5/29/05	5/30/05	9.1	299,787	243,479	81.2%
39	American Shad	Hudson-Coxsackie	5/30/05	5/31/05	3.6	126,443	70,014	55.4%
40	American Shad	Hud.- L. Schodack I.	5/31/05	6/1/05	8.7	385,985	290,295	75.2%
41	American Shad	Delaware	5/31/05	6/1/05	0.7	29,858	14,885	49.9%
42	American Shad	Delaware	5/31/05	6/1/05	0.6	18,310	5,763	31.5%
43	American Shad	Delaware	5/31/05	6/1/05	5.8	288,693	51,327	17.8%
44	American Shad	Hud.- L. Schodack I.	6/1/05	6/2/05	11.6	465,976	373,070	80.1%
45	American Shad	Delaware	6/1/05	6/2/05	13.2	675,738	274,504	40.6%
46	American shad	Hud. L. Schodack I.	6/2/05	6/3/05	1.7	133,109	44,982	33.8%
47	American shad	Delaware	6/2/05	6/3/05	4.7	240,604	37,867	15.7%
48	American Shad	Hud. L. Schodack I.	6/4/05	6/5/05	7.2	322,568	200,637	62.2%
49	American Shad	Hud. L. Schodack I.	6/5/05	6/6/05	1.5	60,866	46,410	76.2%
Totals			No. of shipments					
	American shad	Hudson	13		78.2	2,923,555	2,115,948	72.4%
		Delaware	18		145.6	6,213,988	1,975,881	31.8%
		Susq.-Conowingo	11		148.6	7,998,778	1,913,801	23.9%
		Susq.-Lapidum						
		Susq.-Muddy Run						
		Grand total	**42**		**372.4**	**17,136,321**	**6,005,631**	**36.6%**
	Hickory shad	Susq.-Conowingo	**7**		**74**	**28,727,411**	**17,645,251**	**61.4%**

Table 2. Annual summary of American shad production, 1976-2005.

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

Table 2. (continued).

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
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	5,208	0.30	0.87
						Total	240,420		
				Total since 1985 (OTC marked)			209,023		

*Includes fry reared at Manning Hatchery.

Table 3. American shad stocking and fish transfer activities, 2005.

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age	Size
4/28/05	A1 1	HS	958,164	Muddy Creek Access	3	Susquehanna	4	Fry
4/30/05	A2 1	HS	2,999,133	Pennypack Cr.	3	Susquehanna	4	Fry
4/30/05	A3 1	HS	2,005,954	Pennypack Cr., Ridley Cr.	3	Susquehanna	4	Fry
4/30/05	A4 1	HS	1,966,912	Pennypack Cr., Delaware River (Yardley)	3	Susquehanna	4	Fry
5/3/05	B1 1	HS	1,025,036	Muddy Creek Access	3	Susquehanna	4	Fry
5/3/05	B2 1	HS	1,594,247	Muddy Creek Access	3	Susquehanna	4	Fry
5/4/05	B3 1	HS	1,654,762	Pennypack Cr., Delaware River (Yardley)	3	Susquehanna	4	Fry
5/4/05	B4 1	HS	808,900	Pennypack Cr., Delaware River (Yardley)	3	Susquehanna	4	Fry
5/7/05	C1 1	HS	796,353	Muddy Creek Access	3	Susquehanna	4	Fry
5/7/05	C2 1	HS	981,580	Muddy Creek Access	3	Susquehanna	4	Fry
5/8/05	C3 1	HS	1,017,005	Pennypack Cr., Delaware River (Yardley)	3	Susquehanna	4	Fry
5/8/05	C4 1	HS	1,352,486	Pennypack Cr., Delaware River (Yardley)	3	Susquehanna	4	Fry
5/18/05	D1 1	AS	201,058	Millerstown (Greenwood)	3,6,9	Susquehanna	10	Fry
5/24/05	D2 1	AS	515,764	Millerstown (Rt. 17 Bridge)	3,6,9	Susquehanna	10	Fry
6/2/05	D3 1	AS	311,639	Schuylkill R.	3,6,9,12	Delaware	14	Fry
5/30/05	D4 1	AS	132,608	Thompsontown	3,6,9	Susquehanna	12	Fry
6/6/05	E1 1	AS	335,083	West Branch Susquehanna River	3,6,9,12,15	Susquehanna	17	Fry
6/2/05	E2 1	AS	117,664	Schuylkill R.	3,6,9,12	Delaware	13	Fry
6/3/05	E3 1	AS	112,011	Mifflin	3,6,9	Susquehanna	11	Fry
6/16/05	E4 1	AS	352,285	Lehigh R.	9,12,15	Delaware	22	Fry
6/16/05	F1 1	AS	92,558	Lehigh R.	9,12,15	Delaware	20	Fry
6/5/05	F2 1	AS	86,035	Mexico	3,6,9	Susquehanna	10	Fry
6/17/05	F3 1	AS	126,124	Smithfield Beach	3,9,12,15,18	Delaware	20	Fry
6/10/05	F4 1	AS	273,571	Clemson Island	3,6,12	Hudson	13	Fry
6/13/05	G1 1	AS	137,529	Liverpool	3,6,9	Susquehanna	15	Fry
6/15/05	G2 1	AS	197,310	Liverpool	3,6,12	Hudson	16	Fry
6/16/05	G3 1	AS	223,949	Lehigh R.	9,12,15	Delaware	16	Fry
6/15/05	G4 1	AS	163,803	Liverpool	3,6,12	Hudson	14	Fry
6/27/05	H1 1	AS	116,156	Schuylkill R.	3,6,9,12	Delaware	26	Fry
6/15/05	H1 1	AS	20,000	Liverpool	3,6,9,12	Delaware	14	Fry
6/17/05	H2 1	AS	123,633	Liverpool	3,6,9	Susquehanna	16	Fry
6/17/05	H3 1	AS	85,995	Liverpool	3,6,9	Susquehanna	13	Fry
6/21/05	H4 1	AS	94,295	Millerstown (Greenwood)	3,6,12	Hudson	15	Fry
6/20/05	I1 1	AS	252,366	Millerstown (Rt. 17)	3,6,12	Hudson	13	Fry
6/22/05	I2 1	AS	234,297	Huntingdon	3,6,12	Hudson	13	Fry
6/28/05	I3 1	AS	43,678	Smithfield Beach	3,9,12,15,18	Delaware	19	Fry
1/0/00	I4 1	AS	5,819	Genetics study- Not stocked	none	Delaware	0	Fry
6/23/05	A1 2	AS	398,808	Mifflin	3,6,12	Hudson	13	Fry
6/27/05	A2 2	AS	232,404	Schuylkill R.	3,6,9,12	Delaware	17	Fry
6/27/05	A3 2	AS	20,821	Schuylkill R.	3,6,9,12	Delaware	17	Fry
6/29/05	A4 2	AS	206,509	Millerstown (Rt. 17)	3,6,12	Hudson	17	Fry

Table 4. Production and utilization of juvenile Alosines, Van Dyke, 2005.

	Site	Fry
American shad Releases	Millerstown (Greenwood)	295,353
	Millerstown (Rt. 17 Bridge)	974,639
	Miller's Canoe Rental	
	Thompsontown	132,608
	Muskrat Springs	
	Mexico	86,035
	Mifflin	510,819
	Huntingdon	234,297
	Warrior Ridge Dam	
	Tuscarora Creek	
	Juniata River Subtotal	2,233,750
	Clemson Island	273,571
	Montgomery Ferry	
	Millersburg Ferry	
	Liverpool	728,271
	Mahantango	
	Conodoguinet Creek	
	Conestoga River	
	Swatara Creek	
	West Conewago Creek	
	North Branch Susquehanna River (PA)	
	West Banch Susquehanna River	335,083
	Chemung River	
	North Branch Susquehanna River (NY)	
	Susquehanna River Basin Subtotal	3,570,675
	Delaware River	169,802
	Schuylkill River	798,683
	Lehigh River	668,792
	Nanticoke River	
	Raritan River	
	Total American shad	5,207,952
Hickory shad releases	Muddy Creek Access Area	5,355,381
	Susquehanna River Basin Subtotal	5,355,381
	Delaware River	3,200,000
	Pennypack Creek	8,005,151
	Ridley Creek	600,000
	Delaware River Basin Subtotal	11,805,151
	Total Hickory shad	17,160,532

Table 5. Summary of marked Alosines stocked in Pennsylvania, 2005.

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										
1,820,958	Fry	3,6,12	Juniata/Susq. R.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
1,394,634	Fry	3,6,9	Juniata/Susq. R.	Susquehanna	256ppm OTC	100%	-	-	Van Dyke	-
20,000*	Fry	3,6,9,12	Juniata/Susq. R.	Delaware	256ppm OTC	100%	-	-	Van Dyke	-
335,083	Fry	3,6,9,12,15	W. Br. Susq. R.	Hudson	256ppm OTC	100%	-	-	Van Dyke	-
-	Fry	3,6,12,15	Conodoguinet Cr.	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,9,12,15	Conestoga R.	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,9,12,15,18	W. Conewago Cr.	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,6,9,15,18	Swatara Cr.	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,6,9,15	N. Br. Susq. R.(PA)	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,6,9,12,18	N. Br. Susq. R.(NY)	Hudson	256ppm OTC		-	-	Van Dyke	-
-	Fry	3,15,18	Chemung R. (NY)	Hudson	256ppm OTC		-	-	Van Dyke	-
169,802	Fry	3,9,12,15,18	Delaware R.	Delaware	256ppm OTC	100%	-	-	Van Dyke	-
668,792	Fry	9,12,15	Lehigh R.	Delaware	256ppm OTC	N/E**	-	-	Van Dyke	-
798,683	Fry	3,6,9,12	Schuylkill R.	Delaware	256ppm OTC	100%	-	-	Van Dyke	-
-	Fry	3	Raritan R. (NJ)	Hudson	256ppm OTC		-	-	Van Dyke	-
1,250	Fing.	Various + single feed	Juniata R.	various	256ppm OTC	100%	88g OTC per kg food***	5%	Van Dyke	Benner Spring
Hickory shad										
5,355,381	Fry	3	Conowingo Res.	Susquehanna	512ppm OTC	100%	-	-	Van Dyke	-
3,200,000	Fry	3	Delaware River	Susquehanna	512ppm OTC	100%	-	-	Van Dyke	-
8,005,151	Fry	3	Pennypack Cr.	Susquehanna	512ppm OTC	100%	-	-	Van Dyke	-
600,000	Fry	3	Ridley Cr.	Susquehanna	512ppm OTC	100%	-	-	Van Dyke	-

* Approximately 20,000 larvae erroniously stocked in the Susquehanna River at Liverpool

** Not evaluated- larvae stocked in raceway for tag retention did not survive

*** Used AMTECH Oxytetracycline HCL instead of Pfizer Terramycin 343

Table 6. Proposed marking plan for Alosines stocked in Pennsylvania, 2004-2009.

Size	Immersion mark (days)	Immersion mark	Stocking Location	Egg Source	Years
American shad					
Fry	3,9,12,21	256ppm OTC	Juniata/Susq. R.	Hudson/Potomac	2006, 2009
Fry	3,9,12	256ppm OTC	Juniata/Susq. R.	Hudson	2004, 2007
Fry	3,6,12	256ppm OTC	Juniata/Susq. R.	Hudson	2005, 2008
Fry	3,6,9	256ppm OTC	Juniata/Susq. R.	Susquehanna	2004-2009
Fry	3,6,9,12,15	256ppm OTC	W. Br. Susq. R.	Hudson/Potomac	2004-2009
Fry	3,6,12,15	256ppm OTC	Conodoguinet Cr.	Hudson/Potomac	2004-2009
Fry	3,9,12,15	256ppm OTC	Conestoga R.	Hudson/Potomac	2004-2009
Fry	3,9,12,15,18	256ppm OTC	W. Conewago Cr.	Hudson/Potomac	2004-2009
Fry	3,6,9,15,18	256ppm OTC	Swatara Cr.	Hudson/Potomac	2004-2009
Fry	3,6,9,15	256ppm OTC	N. Br. Susq. R.(PA)	Hudson/Potomac	2004-2009
Fry	3,6,9,12,18	256ppm OTC	N. Br. Susq. R.(NY)	Hudson/Potomac	2004-2009
Fry	3,15,18	256ppm OTC	Chemung R. (NY)	Hudson/Potomac	2004-2009
Fry	9,12,15	256ppm OTC	Lehigh R.	Delaware	2004-2009
Fry	3,6,9,12	256ppm OTC	Schuylkill R.	Delaware	2004-2009
Fry	3	256ppm OTC	Raritan R. (NJ)	Hudson	2004-2009
Fry	3,6,12,15,18	256ppm OTC	Del. R. (Smithfield)	Delaware	2004-2009
Hickory shad					
Fry	3	512ppm OTC	Conowingo Res.	Susquehanna	2004-2009
Fry	3	512ppm OTC	Delaware River	Susquehanna	2004-2009
Fry	3	512ppm OTC	Ridley Cr.	Susquehanna	2004-2009
Fry	3	512ppm OTC	Pennypack Cr.	Susquehanna	2004-2009

Appendix 1

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2005

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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 on day 5 and stocked at 7 days of age to avoid anticipated high mortality due to an unknown (disease?) factor. 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 fish stocked at 22 and 26 days of age (St. Pierre, 1994).

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

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

A study was designed in 1997 to test this hypothesis, however, logistical considerations forced us to deviate from the plan and no conclusions could be drawn regarding the benefit of spreading larvae out to various stocking sites (Hendricks, 1998). Due to insufficient unique marks, we have never been able to conduct a controlled experiment to test the benefits of stocking larvae at various sites. Results in 1997, 1998 and 1999 suggested that small groups of larvae stocked in tributaries at older ages can survive as well as those stocked in the Juniata River at 7-10 days of age. In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2005 and summarizes results from 1995 to 2005.

Materials and Methods

Production larvae, stocked in 2005, included 1.82 million Hudson River source (strip-spawn) larvae marked at 3, 6, and 12 days of age; and 1.39 million Susquehanna River source (tank-spawn) larvae marked at 3, 6, and 9 days of age. These groups were stocked at various sites in the Juniata River or Susquehanna River at Liverpool and Clemson Island. In addition, approximately 20,000 Delaware River source larvae, marked on days 3, 6, 9, and 12 were erroneously stocked in the Susquehanna River at Liverpool. Sites were generally stocked in succession, moving upriver. Repeated stockings at one site, within a short time interval, were avoided. Smaller numbers (335,000) of uniquely marked larvae were stocked in the West Branch Susquehanna River. Other sites commonly stocked in previous years were not stocked due to poor egg production. These sites included the North Branch Susquehanna River in PA and NY, the Chemung River, Swatara Creek, Conodoguinet Creek, West Conewago Creek and Conestoga River.

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 by the total number of fish collected in a sample and dividing by the number of fish sub-sampled for otolith analysis. Data for 1995 to 2004 was similarly corrected to account for the total number of shad collected, not just those sampled. Recovery rates were calculated for each group by dividing the expanded number of fish recovered by the number stocked and multiplying by 10,000 to remove the decimal point and convert the rate to a whole number. Relative survival was calculated by dividing the recovery rate for each group by the highest recovery rate.

Results and Discussion

In 2005, Susquehanna River source larvae stocked in the West Branch Susquehanna River exhibited the best survival (relative survival set to 1.00, Table A1-1). Hudson River egg source larvae and Susquehanna River egg source larvae, both stocked in the Juniata River and middle Susquehanna River near Montgomery Ferry, each exhibited relative survival of 0.16. Delaware River source larvae (approximately 20,000), stocked by mistake in the Susquehanna River at Liverpool, exhibited a relative survival of 0.35. Other sites were not stocked due to poor egg deliveries.

A summary of the results of ten years of uniquely marking larvae according to stocking site is provided in Table A1-2. Recovery rates for 2005 varied from 0.22 to 1.44. The overall recovery rate for 2005 (0.35) was near the median for the ten year time period, however, increased collecting effort at Peach Bottom, in conjunction with a comprehensive impingement study, may have skewed the results and resulted in more recaptures than would have been expected. This suggests that survival of hatchery larvae was poor in 2005, a result also confirmed by low CPUE for haul seine and lift net collections (see Job IV). The cause of the poor survival in 2005 is not known, but it cannot be explained by high water, as was the case in 2003 and 2004.

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

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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, 2005.

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./ middle Susq. R. near Mont. Ferry	Hudson	13-16	6/10-6/22	1,820,958	51%	43	35	0.24	0.16
Juniata R./ middle Susq. R. near Mont. Ferry	Susq.-Con	10-16	5/18-6/17	1,394,634	39%	31	25	0.22	0.16
W. Br. Susq. R.	Susq.-Con	17	6/6	335,083	9%	48	39	1.44	1.00
Susq. R. Liverpool	Delaware	14	6/15	20,000	1%	1	1	0.50	0.35
			Total	3,570,675		123		0.35	

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, 1995-2005.

Stocking Site	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005
Recovery Rate										
Juniata R./Susq. R. @ Mont. Ferry	2.12	0.10	1.85	-	-	0.72	2.07	0.15	0.05	0.24
Juniata R.(various sites)	-	-	2.09	0.15	0.63	-	-	-	-	-
Juniata R.(Susq. eggs)	-	-	-	0.10	-	-	1.32	0.37	0.14	0.22
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	-
mouth of Conodiguinet Cr.	2.96	-	-	-	-	-	-	-	-	-
Conestoga R.	3.28	0.00	0.26	0.00	0.87	0.13	0.22	0.00	0.00	-
mouth of Conestoga Cr.	1.18	-	-	-	-	-	-	-	-	-
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-
Conewago Cr.	-	-	-	0.19	0.18	0.61	0.18	0.00	0.10	-
Swatara Cr.	-	-	-	0.20	0.69	0.00	1.15	0.00	0.19	-
W. Br. Susq. R.	-	0.09	0.86	0.00	0.00	0.17	0.09	0.54	0.07	1.44
N. Br. Susq. R.(PA)	-	0.34	2.02	0.21	0.19	0.40	1.06	0.00	0.09	-
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.64	0.04	-
Chemung R.	-	-	-	-	-	-	-	1.02	0.00	-
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.50
Overall	2.13	0.12	1.77	0.15	0.54	0.62	1.37	0.27	0.07	0.35
Relative Survival										
Juniata R./Susq. R. @ Mont. Ferry	0.65	0.31	0.89	-	-	1.00	1.00	0.15	0.39	0.16
Juniata R.(various sites)	-	-	1.00	0.72	0.73	-	-	-	-	-
Juniata R.(Susq. eggs)	-	-	-	0.49	-	-	0.64	0.37	1.00	0.16
Huntingdon	-	-	0.72	-	-	-	-	-	-	-
Standing Stone Cr.	-	0.00	-	0.00	-	-	-	-	-	-
Conodoguinet Cr.	0.77	0.37	0.14	0.25	0.59	0.74	0.03	0.00	0.44	-
mouth of Conodiguinet Cr.	0.90	-	-	-	-	-	-	-	-	-
Conestoga R.	1.00	0.00	0.12	0.00	1.00	0.18	0.11	0.00	0.00	-
mouth of Conestoga Cr.	0.36	-	-	-	-	-	-	-	-	-
Muddy Cr.	0.00	-	-	-	-	-	-	-	-	-
Conewago Cr.	-	-	-	0.89	0.20	0.84	0.09	0.00	0.75	-
Swatara Cr.	-	-	-	0.96	0.80	0.00	0.56	0.00	1.36	-
W. Br. Susq. R.	-	0.28	0.41	0.00	0.00	0.23	0.05	0.54	0.50	1.00
N. Br. Susq. R.(PA)	-	1.00	0.97	1.00	0.21	0.56	0.51	0.00	0.64	-
N. Br. Susq. R.(NY)	-	-	-	-	-	-	-	0.62	0.30	-
Chemung R.	-	-	-	-	-	-	-	1.00	0.00	-
Liverpool (Del. source)	-	-	-	-	-	-	-	-	-	0.35

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, 2005

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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 2005.

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 3,896 adult shad were collected at the Conowingo West Lift. The majority of these were released back into the Conowingo tailrace. Some 1,012 were retained for tank spawning. In addition, 404 American shad were transported and released upstream in conjunction with a fishway efficiency study at York Haven Dam.

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 2005 spring migration, Conowingo East Lift passed 68,926 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 34,189, 25,425 and 1,771 American shad, respectively. Only four river herring were passed at Conowingo Dam and none passed at Holtwood.

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 2005 production season, the PFBC Van Dyke Research Station for Anadromous Fish produced 3.6 million shad larvae which were released in the Susquehanna Basin in Pennsylvania. Larvae were released coinciding with receding flows (Figure 1) between 18 May and 29 June in the following locations and numbers:

Juniata River (various sites)	2,233,750
Susquehanna River (near Montgomery Ferry)	1,001,842
West Branch Susquehanna River	335,083

In addition to the larvae released, approximately 1,250 American shad fingerlings were released at Huntingdon on October 25, 2005. The production goal of 10 million larvae was not met, primarily due to fewer eggs shipped from the Hudson River.

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.

Haul Seining - Main Stem

Haul seining in the lower Susquehanna River was scheduled once each week beginning mid-July and continuing through October. Fifteen weekly sampling events were planned for 2005, however, high river flow in late October necessitated postponement of the final sampling until November 8. A total of 15 sampling events occurred. 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 APS, and Conowingo Dam

Sampling at the Holtwood Dam inner fore-bay began on 13 September and continued every third day through November 2005. A total of 30 sampling events was planned for 2005. By late November, it was apparent that the out-migration was over. Therefore, the program was terminated after completion of 27 of the 30 scheduled events.

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

A comprehensive program to monitor intake screens for impinged alosines at Peach Bottom Atomic Power Station was conducted in 2005. Sampling was conducted on a 24-hour basis, twice per week from Sept. 1 to Dec. 31. When shad were collected in the Holtwood lift net during the previous week, an additional (third) sample was collected the following week at Peach Bottom. A total of 50 samples were collected during September through December. Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosines twice weekly from 3 October to 8 December for a total of 16 samples.

Susquehanna River Mouth and Flats

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

Disposition of Samples

Sub-samples of up to 30 juveniles per day were used for otolith analysis. Samples of shad from most collections were returned to 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

A total of 23 juvenile American shad were captured by haul seine resulting in a Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) of 0.16 (Tables 1 and 2). Juvenile American shad were captured from July 20 to October 20 with no apparent peak in abundance. Two of the 5 shad captured on August 2 were hatchery. All other shad captured by haul seine were wild in origin. Table 3 lists weekly catches of American shad by haul seine from 1989 to 2005. Catches generally peaked in August and September, except in 1989 and 1992 when catches peaked in July, and in 2005 when there was no peak.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner fore-bay resulted in 200 juvenile American shad captured in 300 lifts (Table 4). All shad were captured between October 25 and October 31, with 171 captured on October 28. Geometric Mean CPUE (individual lift) was 0.10 while GM CPUE (combined daily) was 0.15 (Table 5). Historical weekly catches peaked in October, except in 1985, 1997, 2000, and 2001 when catches peaked in November (Table 5). Four alewife were captured by lift-net on 28 October 2005.

Peach Bottom intake screens produced 135 juvenile American shad and 29 alewives (Table 7).

Cooling water strainers at Conowingo produced 25 American shad, collected between 21 October and 7 November (Tables 8 and 9).

Susquehanna River Mouth and Flats

In 2005, 115 juvenile American shad were captured at seven permanent sites by Maryland DNR's juvenile finfish haul seine survey during 42 hauls, and 129 juvenile American shad were captured at the auxiliary sites during 30 hauls (Table 10).

Otolith Mark Analysis

Results of otolith analysis are presented in Table 11. A total of 368 juvenile American shad were collected in haul seines, lift nets, Peach Bottom intakes and Conowingo strainers. Of the 230 specimens evaluated for hatchery tags, 58.5% were wild and 41.5% were hatchery. Each group of uniquely marked fish was represented in the catch (see Job III, Appendix 1 for a discussion of relative survival).

DISCUSSION

Spring river conditions for the Susquehanna River Basin during 2005 could be characterized by relatively stable flows with two minor peaks in mid-June (Figure 1) followed by drought conditions until early November (Figures 2 and 3). Water temperatures at Conowingo Dam were less than 60F from 15 April to 10 May, jumped from 62 to 66F from 11 May to 16 May, remained above 66F until 31 May, and then remained above 70F until the fish lift closed for the season on 8 June. Stable flows and cool temperatures extended the length of the spawning season and contributed to an increase in eggs delivered to the hatchery from Conowingo tank-spawning.

The relatively stable flows in the watershed during the 2005 stocking season should have promoted good survival of larvae (Figure 1). This is in contrast to 2004, when many of the stocking events were followed by increases in flow resulting in conditions that were not optimal for larval survival.

Fish passage at Holtwood was better than average with 50% passage, based on counts at Conowingo and Holtwood (mean = 30%). Fish passage at Safe Harbor was equal to the long-term mean of 74%, based on counts at Holtwood and Safe Harbor. Fish passage at York Haven (7%) was lower than the average of 14%, based on counts at Safe Harbor and York Haven. Some 1,772 shad were counted passing the York Haven Dam fishway.

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 2005, haul seine and lift net CPUE were among lowest ever recorded.

GM CPUE for haul seine (both individual lifts, and combined daily lifts, Table 2) was the second lowest value ever recorded for that gear type since 1990. GM CPUE for lift net collections (Table 5) in the Holtwood Dam forebay was slightly more encouraging, but was still an order of magnitude lower than in 1985-1988, 1990, 1993, 1995 or 2001. Juvenile shad abundance has been below normal for four consecutive years, a disturbing trend that may impact fish passage during 2006 to 2010. 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. The apparent poor catch rates for juvenile shad in 2005 may have been due, in part, to fewer larvae stocked.

Stock Composition and Mark Analysis

Hatchery contribution varied between sites and collection dates. Contribution of hatchery fish from Columbia, Holtwood, Peach Bottom and Conowingo was 9%, 41%, 53% and 21%, respectively. Hatchery contribution varied on a daily basis. For example, on 26 October, hatchery fish constituted 44% of the catch at Peach Bottom. One day later, on October 27, hatchery contribution was 64%.

SUMMARY

- Juvenile American shad were successfully 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 0.24 was the second lowest recorded for that gear type since 1990.
- Lift-net GM CPUE (combined daily lifts) of 0.15 was among the lowest recorded for that gear type since 1985.
- Otoliths from the four sites combined were 42% wild and 58% 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.

ACKNOWLEDGMENTS

Normandeau Associates (Drumore, PA) was contracted by the PFBC to perform juvenile collections. Many individuals supplied information for this report. Ken Woomer and Coja Yamashita, PFBC seasonal employees, processed shad otoliths.

Figure 1. Number of American shad larvae stocked and river flow in the Juniata River, 2005.

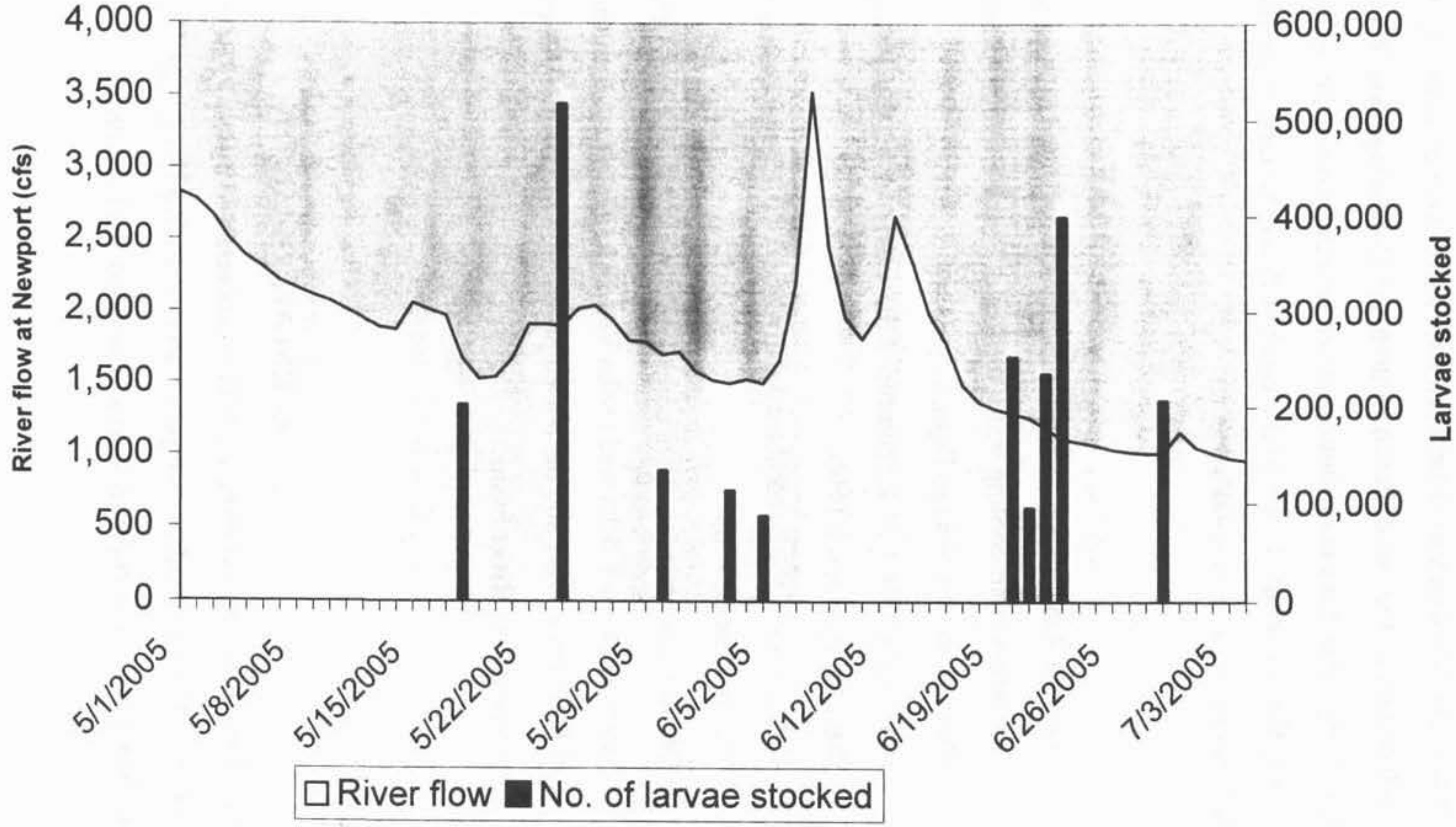

Figure 2. Number of American shad collected by haul seine and river flow, Susquehanna River, 2005.

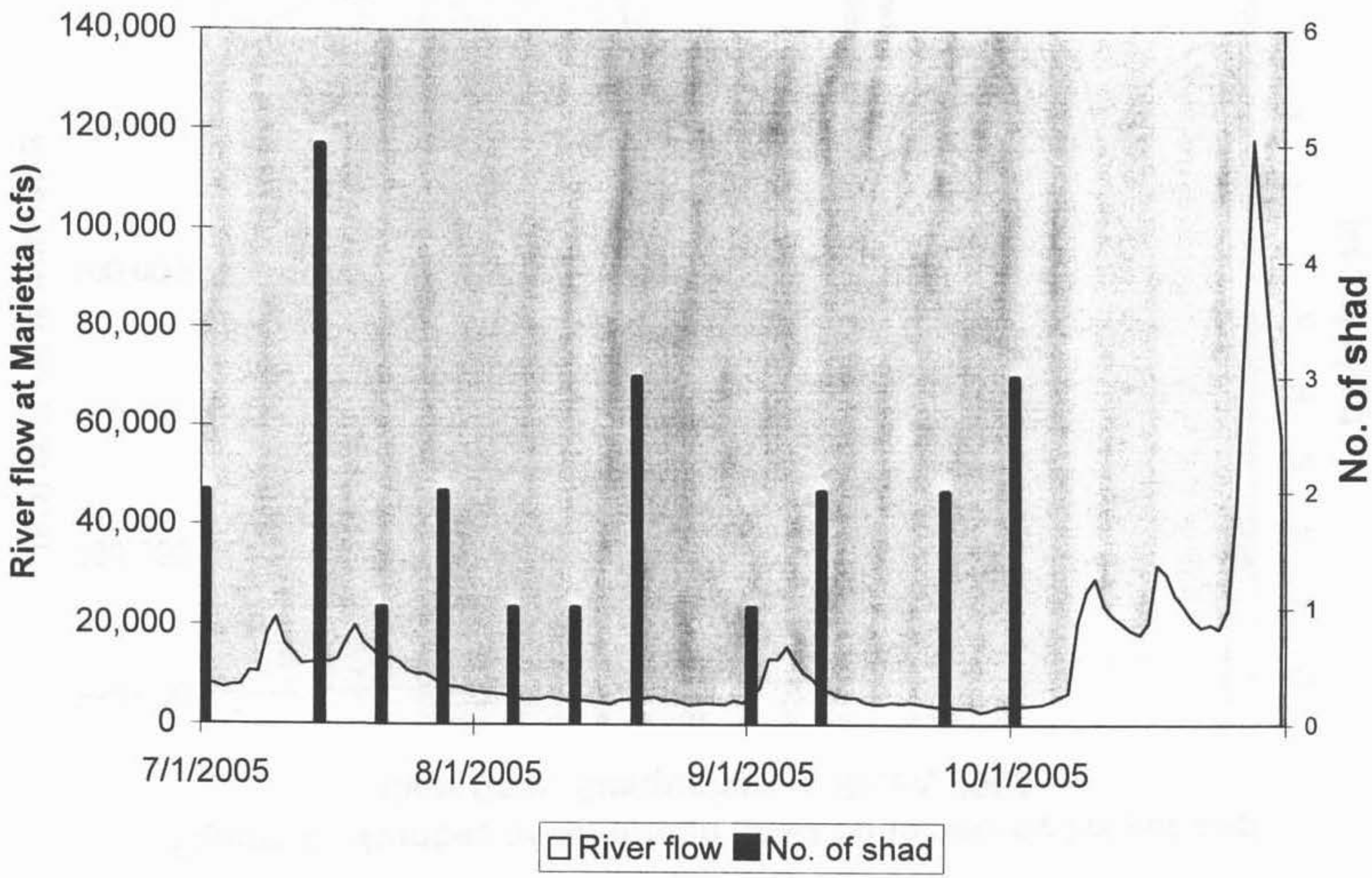

Figure 3. Number of American shad collected by lift net and river flow, Susquehanna River, 2005.

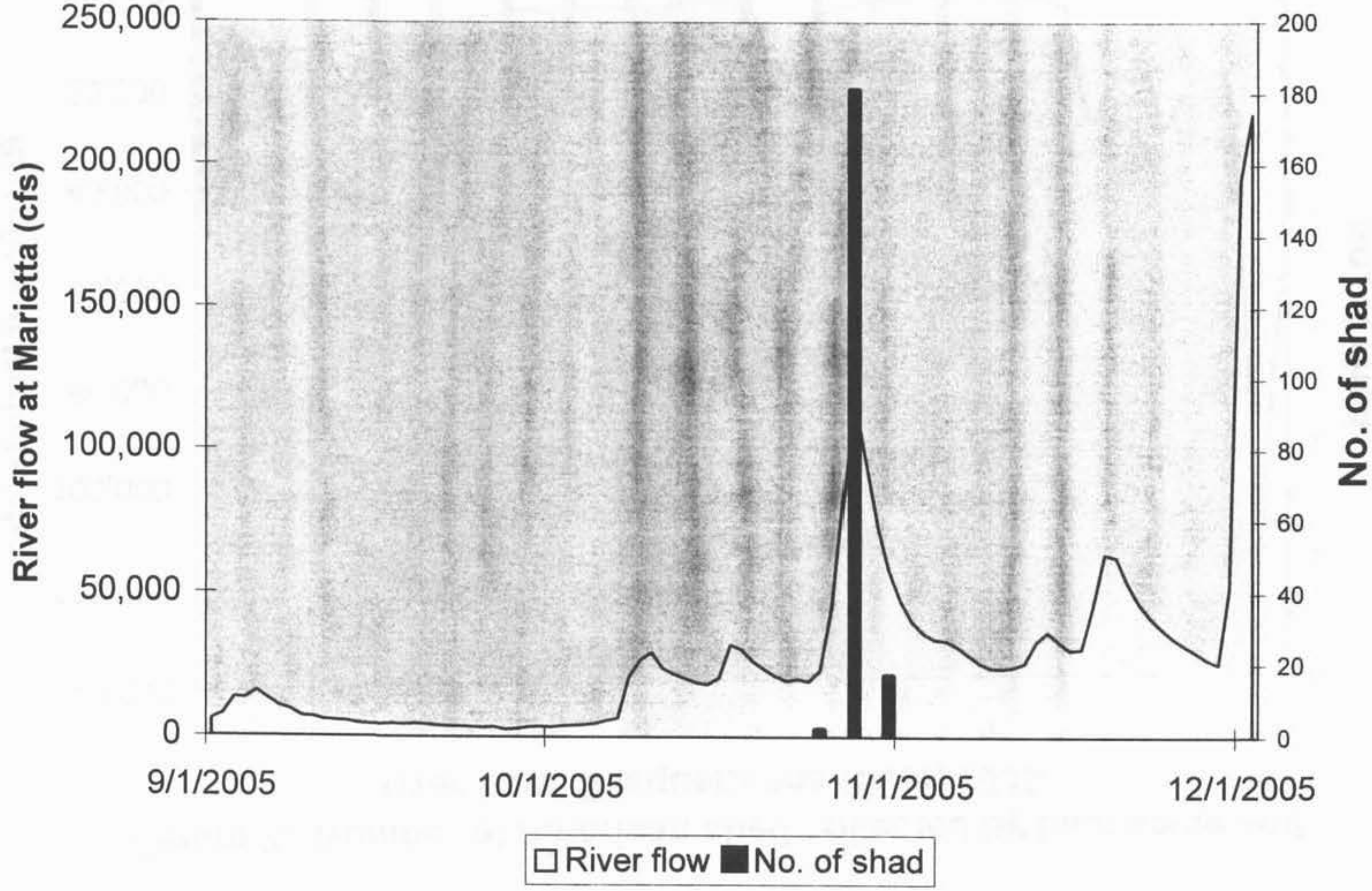

Table 1. Number of collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2005.

Date	20-Jul	26-Jul	2-Aug	9-Aug	16-Aug	24-Aug	31-Aug	7-Sep	14-Sep	20-Sep	28-Sep	5-Oct	12-Oct	20-Oct	8-Nov	Total
Daily Mean River Flow (cfs)	14,900	9,400	6,500	5,510	4,360	3,200	4,470	10,500	4,430	4,080	3,150	5,030	21,800	23,400	25,400	
Water Temperature (°C)	30.5	31.0	32.0	28.0	23.0	27.5	27.0	26.5	25.2	26.5	21.5	24.0	16.8	15.1	11.5	
Secchi Disk (in)	30	35	35	40	40	50	50	40	55	60	60	78	34	34	45	
American shad	2		5	1	2	1	1	3		1	2		2	3		23
Gizzard shad	90	195	23	18	23	71	16	22	10			3	2	16	1	490
Comely shiner				4	5			4	6				1	1		21
Spottail shiner	1					5				1	7	2				16
Spotfin shiner	39	52	13	4	8		3	9	5	2	1		8	1		145
Fallfish									3							3
Quillback	1								9							10
Northern hog sucker			3					1								4
Channel catfish			1	1				1				1				4
Rock bass	1												2	7		10
Bluegill								1				1	2	4		8
Smallmouth bass											1				1	2
Largemouth bass						1										1
Tessellated darter							2									2
Walleye			1		2	1		3	2			1	2	4	1	17
Total	**134**	**247**	**46**	**28**	**40**	**79**	**22**	**44**	**35**	**4**	**11**	**8**	**19**	**36**	**3**	**756**
No. of Species	**6**	**2**	**6**	**5**	**5**	**5**	**4**	**8**	**6**	**3**	**4**	**5**	**7**	**7**	**3**	**15**

Table 2. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990-2005.

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

Table 3. **Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River, 1989 through 2005.**

Week	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
I Jul				0		2												2
II Jul	1,048		0	120	0	27		2	44	10	0	7						1,258
III Jul			0	6		70	53	18	28	14	0	3	46	0	0	0	2	238
IV Jul	45	31			0	60	24	15	22	144	1	0	23	0	0	0	0	365
I Aug		0	0	20	0	24	29	32	14	30	1	2	19	0	*	*	5	171
II Aug	61	0	0	2	8	13	35	56	20	0	0	6	70	0	*	*	1	271
III Aug	7	69	0	16	0	46	40	43	171	9	0	1	37	0	*	0	2	439
IV Aug					13		42	39	120	10	8	0	36	0	0	*	1	268
I Sep		25	12		20		43	34	129	3	2	0	36	0	8	16	1	312
II Sep		4			15	50	31	3	46	3	*	0	23	0	5	0	3	180
III Sep		93	16		26	25	34	1	89	3	264	0	31	0	4	9	0	586
IV Sep		28	30		27	14	46	12	59	1	17	0	15	0	0	*	1	249
V Sep		0	73		11	5	15	15	32	0	20	1	34	0	*	*	2	206
I Oct		0	69	2	22	5	19	10	91	3	1	0	6	0	*	*	0	228
II Oct		0	7		0	2	31	3	0	0	3	11	1	0	*	0	2	58
III Oct			5			10			14	0	5	0	0	*	0	0	3	34
IV Oct			0	0			0	0					0	0	*	0	0	0
TOTAL	**1,161**	**250**	**212**	**166**	**142**	**353**	**442**	**283**	**879**	**230**	**322**	**31**	**377**	**0**	**17**	**25**	**23**	**4,865**

* No sampling due to high river flow.

Table 4. Number of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 13 September through 30 November, 2005.

Date:	13 Sep	16 Sep	19 Sep	22 Sep	25 Sep	28 Sep	01 Oct	04 Oct	07 Oct	10 Oct	13 Oct	16 Oct	19 Oct	22 Oct
Water Temp (°C):	26.0	26.5	25.5	25.5	24.5	23.0	22.0	22.0	21.5	20.0	17.0	16.5	15.5	15.0
Secchi (in):	40	48	45	45	51	50	50	41	40	22	37	34	40	38
River Flow (cfs):	5,110	4,170	4,550	3,470	3,340	3,150	3,400	4,330	7,450	28,500	19,500	21,400	25,400	19,500
Start Time (hr):	1846	1822	1824	1823	1820	1832	1846	1824	1814	1810	1816	1818	1800	1745
End Time (hr):	2006	1953	1940	1948	1945	1945	1950	1958	1936	1940	1934	1912	1909	1905
Alewife	-	-	-	-	-	-	-	-	-	-	-	-	-	-
American shad	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gizzard shad	156	-	62	125	-	3	-	-	1	39	15	28	142	25
Comely shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	-	-	-	-	-	-	-	-	5	-	-	-	3
Channel catfish	-	-	3	-	1	-	1	-	-	1	-	-	-	-
Striped bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	4	-	-	-	-	-	2	-	1	-	-	1	-
Largemouth bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	1	-	-	-	3	-	1
Total	**156**	**4**	**65**	**125**	**1**	**3**	**1**	**3**	**1**	**46**	**15**	**31**	**143**	**29**

Date:	25 Oct	28 Oct	31 Oct	03 Nov	06 Nov	09 Nov	12 Nov	15 Nov	18 Nov	21 Nov	23 Nov	27 Nov	30 Nov	
Water Temp (°C):	12.9	9.5	9.0	10.0	11.2	12.2	11.0	10.0	9.5	7.0	6.0	3.5	6.0	
Secchi (in):	40	20	21	31	40	42	42	50	44	42	40	68	48	
River Flow (cfs):	25,800	116,700	55,600	35,400	30,800	23,800	25,500	32,500	50,200	52,100	41,100	29,100	57,400	
Start Time (hr):	1740	1730	1628	1632	1640	1624	1622	1630	1624	1619	1619	1616	1626	
End Time (hr):	1855	1848	1743	1748	1808	1734	1742	1750	1737	1721	1752	1730	1711	**TOTAL**
Alewife	-	4	-	-	-	-	-	-	-	-	-	-	-	4
American shad	2	181	17	-	-	-	-	-	-	-	-	-	-	200
Gizzard shad	1	578	289	104	58	396	8	-	119	-	1	-	-	2,150
Comely shiner	-	-	-	-	-	-	-	1	-	-	1	-	-	2
Spotfin shiner	-	-	-	-	1	-	-	-	-	-	-	-	-	9
Channel catfish	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Striped bass	-	-	-	-	1	-	-	4	-	-	-	-	-	5
Bluegill	-	-	5	2	-	-	-	-	-	-	-	-	-	15
Largemouth bass	-	-	2	-	-	-	-	-	-	-	-	-	-	2
Walleye	-	-	1	-	2	-	-	2	-	-	-	-	-	10
Total	**3**	**763**	**314**	**106**	**62**	**396**	**8**	**7**	**119**	**0**	**2**	**0**	**0**	**2,403**

Table 5. Index of abundance for juvenile American shad collected by lift net in the fore-bay of Holtwood Hydroelectric Station, 1985-2005.

Year	No. Lifts	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Lift CPUE*	No. Wild Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	No. Hatchery Fish	Mean Combined Daily CPUE (Hatchery)	GM Combined Daily CPUE (Hatchery)	Migration Duration (days)
1985	378	3,626	20.31	7.55		**	**					65
1986	404	2,926	10.30	5.71		**	**					64
1987	428	832	3.17	1.90		**	**					72
1988	230	929	3.87	1.28		**	**					51
1989	396	556	0.55	0.26		**	**					35
1990	300	3,988	13.29	3.44		70	0.23	0.18	3,918	13.06	3.62	72
1991	290	208	0.72	0.52		19	0.07	0.06	189	0.65	0.47	71
1992	300	39	0.13	0.10		14	0.05	0.04	25	0.08	0.07	43
1993	300	1,095	3.65	1.27		669	2.79	0.64	426	1.42	0.57	56
1994	300	206	0.69	0.39		35	0.13	0.13	171	0.57	0.32	71
1995	115	1,048	9.11	1.26		83	0.72	0.32	965	8.39	1.20	34
1997	300	1,372	4.57	0.88	0.61	100	0.33	0.23	1,272	4.24	0.85	46
1998	300	180	0.60	0.37	0.22	9	0.03	0.03	171	0.57	0.35	67
1999	300	490	1.63	0.78	0.50	19	0.06	0.07	471	1.57	0.76	40
2000	300	406	1.35	0.61	0.18	4	0.01	0.01	402	1.34	0.60	43
2001	299	1,245	4.18	1.37	0.43	538	1.81	0.45	707	2.36	0.99	73
2002	300	68	0.23	0.11	0.06	15	0.05	0.04	53	0.18	0.09	13
2003	300	61	0.20	0.13	0.07	3	0.01	0.01	58	0.19	0.12	22
2004	240	0	0.00	0.00	0.00	0	0.00	0.00	0	0.00	0.00	-
2005	300	200	0.67	0.15	0.10	47	0.16	0.11	153	0.51	0.11	7

* Required by ASMFC

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

Note: Collections were cut short in some years when it was clear that the outmigration was over.
Simulated lifts were recorded to ensure comparable CPUE.

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, August - December 1985 - 2005*.

	Year																			
Week	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
II Aug	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-	-	-
III Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-
IV Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-
I Sep	-	-	-	0.0	-	0.8	0.0	1.4	0.0	0.5	0.0	-	-	-	-	-	-	-	-	-
II Sep	-	-	1.3	-	-	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.0	0.0	-	-	-	-
III Sep	-	-	0.7	-	2.3	0.0	0.0	0.5	0.0	0.0	-	0.0	0.0	9.7	0.0	0.0	-	-	-	-
IV Sep	-	-	0.3	-	-	7.5	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.3	0.0	2.6	0.0	0.0	0.0	**0.0**
V Sep	-	-	0.9	0.0	1.2	3.9	0.1	0.1	0.2	4.3	0.1	0.0	0.1	4.7	0.0	0.5	0.0	0.0	**	**0.0**
I Oct	-	16.7	4.1	0.1	1.2	2.0	0.1	0.0	0.2	3.5	0.0	0.0	0.8	3.7	0.0	0.1	0.0	0.4	0.0	**0.0**
II Oct	0.1	30.3	4.5	0.0	3.2	52.0	0.6	0.2	0.1	0.7	5.0	0.0	1.9	2.1	0.1	0.2	0.0	1.6	0.0	**0.0**
III Oct	1.0	5.4	1.3	10.0	0.5	50.2	0.9	0.3	17.5	0.3	68.9	0.2	1.3	1.0	0.7	0.0	1.7	0.5	0.0	**0.0**
IV Oct	41.6	5.3	4.8	19.1	0.0	34.3	1.1	0.1	14.8	0.1	56.0	0.0	1.7	0.0	2.5	2.5	1.7	0.3	0.0	**0.0**
I Nov	28.6	4.1	4.5	2.0	0.0	1.7	2.4	0.0	19.0	0.6	9.3	25.1	1.6	0.0	0.6	4.7	0.0	0.0	0.0	**9.2**
II Nov	10.8	19.5	0.3	0.3	0.0	0.4	0.5	0.7	1.6	0.1	0.0	27.1	0.1	0.0	13.2	4.2	0.0	0.0	0.0	**1.7**
III Nov	57.6	6.3	0.7	0.5	-	0.0	0.8	0.0	0.1	0.0	0.0	3.0	0.1	0.0	5.5	0.1	0.0	0.0	0.0	**0.0**
IV Nov	15.1	-	-	0.3	-	0.0	1.6	-	0.0	0.0	0.0	0.5	0.0	0.0	1.2	7.0	0.0	0.0	0.0	**0.0**
I Dec	62.8	14.2	0.0	0.0	-	-	-	0.9	-	0.0	-	0.0	0.0	0.0	0.0	30.9	0.0	0.0	0.0	**0.0**
II Dec	4.3	0.1	-	-	-	-	1.2	-	-	-	-	-	0.6	-	-	-	-	0.0	0.0	**0.0**
III Dec	0.5	0.0	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
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**
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	290	300	260	300	240	**280**
CPUE	9.6	7.2	1.9	4.0	1.9	13.8	0.6	0.2	4.6	0.8	9.1	4.6	0.6	1.6	1.4	4.2	0.3	0.2	0.0	**0.7**

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

** No sampling due to high river flows (>600,000 cfs), which flooded the forebay area.

Table 7. Number of fish collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall, 2005.

Species	Unit 2	Unit 3	Total
Alewife	15	14	**29**
American shad	47	88	**135**
Gizzard shad	22,048	34,896	**56,944**
Common carp	5	11	**16**
Golden shiner	1	1	**2**
Comely shiner	9	20	**29**
Spottail shiner	5	2	**7**
Swallowtail shiner	1	0	**1**
Spotfin shiner	4	11	**15**
Quillback	2	0	**2**
Northern hogsucker	1	9	**10**
Shorthead redhorse	1	0	**1**
Yellow bullhead	0	1	**1**
Channel catfish	197	149	**346**
Flathead catfish	7	12	**19**
Mummichog	0	1	**1**
White perch	4	5	**9**
Striped bass	0	2	**2**
Rock bass	13	23	**36**
Redbreast sunfish	0	1	**1**
Green sunfish	17	18	**35**
Pumpkinseed	4	1	**5**
Bluegill	1,469	1,882	**3,351**
Smallmouth bass	6	7	**13**
Largemouth bass	7	15	**22**
White crappie	36	29	**65**
Tessellated darter	3	12	**15**
Yellow perch	31	86	**117**
Walleye	68	130	**198**
Banded darter	1	0	**1**
Greenside darter	0	1	**1**
TOTAL	***24,002***	***37,427***	***61,429***

Table 8. Species and number of fish collected during cooling water intake sampling at Conowingo Dam in fall, 2005.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	22	3	**25**
Gizzard shad	11,273	23,635	**34,908**
Carp	1	0	**1**
Comely shiner	6	5	**11**
Spotfin shiner	1	0	**1**
Channel catfish	30	4	**34**
White Perch	1	0	**1**
Striped bass	1	0	**1**
Bluegill	6	6	**12**
Smallmouth bass	1	0	**1**
Yellow Perch	0	2	**2**
Walleye	4	0	**4**
TOTAL	***11,346***	***23,655***	***35,001***

Table 9. Number of juvenile American shad collected during cooling water intake strainer sampling at Conowingo Dam in fall, 2005.

Date	Francis Units (7)	Kaplan Units (4)	Total
21 Oct	5	0	**5**
24 Oct	5	0	**5**
28 Oct	7	0	**7**
31 Oct	5	2	**7**
07 Nov	0	1	**1**
TOTAL	***22***	***3***	***25***

Table 10. Catch of juvenile American shad by location from the upper Chesapeake Bay during the 2005 Maryland DNR Juvenile Finfish Haul Seine Survey.

Permanent Sites

Location	Round 1	Round 2	Round 3	Totals
Howell Point	2	17	19	38
Tims Creek	0	0	0	0
Ordinary Point	0	0	1	1
Parlor Point	0	0	0	0
Elk Neck State Park	22	10	0	32
Welch Point	5	5	2	12
Hyland Point	20	12	0	32
Total	49	44	22	115
Mean Catch Per Haul	3.50	3.14	1.57	

Auxiliary Sites

Location	Round 1	Round 2	Round 3	Totals
Carpenter Point	7	23	1	31
Popular Point	N/A	N/A	N/A	N/A
Plum Point	34	30	7	71
Spoil Island	1	5	0	6
Tydings Estate	11	10	0	21
Tolchester	0	0	0	0
Total	53	68	8	129
Mean	5.3	6.8	0.8	

Table 11. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2005.

Collection Site	Coll. Date	Immersion marks: Day 3,6,12 Jun. R./ Susq. R.	Days 3,6,9 Jun. R./ Susq. R.*	Days 3,6,9, 12,15 W. Br. Sus. R.	Days 3,6,9,12 Susq. R. Liverpool	Single Feed Mark Hunt ingdon	Total Hatchery	Total Wild	Total Processed	Total Collected
Columbia	7/20/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	8/2/05	0.0	2.0	0.0	0.0	0.0	2.0	3.0	5	5
	8/9/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	8/16/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	8/24/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	8/31/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	9/7/05	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3	3
	9/20/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	9/28/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	10/12/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	10/20/05	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3	3
Holtwood	10/25/05	0.0	1.0	0.0	0.0	0.0	1.0	1.0	2	2
	10/28/05	32.9	9.9	36.2	0.0	0.0	79.0 **	102.0	55	181
	10/31/05	1.0	1.0	0.0	0.0	0.0	2.0	15.0	17	17
Peach Bottom Impingement	10/12/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	10/13/05	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4	4
	10/14/05	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
	10/19/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	10/20/05	0.0	1.0	0.0	0.0	0.0	1.0	3.0	4	4
	10/21/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	10/25/05	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
	10/26/05	1.1	6.4	0.0	0.0	0.0	7.4 **	9.6	16	17
	10/27/05	7.0	5.0	4.0	0.0	0.0	16.0	9.0	25	25
	10/28/05	0.0	0.0	1.0	0.0	0.0	1.0	2.0	3	3
	10/31/05	1.0	6.0	7.0	1.0	1.0	16.0	3.0	19	19
	11/1/05	3.1	9.4	5.2	0.0	3.1	20.8 **	4.2	24	25
	11/2/05	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	11/3/05	0.0	0.0	0.0	0.0	0.0	0.0	7.0	7	7
	11/4/05	0.0	0.0	0.0	0.0	0.0	0.0	7.0	6	7
	11/9/05	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
Conowingo Strainers	10/21/05	0.0	0.0	0.0	0.0	0.0	0.0	5.0	2	5
	10/24/05	0.0	0.0	0.0	0.0	0.0	0.0	5.0	3	5
	10/28/05	0.0	0.0	0.0	0.0	0.0	0.0	7.0	6	7
	10/31/05	1.4	1.4	1.4	0.0	0.0	4.2	2.8	5	7
	11/7/05	None processed							0	1
Holt./P. Bot./Con.		47.5	43.0	54.8	1.0	4.1	150.5 **	193.5 **	207.0	345.0
Percent		13.8%	12.5%	15.9%	0.3%	1.2%	43.6%	56.1%		
Grand Total		47.5	45.0	54.8	1.0	4.1	152.5 **	214.5 **	230.0	368.0
Percent		12.9%	12.3%	14.9%	0.3%	1.1%	41.5%	58.5%		

*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.

Job V Task 1

Progress Report on Two-Year Genetics Assessment of Susquehanna River American Shad

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Introduction

American shad (*Alosa sapidissima*) are an anadromous fish native to rivers along the Atlantic coast of North America. Within the Susquehanna River, shad populations have declined due to a variety of causes, including loss of access to the river due to dams, exploitation, and altered habitat in the river, Chesapeake Bay, and ocean. Restoration efforts for shad in the Susquehanna River have included creating and improving fish passage, introductions of adult spawners from other populations in both the native and introduced range, and stocking of cultured larvae into tributaries and the mainstem of the lower river.

Hatchery propagation and stocking of American shad also represent a large component of the restoration efforts. Larval shad are stocked from hatchery propagation of adults returning to three rivers: the Susquehanna, Delaware, and Hudson. Management operates under the assumption that cultured shad from the Susquehanna are genetically better fit than out-of-basin stock transfers, and therefore make a greater contribution to the restoration program. If true, then the contribution of Susquehanna River origin shad should be measurable in terms of (a) relative return rates as spawning adults; (b) greater contribution of Susquehanna origin individuals on spawning grounds (i.e. at Lapidum); and (c) overall reproductive success.

Purpose of study

Evaluation of the wild origin shad returns to the Susquehanna River may provide information regarding the origin of the parental stocks that are successfully reproducing in the river, and be used to guide further restoration efforts. Analyses include comparison of estimates of genetic diversity relative to neighboring drainages (Hudson and Delaware rivers), and comparisons of genetic diversity between hatchery and wild origin shad. If genetic differences exist between groups of adult shad returning to different river reaches, the information could be useful to guide egg take and stocking strategies, and therefore aid in restoration efforts. Comparisons of estimates of genetic diversity between shad of hatchery and wild origin may identify which introduced stocks were successful in establishing reproducing populations. Additionally, characterization of shad utilizing different river sections may aid in understanding life history characteristics and behavior.

Materials and methods

Tissues for population genetic analysis were obtained from adult American shad during the spring of 2005. Tissues were obtained from the Susquehanna River (Pennsylvania Fish and Boat Commission and U.S. Fish and Wildlife Service) Delaware River (PFBC), and Hudson River (the Wyatt Group).

Another component of this study was to develop a suite of microsatellite markers. Development of highly variable microsatellite markers will facilitate the ability to identify genetic differences within and between American shad populations. Markers developed will be used to determine if genetic differences exist between shad sampled from the three rivers identified in this study, and if differences exist, evaluate the origin of the wild returning adult spawners to the Susquehanna River. Markers also will be screened for cross-species amplification to determine application for other studies.

Results and Discussion

Otoliths from Susquehanna River shad were analyzed for presence of tetracycline mark to determine origin (hatchery or wild) by PFBC. Of the samples collected from the Susquehanna River, 96 of the 277 individuals sampled at the Conowingo Dam West lift, and 64 of the 162 individuals sampled at Lapidum were identified as wild origin (M. Hendricks, PFBC). Samples were also obtained from adult American shad from the Hudson River (n=91) and Delaware River (n=155).

DNA was extracted from American shad tissue and microsatellite libraries were developed at Genetic Information Systems (Chatsworth, California). Bacterial colonies developed by GIS have been screened at the FWS Region 5 Conservation Genetics Lab, and approximately 1200 sequences with potential microsatellite loci have been obtained. Resulting microsatellite primer sequences will be screened to develop approximately 20 highly variable loci for use in this study. Marker development work to be completed includes primer design, screening for allelic variability and cross-species amplification, and optimization for multi-locus polymerase chain reactions. Following completion of the microsatellite marker development, wild origin samples from the Susquehanna River (n=160), along with the Hudson River and Delaware River samples (n=246) will be genotyped and resulting data will be analyzed.

Job V - Task 2
Analysis of adult American shad otoliths, 2005

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Abstract

A total of 277 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2005. Based on tetracycline marking, 35% of the 274 readable otoliths were identified as wild and 65% 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 1986-1997 year classes, stocking of approximately 181 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 138 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.80 adults to upstream areas was required to return one wild fish to the lifts. Actual survival is even higher since not all surviving adults enter the lifts.

Introduction

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

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

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

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

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad which entered the West lift. In addition, some 162 adult shad were collected by gill net during egg-take operations at Lapidum, near the head of tide, three to four miles downstream from Conowingo Dam. Adult American shad collected in the upper Chesapeake Bay by Maryland DNR were 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 specimens were 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. Aging was done by a single researcher. After initial aging, 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 2005. Age composition data was gathered as follows: for 1996 to 2005, 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. 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 277 shad was sacrificed for otolith analysis from Conowingo Dam in 2005. 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 96 (35%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 178 (65%) fish exhibited tetracycline marks including single, double, 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 1989-2005 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in the West 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).

A total of 162 shad was sacrificed for otolith analysis from gill net collections at Lapidum in 2005 (Table 1). There were four unreadable otoliths. A total of 64 (41%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 94 (59%) fish exhibited tetracycline marks including single, double, triple, quadruple and quintuple marks. Shad were collected at this site as part of a cooperative genetics study with the U. S. Fish and Wildlife Service, Northeast Fishery Center in Lamar, PA. Since this site is a known spawning site for the indigenous upper Bay spawning stock, it was presumed that wild fish would be more prevalent here than at the fish lifts at Conowingo Dam. The data supports that presumption with 41% wild at Lapidum and 35% wild at Conowingo Dam, however, the difference was not statistically significant (Chi-square = 1.29 , a = .05).

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 slight decrease in 2004 and 2005. Age distributions were similar for wild and hatchery fish. Sex ratios (Table 8) have ranged from 7:10 to 19:10 (males: females) with no trend over time. Tables 9 and 10 provide age and repeat spawning data for otolith and scale ages. Repeat spawning has been highly variable, ranging from 1% in 2001 to 49% 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. 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 1998 are not fully recruited and are not included in the analysis. For the period 1986-1998, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 60 to 620, with an overall value of 181 (Table 12). L/A was highest (431-620) for the early cohorts (1986 – 1989). During 1990 to 1998, L/A improved to 60-289, 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 13). For the period 1986-1998, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 40 to 386, with an overall value of 138. 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 225 recruited adults for the 1995 cohort and 43 for the 1996 cohort, when no fingerlings were stocked, is an artifact of erroneous ageing, and highlights the problems with ageing American shad.

A similar analysis was tabulated for wild fish (Table 14). For the period 1986 to 1998, transport of an average of 0.80 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 are improving in recent years and must continue to do so to allow for successful restoration.

Virtual survival rates by cohort and stocking site are reported in Table 15. As expected, some cohorts survived better than others, probably due to environmental conditions. The 1996 cohort exhibited the highest virtual survival rate (146) followed by 1997 (134). The 1999-2000 cohorts are not yet fully recruited.

Adult relative survival for individual stocking sites was highly variable between cohorts (Table 15). For example, relative survival for the Juniata River/Juniata or middle Susquehanna sites ranged from 0.31 to 1.00. For the North Branch Susquehanna River the range was from 0.25 to 0.46. For West Conewago Creek, relative survival ranged from 0.00 to 1.00. For Swatara Creek, relative survival ranged from 0.00 to 0.39. 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 0.90 respectively). Both adult and juvenile relative survival rates were consistently poor for the West Branch Susquehanna River.

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=0.153). 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 40 to 50% (David Hopler, Virginia Commonwealth University, unpublished data). Aging errors, coupled with small sample size in some of the recapture groups (Table 15) 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).

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

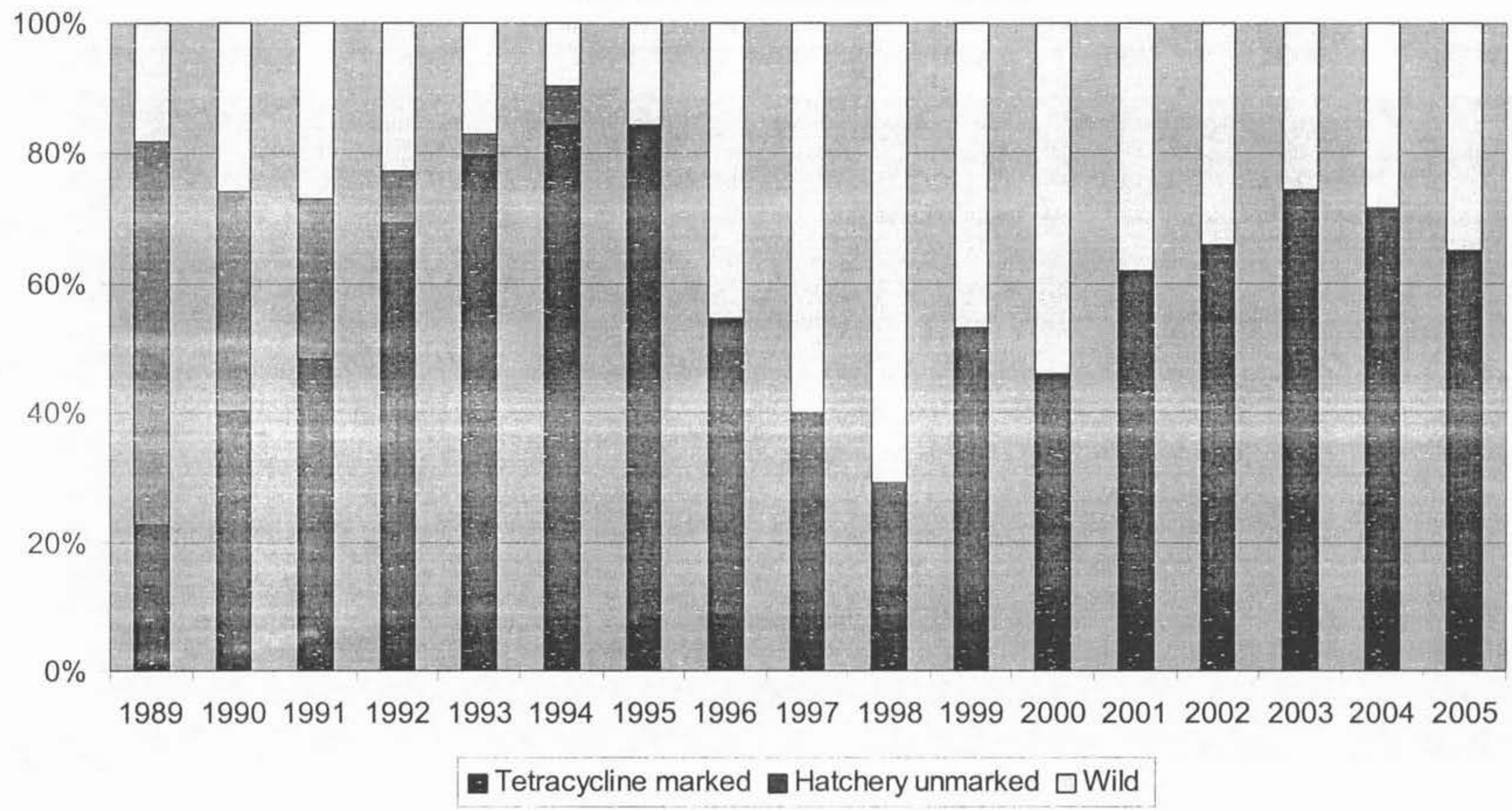

Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

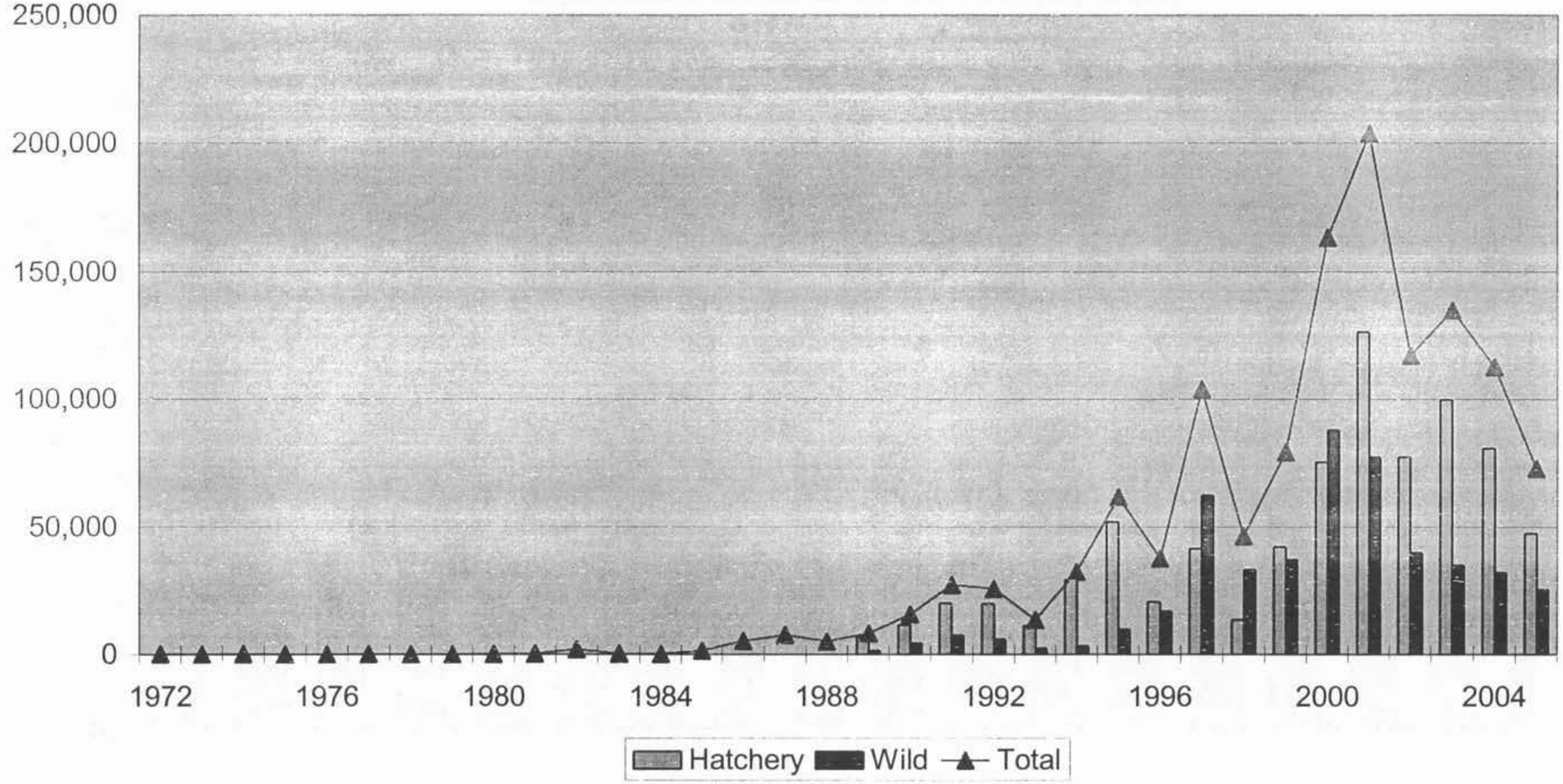

Figure 3. Stocking site/cohort specific relative survival of juvenile shad vs. adult shad, Susquehanna River, 1995-2001.

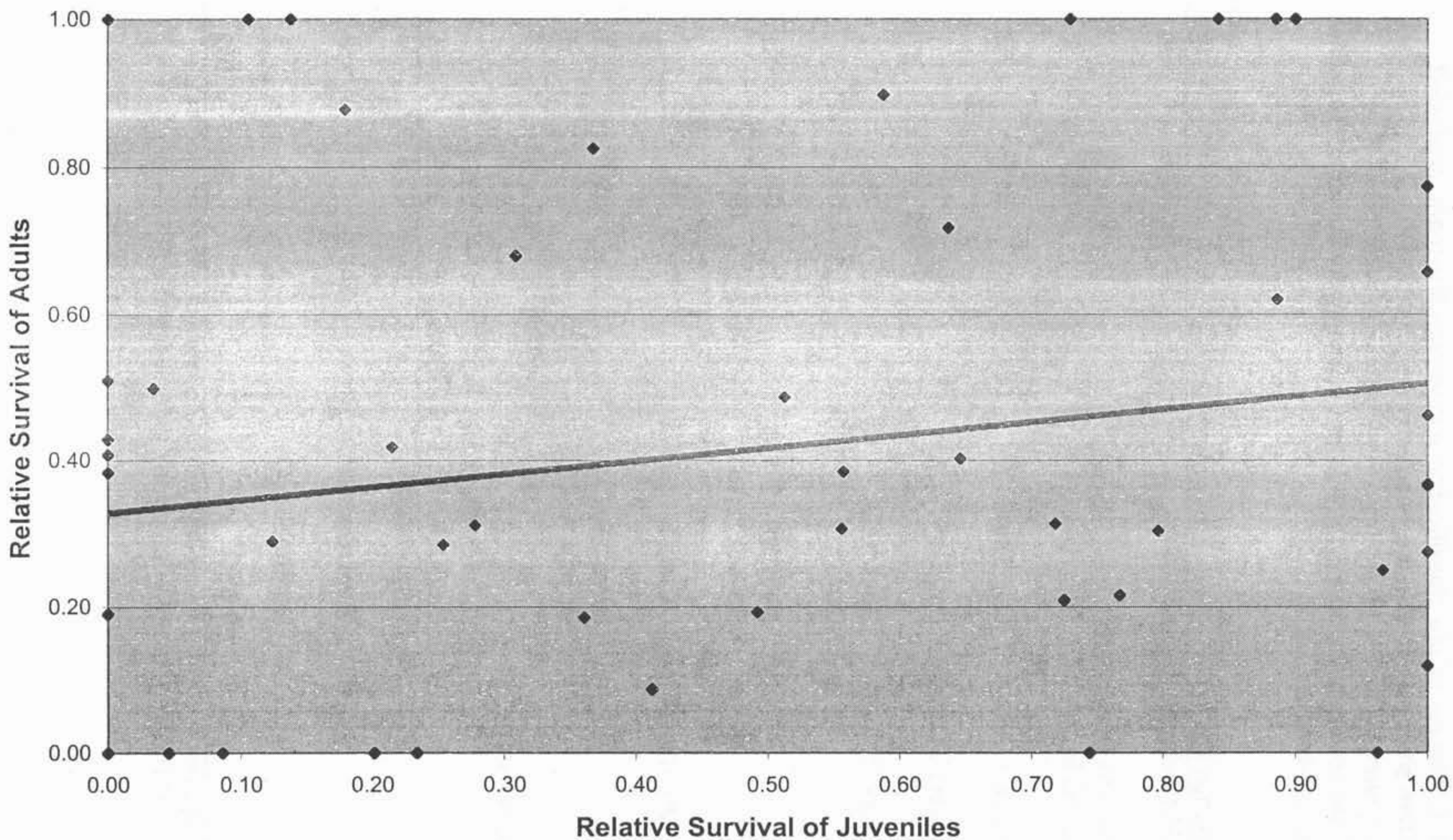

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2005.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis. Specimerns from Lapidum were collected by gill net during egg-take operations.

		Conowingo Dam		Lapidum	
Conowingo Dam		N	%	N	%
Wild Microstructure, No TC Mark		96	35%	64	41%
Hatchery Microstructure					
No TC Mark*			0%		0%
Single TC Mark	Day 3 or 5	141	51%	83	53%
Double TC Mark	Days 3,6 or 3,7	2	1%	1	1%
Triple TC Mark	Days 3,6,9	20	7%	2	1%
	Days 5,9,13		0%		0%
	Days 3,13,17		0%		0%
	Days 3,9,12		0%	1	1%
	Days 9,12,15		0%		0%
Quadruple TC Mar	Days 5,8,13,17	1	0%		0%
	Days 3,6,9,12	2	1%	1	1%
	Days 3,6,9,15		0%	1	1%
	Days 3,9,12,15	4	1%	1	1%
Quintuple TC Mark	Days 3,6,9,15,18	1	0%		0%
	Days 3,6,9,12,18	1	0%		0%
	Days 3,6,12,15,18	6	2%	4	3%
	Total Hatchery	178	65%	94	59%
	Total readable otoliths	274		158	
	Unreadable Otoliths**	3		4	
	Total	277		162	

*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.

	Sample:	Hatchery										
		Larvae									
	One in	Susquehanna		below Conowingo Dam		Fingerling		Unmarked**	Naturally reproduced		Total sample
Year	??	N	%*	N	%*	N	%*	N	N	%	size
1989	50	36	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
Totals		1,856	61	151	5	25	1	241	1,126	33	3,399

*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, 1993-2005.

Males

TL - mm	1993	1994	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005
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
400	18		31	45	48	6	13	7	4	11	8	2	18
425	27		80	56	47	13	40	32	5	5	12	14	26
450	6		107	44	34	26	22	55	20	9	27	15	33
475			71	32	24	19	15	27	34	14	24	19	31
500			18	13	6	2	4	12	20	24	12	12	11
525			4	9	1	1	1	3	1	8		3	4
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

Females

TL - mm	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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
450	7		6	11	4	4	12	3	3	1	5	4	6
475	14		64	28	28	11	20	14	16	4	11	10	19
500	4		91	36	20	27	26	12	36	14	14	24	44
525	1		47	49	12	24	14	21	39	32	19	26	34
550			14	17	10	6	8	5	18	42	21	12	29
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

Table 3. (continued).

Sexes Combined

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

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

Table 4. Age-frequency of American shad collected in the Susquehanna River at the Conowingo West Fish Lift, 1995-2005.

Wild Males

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
2		3									
3	2	54	33	1	11	12	2	6	2	8	4
4	25	41	58	27	22	48	12	3	8	5	30
5	8	15	5	17	8	8	11	7	7	6	10
6	2		3			2	2	3	5	2	4
7									1	3	
8										1	
9											
??	2	8									1
Total		121	99	45	41	70	27	19	23	25	49
Mean Age		3.4	3.8	6.2	4.1	4.0	4.5	4.4	4.8	4.6	4.2

Hatchery Males

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

Wild Females

Otolith Age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
2											
3		3	2			1					1
4	4	20	23	8	14	11	11	5	4	1	9
5	7	14	16	28	22	13	27	14	7	9	11
6	2	6	9	9	8	6	10	18	11	3	18
7				1	1			4	4	5	3
8								1		1	3
9											1
??		6			2			1			1
Total		49	50	46	47	31	48	43	26	19	47
Mean Age		4.2	4.6	5.1	4.7	4.8	5.0	5.4	5.6	5.8	5.3

Hatchery Females

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

Table 5. Mean total length and weight of adult American shad collected at the Conowingo Dam West Fish Lift, 1993-2005.

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

Table 6. Mean total length (mm) at age for American shad collected at the Conowingo Dam West Fish Lift, 1995-2005.

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

Scale age	1995*	1996*	1997*	1998*	1999*	2000*	2001	2002	2003	2004	2005
Male											
2											
3						453	447	418	440	366	424
4						463	481	470	467	397	443
5	scales not read					488	488	502	495	434	472
6						516	500	522	518	448	495
7								509		477	493
8										410	
9											
Female											
2											
3						461	510		470		405
4						512	511	528	508	450	490
5						518	527	545	545	461	522
6	scales not read					550	548	554	577	490	531
7						587	551	580	600	494	550
8								568	570	498	571
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, 1995-2005.

Otolith age	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Male											
2		546									
3	610	662	667	614	642	838	949	669	740	590	608
4	840	869	834	750	717	828	831	986	918.9	834	797
5	936	967	1022	861	855	983	956	1126	1090	1025	982
6	1022	1220	1018		885	1195	1009	1413	1336	1094	1160
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
5	1343	1440	1524	1311	1234	1425	1340	1619	1726	1345	1437
6	1418	1513	1647	1474	1382	1495	1496	1657	1817	1572	1555
7	1826	1321	1695	1210	1500	1885	1460	1841	1989	1739	1740
8								1675	2080	1715	1613
9											2470
10											
11											1900

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

Table 8. Sex ratio of American shad collected at the Conowingo Dam West Fish Lift, 1993-2005.

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

Table 9. Otolith age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2005.

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%

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%

Sexes Combined	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%

Table 10. Scale age and repeat spawning for American shad collected in the Conowingo Dam West Fish Lift, 2000-2005.

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%

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%

Table 10. (continued).

Sexes Combined	**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%

Table 11. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-2005.

												Hatchery Release Site			Wild
												Above Dams		Below Dams	
	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	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	0.0	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719	0.0	0.0	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	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	0.0	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	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	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	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	0.0	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	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	0.0	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370	0.0	0.0	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	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	0.0	0.0	2.0	21.4	50.5	24.0	2.0	0.0	56%	0%	4%	38%
2002	117,348	0.0	0.0	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	0.0	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	0.0	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%

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

Table 12. Recruitment of hatchery larvae, stocked above dams, to the Conowingo Fish Lifts, 1986- 1998.

	Cohort												
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1988	13												
1989	373	16											
1990	1,706	166	0										
1991	6,956	2,250	307	0									
1992	6,652	6,870	2,181	545	0								
1993	277	1,867	4,563	1,867	69	0							
1994	0	859	5,918	14,318	5,059	0	0						
1995		0	1,517	5,907	24,746	13,570	1,916	0					
1996			0	152	2,881	7,430	6,015	1,365	51				
1997				0	0	3,676	6,363	15,695	9,191	141			
1998					0	80	1,125	4,983	3,858	322	0		
1999						205	411	3,081	12,734	17,663	3,902	0	
2000							0	688	6,532	18,221	33,692	6,876	
2001								0	2,339	24,562	57,897	27,486	2,339
2002								413	1,240	4,548	21,088	30,599	11,578
2003									0	1,029	7,204	31,389	25,728
2004										0	1,503	12,024	12,525
2005									171	0	171	857	3,084
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,963	15,830	26,225	36,117	66,487	125,458	109,230	55,255
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
No. of larvae to return 1 adult:	620	431	445	591	172	289	192	249	178	150	60	73	212

Overall number of larvae to return 1 adult (1986-1998): 181

Table 13. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 1998.

	Cohort												
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1988	3 *												
1989	0	0											
1990	0	0	0										
1991	188	61	8	0									
1992	86	89	28	7	0								
1993	7	49	120	49	2	0							
1994	0	12	82	198	70	0	0						
1995		0	24	93	388	213	30	0					
1996			0	3	64	165	134	30	1				
1997				0	0	174	302	744	436	7			
1998					0	6	78	344	266	22	0		
1999						2	5	34	141	196	43	0	
2000							0	0	0	0	0	0	0
2001								0	0	0	0	0	0
2002								0	0	0	0	0	0
2003									0	0	0	0	0
2004										0	0	0	0
2005									0	0	0	0	0
Total recruits to lifts:	285	211	262	350	524	560	548	1,153	845	225	43	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
No. of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	165	0	0		
Overall no. of fingerlings to return 1 adult (1986-1998):				138									

Table 14. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986-1998.

	Cohort												
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1988	55 *												
1989	83	4											
1990	607	59	0										
1991	2,811	910	124	0									
1992	2,091	2,159	685	171	0								
1993	73	496	1,211	496	18	0							
1994	0	104	714	1,727	610	0	0						
1995		0	308	1,201	5,029	2,758	389	0					
1996			0	144	2,741	7,069	5,723	1,298	48				
1997				0	0	6,538	11,317	27,914	16,346	251			
1998					0	255	3,570	15,810	12,240	1,020	0		
1999						201	402	3,012	12,451	17,271	3,816	0	
2000							0	917	8,710	24,295	44,923	9,168	0
2001								0	1,580	16,585	39,093	18,559	1,580
2002								217	652	2,390	11,080	16,077	6,083
2003									0	362	2,534	11,040	9,049
2004										0	599	4,788	4,988
2005									93	0	93	467	1,682
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,822	21,400	49,169	52,119	62,174	102,137	60,100	23,382
Adults passed or 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
of adults transported to return 1 adult:	0.73	1.93	1.56	1.73	1.79	1.47	0.73	0.24	0.55	0.91	0.33	1.73	1.90

Overall no. of adults transported to return 1 adult (1986-1998): 0.80

Table 15. Virtual survival rates of marked American shad, by stocking site, recaptured as adults at the Conowingo Dam West Fish Lift.
Virtual Survival rate = Recruitment to the Conowingo Fish Lifts X 10,000, divided by the number stocked.

Cohort	Number Stocked (M)	Stocking location	Egg source	Number Recaptured (R)	Recruitment to Conowingo Fish Lifts	Virtual Survival Rate	Cohort Virtual Survival Rate	Adult Relative Virtual Survival Rate	Juvenile Relative Survival Rate
1995	9,070,999	Juniata or middle Susq.	Hud./Del.	93	66,229	73		0.40	0.65
1995	220,000	Conodoguinet Cr.	Hudson	1	860	39		0.22	0.77
1995	230,000	Conodoguinet (mouth)	Hudson	7	4,175	182		1.00	0.90
1995	198,000	Conestoga R.	Hudson	1	429	22		0.12	1.00
1995	190,000	Conestoga (mouth)	Hudson	1	638	34		0.18	0.36
1995	93,000	Muddy Cr.	Hudson	1	860	92		0.51	0.00
1995	520,000	below Conowingo (mid-channel)	Hud./Del.	6	3,847	74		0.41	0.00
1995	411,000	below Conowingo (nearshore)	Hud./Del.	6	2,862	70	73	0.38	0.00
1996	5,730,000	Juniata or middle Susq.	Delaware	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	5	3,399	70		0.21	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.	68	41,145	46		0.31	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.	176	94,144	92		1.00	0.73
1999	373,000	Conodoguinet Cr.	Hudson	5	3,085	83		0.90	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		0.66	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	77	0.42	0.21
2000	7,369,000	Juniata & Susq. R.	Hudson	48	17,631	24		0.37	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	4	1,959	20	22	0.31	0.56
2001	1,940,860	Juniata & Susq. R.	Hudson	18	5,680	29		0.77	1.00
2001	1,859,345	Juniata & Susq. R.	Susq.	19	5,050	27		0.72	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.	0	0	0		0.00	0.05
2001	140,821	Conodoguinet Cr.	Susq.	1	266	19		0.50	0.03
2001	169,545	W. Conewago Cr.	Susq.	0	0	0		0.00	0.09
2001	210,831	Conestoga R.	Susq.	3	797	38		1.00	0.11
2001	182,490	Swatara Cr.	Susq.	1	266	15		0.39	0.56
2001	676,982	N. Br. Susq. R.	Hudson	3	1,245	18	24	0.49	0.51

Job V – Task 3
American Eel Sampling at Conowingo Dam, 2005

U. S. Fish and Wildlife Service
Maryland Fishery Resources Office
Annapolis, Maryland

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. On November 12, 2004, the U. S. Secretaries of the Interior and Commerce were petitioned to declare the American eel endangered under the United States Endangered Species Act. The USFWS completed a 90-day finding affirming that the petitioner's claims warranted further investigation, and initiated a 12-month status review.

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.

Ongoing research by Chesapeake Bay area scientists suggests that eels appear to be overfished relative to biological reference points. Maximum spawning potential of the Chesapeake Bay portion of the eel population is well below that needed for stock replacement. Additionally, fishing mortality has been estimated at two to four times natural mortality. Eel densities in surveyed tributaries have decreased over time since the 1980s, and the observed size-at-age structure of eels in the Bay has also declined over time. Management aimed at reducing fishing mortality, opening upstream blockages and maximizing spawning escapement of silver eels are possible methods to help stem this decline.

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 watershed and provides one-half the freshwater to the Bay. 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 are taken by anglers above the dam. These are believed to be remnants of Pennsylvania Fish & Boat Commission stockings in the early 1980s. The Maryland Biological Stream Survey collects eel data in freshwater drainages of Maryland including 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. Areas surveyed directly below the dam contain the highest densities of eels in Maryland. Since eels cannot migrate past the dam they take up residence in potentially less suitable habitat downstream. This also exposes them to commercial harvest in Maryland's eel pot fishery.

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.

Survey Methods and Equipment Placement

To determine the best methods to reintroduce eels into the Susquehanna, a pilot survey was conducted to collect baseline information on eel abundance, migration timing, catchability, and attraction parameters at the base of the Conowingo Dam. Information from this type of study will help determine the potential for upstream eel passage. Stream flow, temperature and other water quality parameters were monitored at collection sites.

Sampling for eels took place from May 18 through August 2, 2005. Boat sampling on the spillway side of the tailrace wingwall was attempted but proved to be difficult. Fluctuating water levels made it difficult to deploy a boat at Shures Landing on a consistent basis; therefore a shore based sampling effort was pursued. After conferring with Susquehanna Electric Company (SECO) management, sampling was limited to the west side of the dam. Sampling by the East fish lift was considered but safety concerns and lack of access to electricity to operate the elver ramp pumps precluded this location.

A modified Irish elver ramp was used to sample for elvers (Figure 2) and eel pots were set to catch larger eels. A data logger was deployed to collect water temperatures four times per day during the sample period (Figure 3). River flows were collected from a USGS gauging station (USGS 01578310) and lunar fraction (percent moon illumination) was collected from the U. S. Naval Observatory (http://aa.usno.navy.mil/). The elver ramp was initially operated using water released from shad culture operations that was gravity fed into the ramp. Large fluctuations in water levels caused by generation made if difficult to keep the ramp operating and the ramp also became entangled in its tether ropes during low water. The ramp was moved to the West fish lift platform and operated using a submersible pump, beginning on June 8. This proved to be a more reliable method to keep the ramp operating in the variable flow conditions. Further refinement in attaching the ramp will need to be developed to improve reliability.

Several mesh sizes of eel pots were initially deployed. This included pots lined with window screen (1 mm square mesh), 6 mm square mesh, and 12 mm square mesh. The 6 mm square mesh pots were chosen for sampling since they caught more eels.

Results

Two hundred fifty-one (251) eels were captured throughout the period sampled (Table 1). Lengths ranged from 93 mm TL to 733 mm TL (Figures 4 and 5) with 41 fish measuring less than 200 mm. Eels captured were sedated, measured (Figure 6), fin clipped and released. Subsamples were frozen for otolith aging. The largest capture of elvers occurred during a period of low lunar fraction on July 6 (Figure 7). Captures of larger eels in pots however, did not reflect a strong correlation to lunar fraction (Figure 8).

The West fish lift has been operated each spring since 1972 and eel captures there have declined significantly since 1976. 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. In 2005, the West lift trapped only 25 eels in 295 lifts over 30 operating days.

The percentage of fin-clipped eels did not increase during the sample period. This suggests that eels move in and out of the area directly below the dam. We believe that abundance estimates could be made by individually marking eels. We will request permission from SECO to continue to sample American eels at Conowingo during 2006. Efforts will be made to improve reliable continuous operation of the elver ramp and to continue to collect biological and environmental data on the timing and abundance of eels below Conowingo Dam.

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.

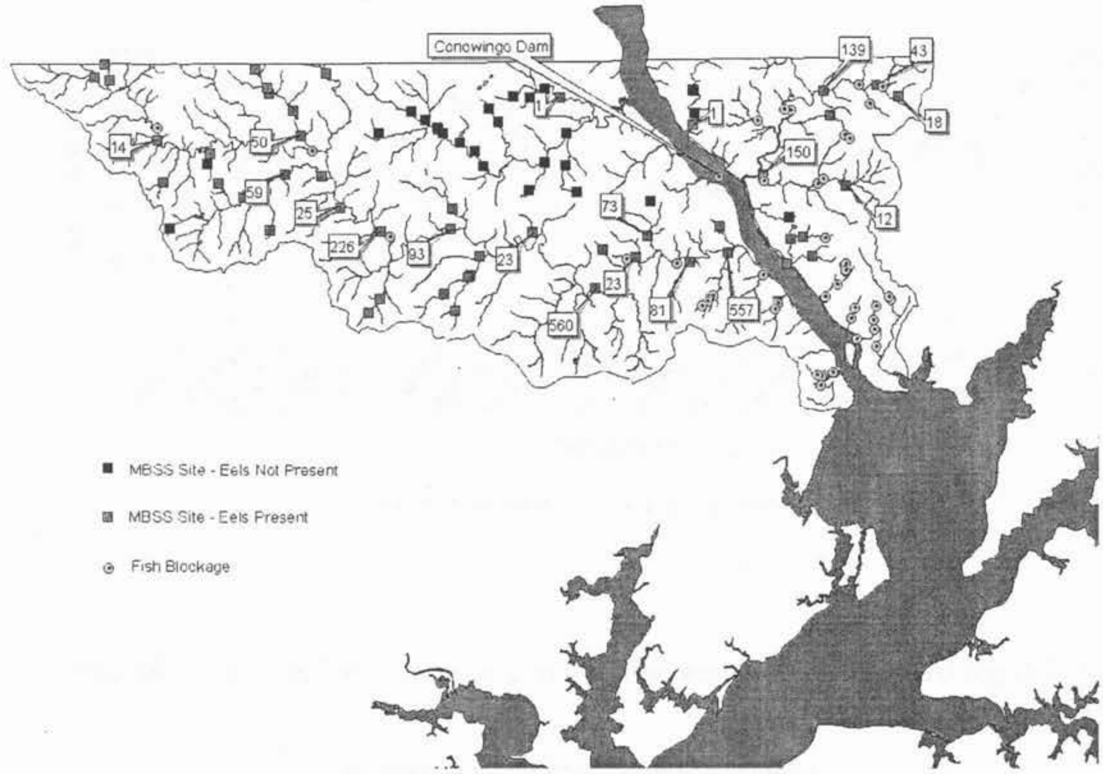

Figure 2. Photo of an Irish Elver Ramp used to sample American eel elvers at the base of Conowingo Dam during 2005.

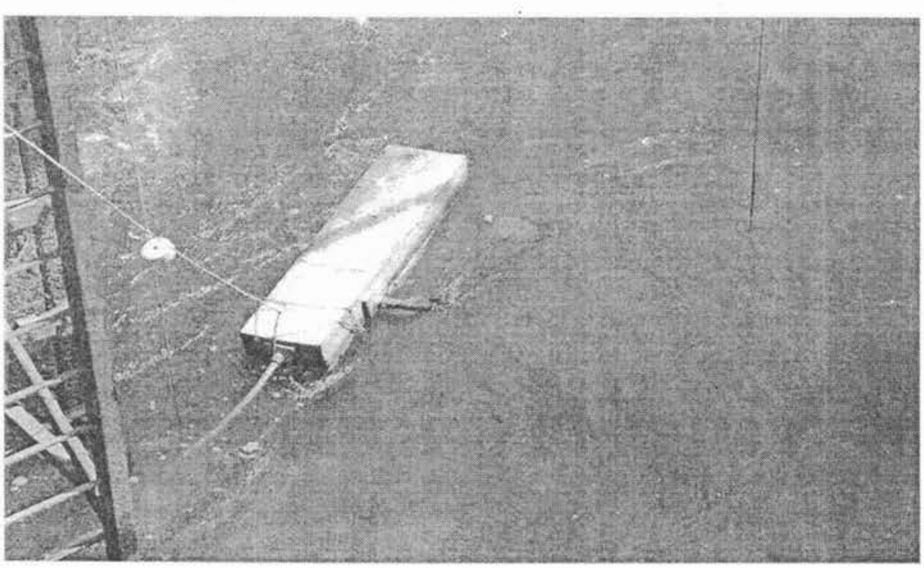

Figure 3. River flow and temperature below Conowingo Dam, 2005.

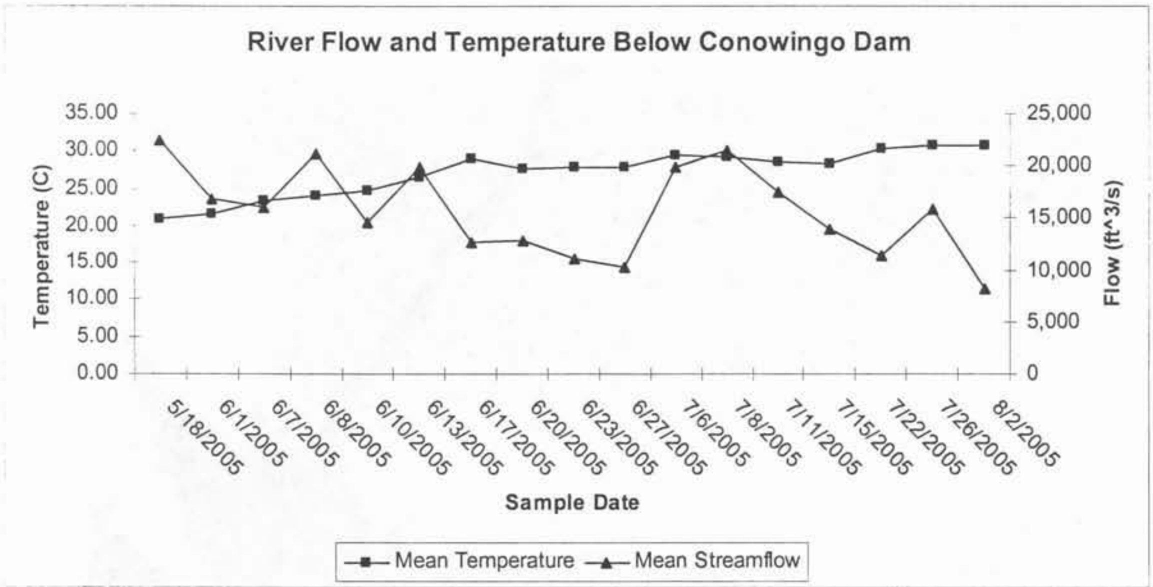

Figure 4. Length frequencies of elvers captured in the Irish Elver Ramp at the base of Conowingo Dam during 2005.

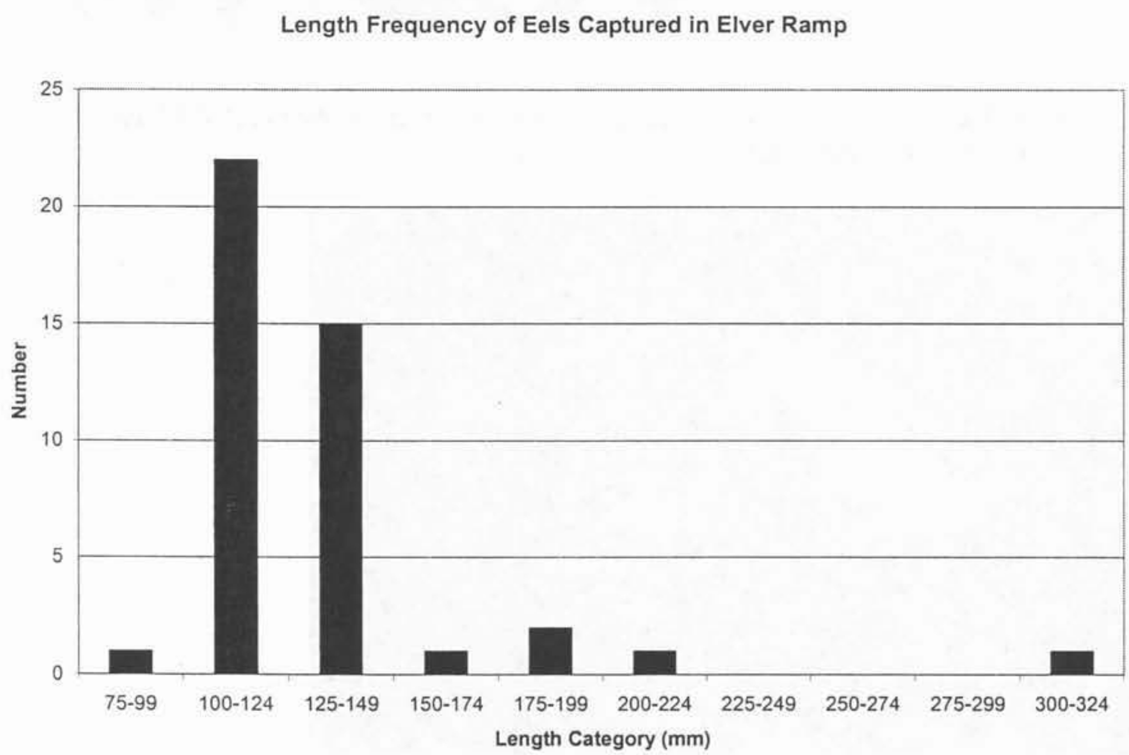

Figure 5. Length frequencies of eels captured in eel pots at the base of Conowingo Dam during 2005.

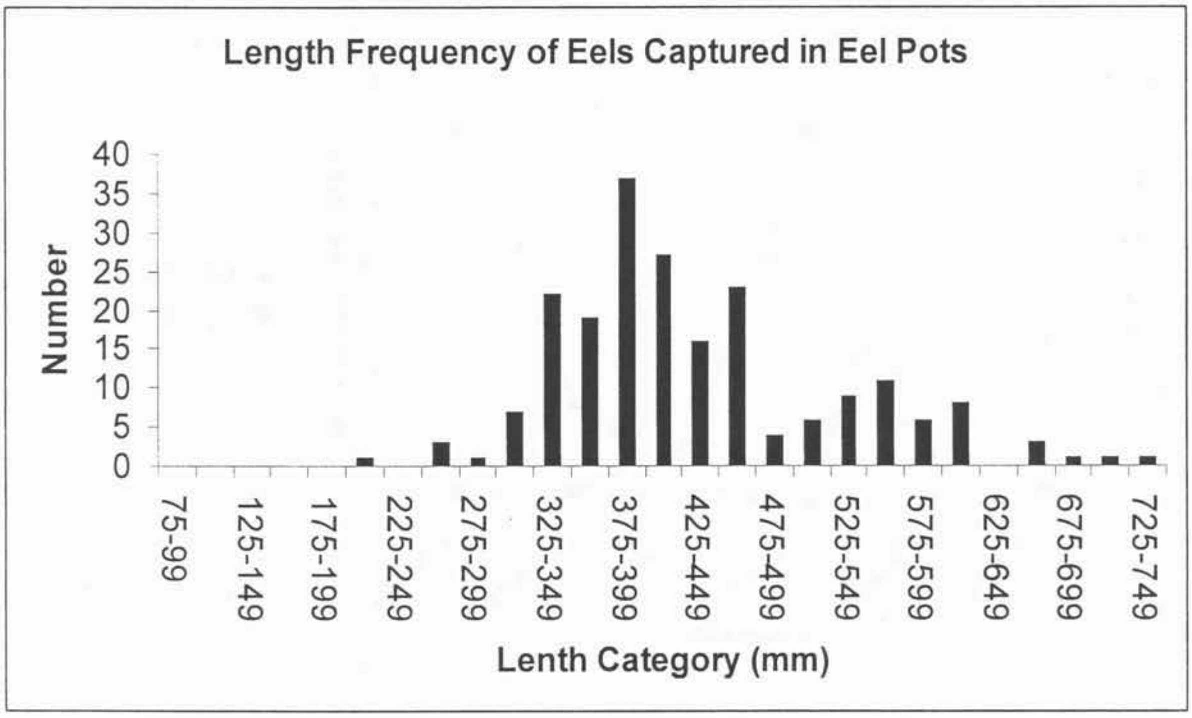

Figure 6. Elver that was captured in modified Irish elver ramp.

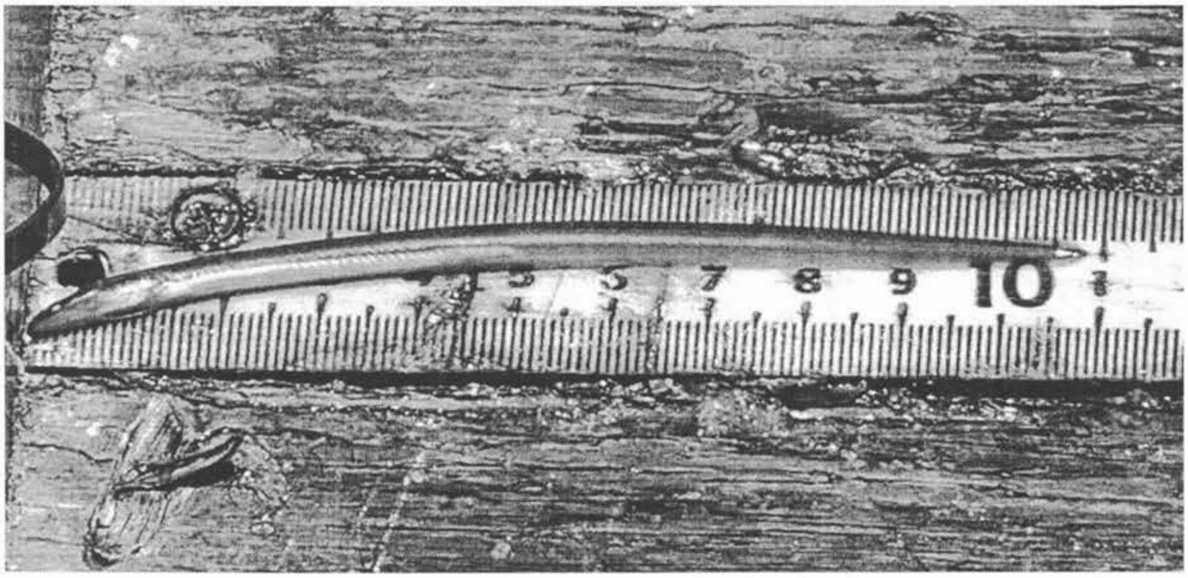

Figure 7. Number of elvers captured against lunar fraction by sample date. Zero lunar fraction is a new moon and 1.0 lunar fraction is a full moon.

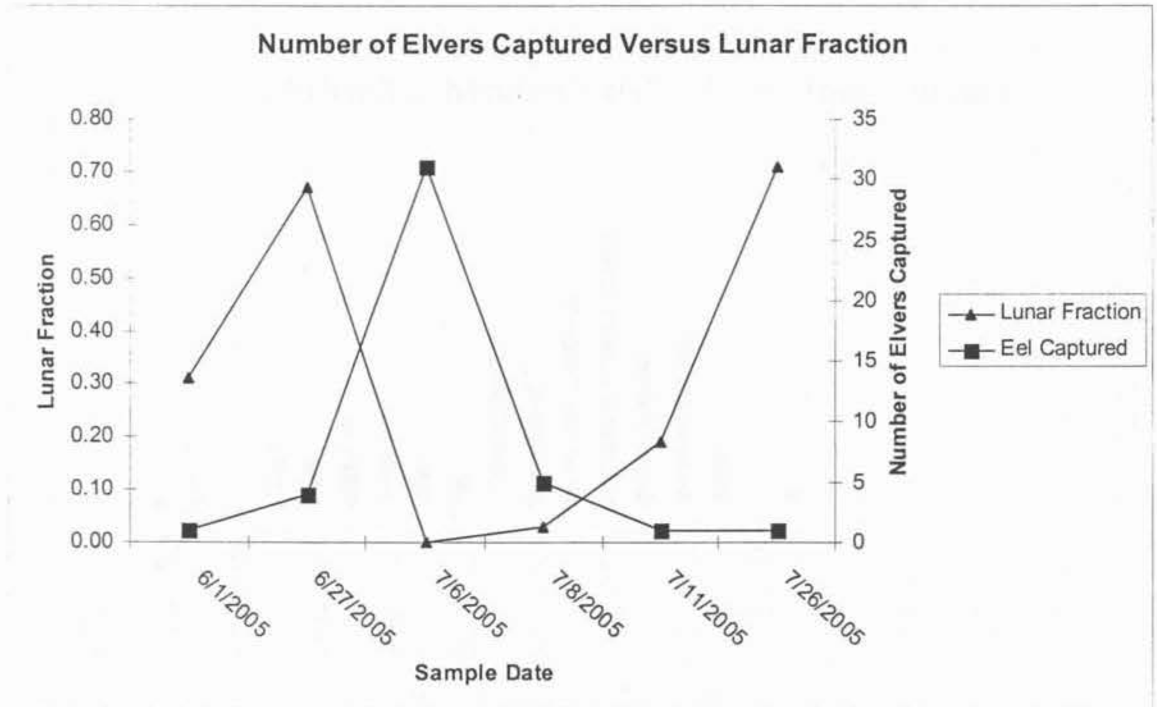

Figure 8. Number of eels captured against lunar fraction by sample date. Zero lunar fraction is a new moon and 1.0 lunar fraction is a full moon.

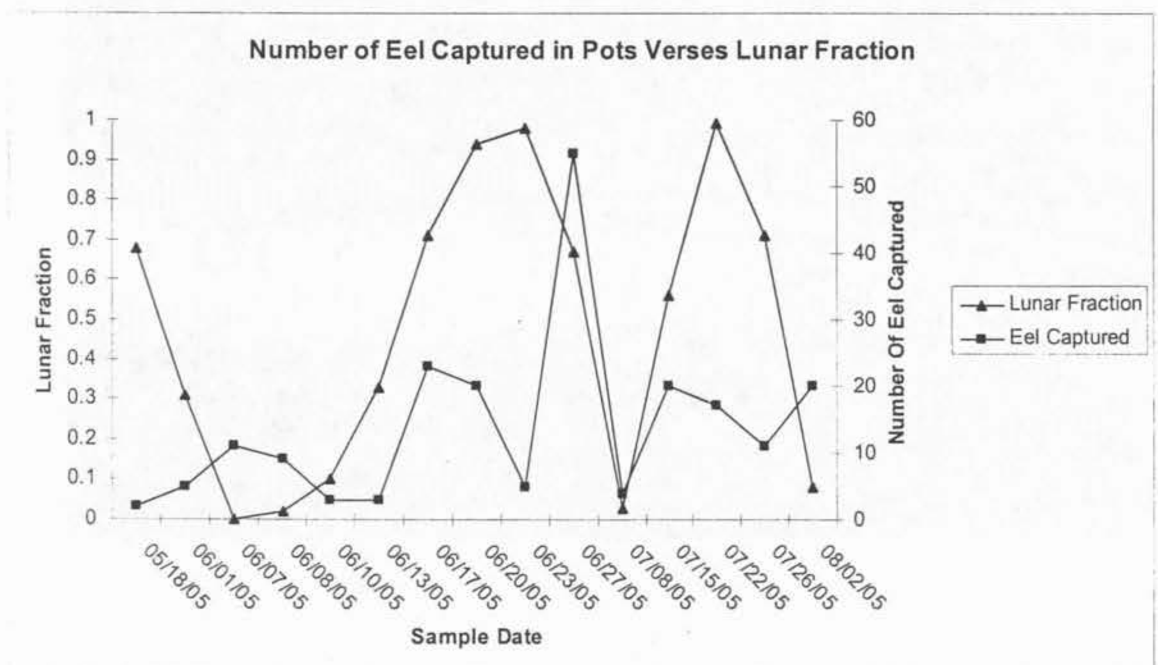

Table 1. Number of eels caught at the base of Conowingo Dam on the Susquehanna River by an Irish Elver Ramp and Eel Pots (data are combined for four pots per collection date).

Collection Date	Unit Effort (days)	Eels Collected in Elver Ramp	Eels Collected in Eel Pots	Total Eel Captured	Average number of Eels Caught per Day
5/18/2005	2	0	2	2	1
6/1/2005	14	1	5	6	0.4
6/7/2005	6	0	11	11	1.8
6/8/2005	1	0	9	9	9
6/10/2005	2	0	3	3	1.5
6/13/2005	3	0	3	3	1
6/17/2005	4	0	23	23	5.8
6/20/2005	3	0	20	20	6.7
6/23/2005	3	0	5	5	1.7
6/27/2005	4	4	55	59	4.8
7/6/2005	9	31	0	31	3.4
7/8/2005	2	5	4	9	4.5
7/11/2005	3	1	0	1	0.3
7/15/2005	4	0	20	20	5
7/22/2005	7	0	17	17	2.4
7/26/2005	4	1	11	12	3
8/2/2005	7	0	20	20	2.9

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 V, Task 4
Evaluation of Acoustic Deterrent Effectiveness on American Shad at Holtwood Dam, 2005

BioSonics, Inc
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Seattle, WA. 98107

Executive Summary

A study was completed in 2005 using a high frequency deterrent sound source to stimulate American and gizzard shad to move into and through the fish bypass system at Holtwood Dam. Objectives included improvement of passage efficiency by guiding with 120-140 kHz deterrent sound sources, determination of optimal deterrent signal duration, and determination of optimal deterrent sound amplification (intensity) levels.

A 420 kHz scientific acoustic system with two split-beam transducers was used to monitor fish response to the deterrent sound sources. The transducers were installed near the downstream end of the bypass intake channel and were aimed horizontally and up current toward the crowder gates. One transducer covered the left half of the channel, the other transducer covered the right half.

Data obtained from experiments indicated that fish were stimulated to movement by the deterrent sound source. Typical movement was up and down the canal, or from side to side. Data also indicated that fish were stimulated to movement by operation of the crowder mechanism or the fish lift assembly, as well as by flow.

Data suggested that the deterrent sound source was not producing sound gradients that could guide fish into desired regions, due in part to the reflective concrete walls of the intake canal. Because of this and also due to crowder failures and operational constraints, the study could not determine the optimal settings for deterrent sound duration and gain.

Tests completed on May 17th indicated some of the strongest fish startle responses. These tests used the highest signal amplification level of 127 dB, indicating that higher sound levels produced stronger startle responses. A series of recommendations are suggested for future developments, based in part on findings from this study.

Introduction

Considerable effort related to restoration of American Shad runs in the Susquehanna River has been focused on improving fish passage past Holtwood Dam. A fish diversion system utilizing an intake channel, fish crowder, and fish lift have been provided to pass American and gizzard shad moving upstream into the tailrace of the dam. However, radio telemetry studies conducted below Holtwood Dam in 2001 suggested relatively poor passage efficiencies. Two problems were identified. First, attractant flows out of the bypass channel were apparently being overwhelmed by the outflow of power generation unit 1, causing fish to congregate away from the intake system of the bypass channel. Second, data indicate that only about half of the fish that do locate and enter the bypass channel are actually passed by the fish lift. The bypass channel enters a dark tunnel – an environment that appears unfavorable for shad passage. Fish passing beyond the intake region of the channel may be forced into the lift mechanism by movable "crowder gates". Fish between the channel intake and the reach of the crowder gates appear to either mill inside the channel or actually move back out into the tailrace.

American shad have been shown to exhibit a startle response to ultra-sonic frequencies in the range of 120 – 140 kHz. By generating pulses of sound in this range from locations near the inlet of the bypass channel, it was thought that fish holding in the channel would move into the inner region of the channel and within the range of the crowder doors.

This project addresses three specific objectives:

1) Improve fish passage at Holtwood Dam using high frequency sound to direct the fish past the crowder gates within the Holtwood Fish lift entrance channel;

2) Determine the signal duration necessary to elicit the desired behavior within the Holtwood Fish Lift entrance Channel;

3) Determine the sound amplification levels necessary to direct fish past the crowder gates within the Holtwood Fish Lift entrance channel.

Methods

The study design implemented consisted of a block design with treatments consisting of variations in the duration and amplification of the deterrent sound pulses. Immediately after the sound pulse was administrated, the crowder doors were closed and the fish lifted upstream. Fish numbers and species in each lift were recorded. Control blocks followed each treatment by 30-40 minutes and consisted of a fish lift without application of the deterrent sound. Table 1 provides a daily summary of the test conditions.

Scientific acoustic techniques were used to monitor fish abundance and behavior inside the intake channel during treatment and control periods. The specifics of each test are provided in Appendix A.

Table 1. Summary of Daily Test Conditions

Daily Sound Test Parameters for 2005 PFBC Sound Study at Holtwood Dam				
Test	Date	Sound Pulse Duration	Sound Pulse Gain	Comments
1	17-May	10	127	Gate A adjusted up 10:00, adjusted down 15:05
2	18-May	20	127	Gate A adjusted up 10:38, adjusted down 15:00, low tailrace level
3	19-May	30	127	Mechanical Problem with Crowder Doors at 13:00
5	22-May	30	110	Crowder Doors Inoperable
6	23-May	20	110	Tailrace Level Fluctuations
7	24-May	10	110	Tailrace Level Fluctuations
8	29-May	10	90	PC failure, Hopper Hoist problems
9	30-May	20	90	Single Crowder Door Operating, Low Water Level
10	31-May	30	90	Single Crowder Door Operating
11	1-Jun	30	45	One Treatment/control our of Order
12	2-Jun	20	45	Tailrace Level Fluctuations
13	3-Jun	10	45	Heavy Rain, Double Sound Pulse on First Treatment
14	5-Jun	30	127	Plant Generation Failure, Tailrace Level Too Low
15	6-Jun	60	127	Tailrace Level Fluctuations

Deterrent Sound Source

A Portable Fish Diversion System manufactured by Ultra Electronics Ocean Systems, Inc. was deployed at Holtwood Dam in early May, 2005. A narrow beam, broad-band 122 to 128 KHz "spooker" transducer was mounted in each of the tailrace fishway entrances (A and B gates) at Holtwood Dam. The transducer mounted in Gate A was located along the East wall approximately 1 meter upstream of the entrance gate. The transducer for Gate B, (which was closed for the entire study), was mounted about 4 meters upstream of the gate in the center of the channel. Figure 1 illustrates these locations.

In an attempt to determine the signal duration and sound amplification necessary to elicit the proper response from American shad entering the tailrace fish lift, four scenarios were proposed for the study. Each scenario consisted of 3 pulse lengths, (10, 20, and 30 second durations), and 4 volume levels, (start gain 45: lowest volume, start gain 90, start gain 110, and start gain 127: highest volume). Generally, each scenario was initiated using the highest volume setting and the longest pulse setting and ended with the lowest volume setting and shortest pulse setting.

During each day of testing, treatment lifts using the spooker transducers prior to crowding the lift were alternated with control lifts, which did not use the spooker before crowding. The number of American shad and gizzard shad passed by each lift with "sound on" or "sound off" was recorded by a Normandeau scientist in the fish lift counting room.

A hydrophone was used to calibrate the "spooker" transducers and determine the decibel levels at each transducer and at the crowder gate. Table 2 provides information from this calibration procedure.

Table 2. Deterrent Sound Source Calibration Data

PFBC - Holtwood Sound Study 2005								
Calibration Parameters were Conducted with a Pulse Length of 10 Seconds								
	Holt02		Holt03		Holt04		Holt05	
	Ch1	Ch2	Ch1	Ch2	Ch1	Ch2	Ch1	Ch2
Pulse Length(seconds)	10	10	10	10	10	10	10	10
Start Gain	45	45	127	127	90	90	110	110
Stop Gain	46	46	128	128	91	91	111	111
Gain Step	64	64	64	64	64	64	64	64
Decibels at Transducer A	165 - 171		172 - 181		165 - 175		168 - 180	
Decibels at Transducer B	150 - 161		170 - 180		163 - 170		165 - 171	
Decibels at Crowder Gate	150 - 160		160 - 170		155 - 160		156 - 165	

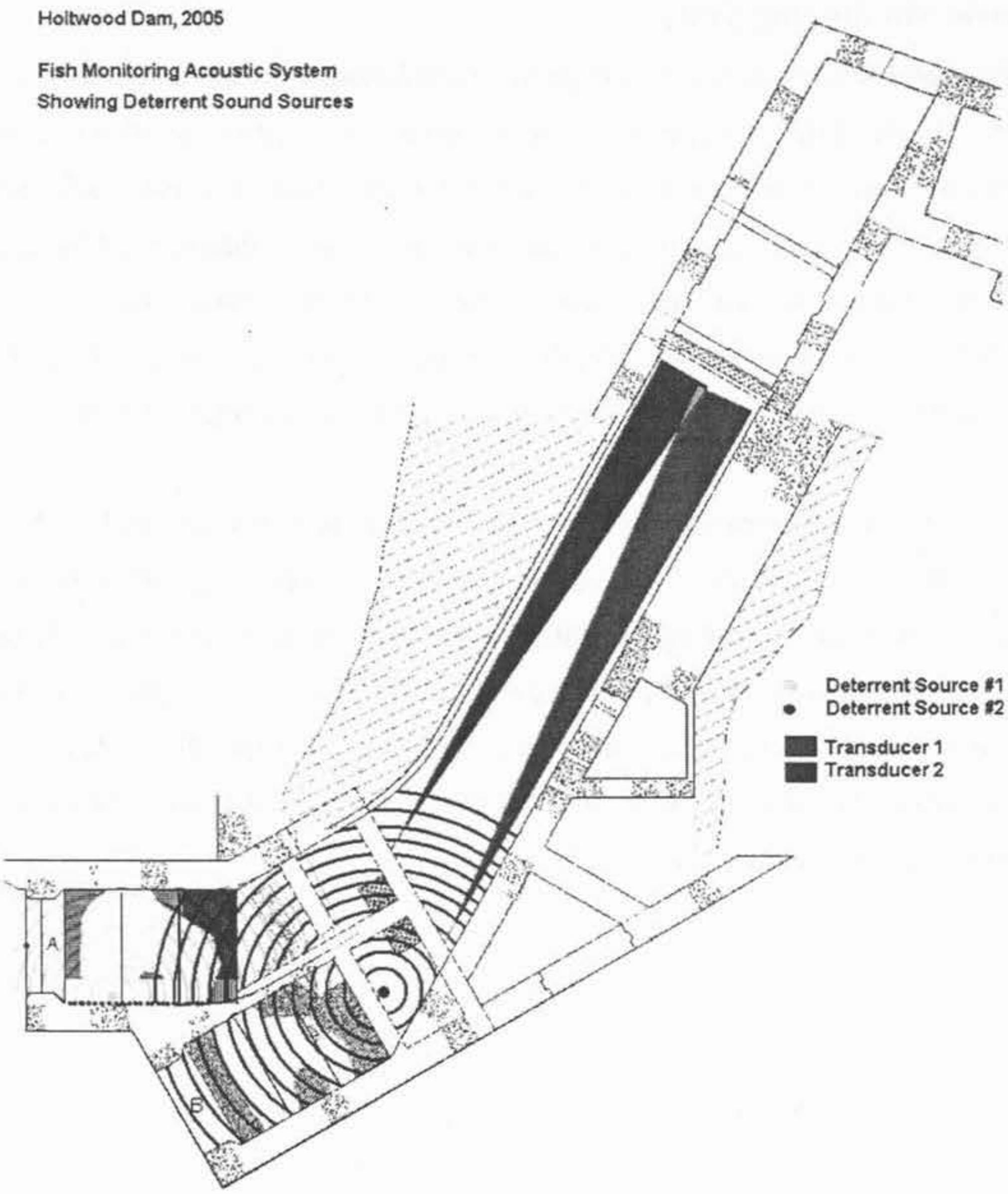


Figure 1. Plan View of Holtwood Dam Fish Collection Facility

Acoustic Monitoring System

Fish abundance was monitored in the bypass channel using a BioSonics DT-X scientific echo sounder. The 420 kHz echo sounder collected data by interrogating two digital split-beam transducers installed near the downstream end of the 'B' intake canal and aimed horizontally toward the crowder doors, as shown in Figures 1 and 2. Each transducer had a 6-degree nominal beam angle, and was operated at a pulse duration of 0.3 msec. and a pulse repetition rate of 5 transmissions per second. Depth below water surface depended on tailrace water elevation and elevation of the gates controlling flow through the bypass system.

The DT-X system is calibrated by measuring its acoustic performance with U.S. Navy Acoustic Standard transducers. The resulting measurements are programmed into memory chips in the electronics, allowing the unit to collect and display acoustic signals in terms of absolute signal intensity. Data files of 15 minute duration were collected continuously during the test procedures, excepting 30 minute data files collected on June 2nd. The data collection computer automatically named each file – file names contained data and time values corresponding to when the file was opened.

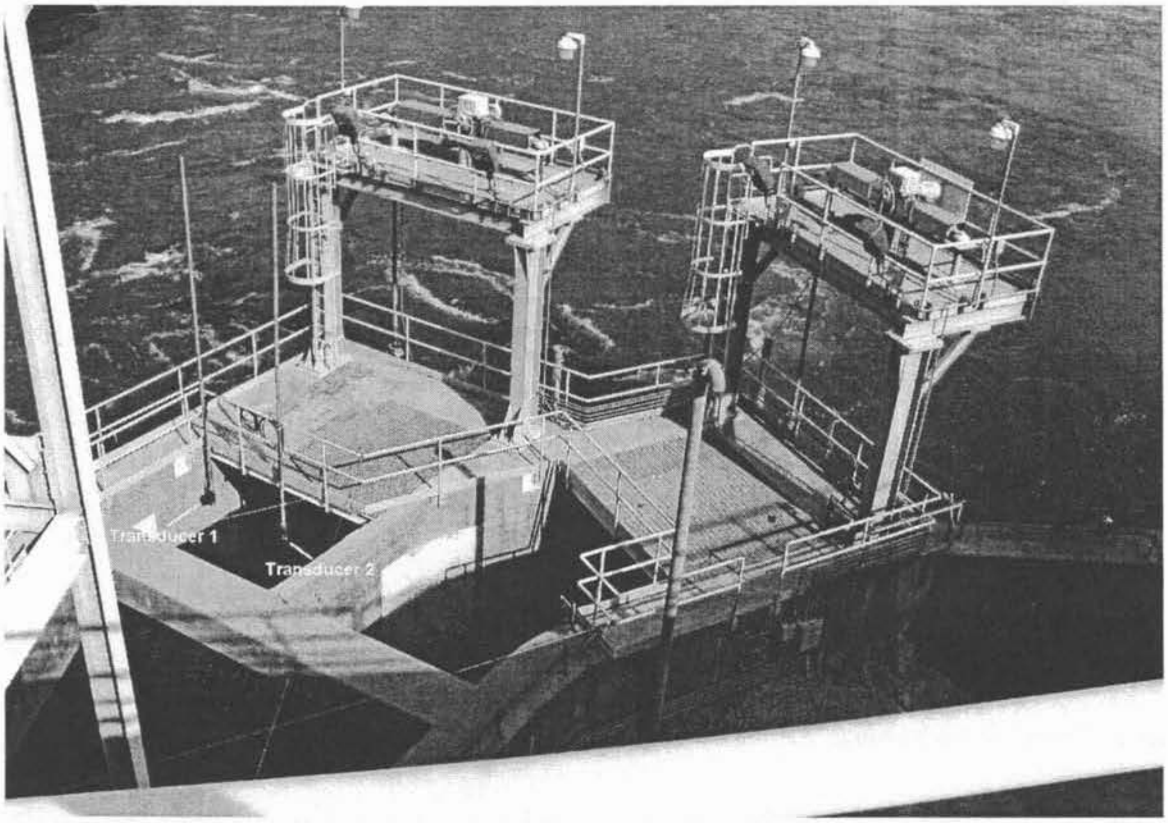


Figure 2. Photograph of Holtwood Dam Fish Collection Facility, Showing Location of Scientific Transducers.

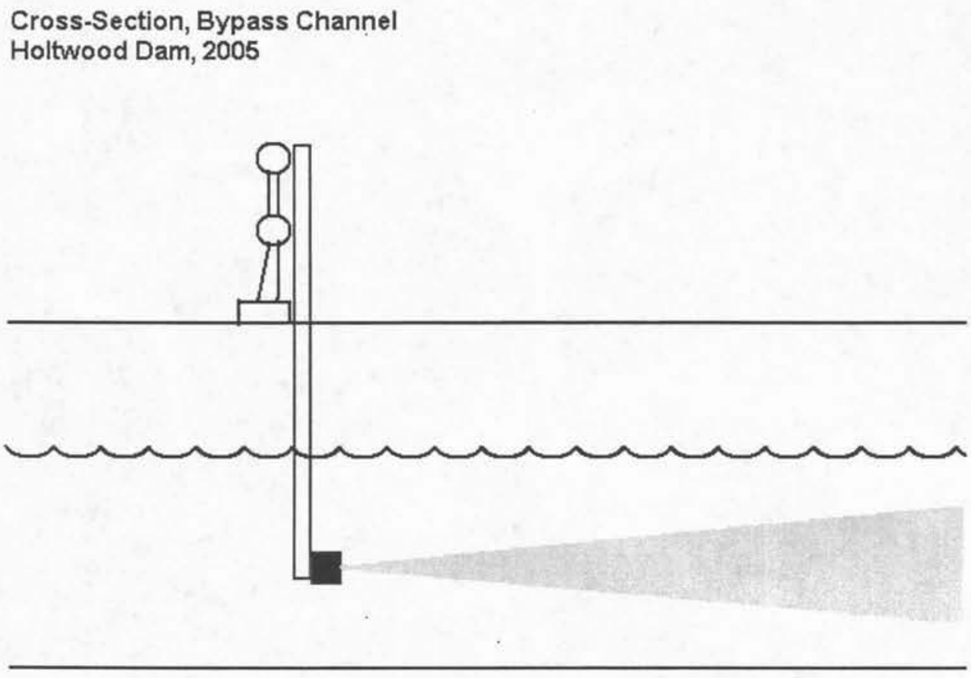


Figure 3. Cross Section Through Railing Mount, Holtwood Dam, 2005.

A standard calibration sphere made of tungsten carbide was suspended adjacent to each wall of the channel within a meter of the crowder gate. The echo sounder was able to detect this target, indicating that the acoustic monitoring system was able to detect fish moving within centimeters of the bypass channel walls.

Analytical Methods

The number of American and gizzard shad passed in each lift was tallied for each treatment and control lift. Examples of these data values are provided in Appendix A.

Signals from the acoustic monitoring system were processed using a technique called echo integration. This technique measures total reflected energy from all echoes, and is used in marine surveys to assess the number of fish in schools. As echo integration measures all reflected energy over the signal threshold, it can be vulnerable to acoustic reflections from entrained air. To reduce these effects, a threshold level of –42 decibels was applied, and signal processing range was limited to 1 - 15 meters. These distances correspond to a range window starting1 meter from the transducers and ending about 1 meter from the crowder assembly positioned in its downstream location.

The output of the echo integration analysis is an index roughly analogous to fish density, but about 1000 times higher. The signals from each transducer were measured in 1-minute time bins with this technique. The output graphs represent a time series of fish abundance in the above range for each of the monitoring transducers.

The data from 3 days were analyzed using the echo integration technique. These days were selected for high, moderate, and low fish abundance samples, and were collected on days when equipment or operational problems did not occur. The data were processed for May 17th (9 treatment and control samples), May 23rd (8 treatments and control samples), and June 2nd (5 treatment and control samples). An arrow on each plot indicates the approximate time of the sound pulse and hopper lifts.

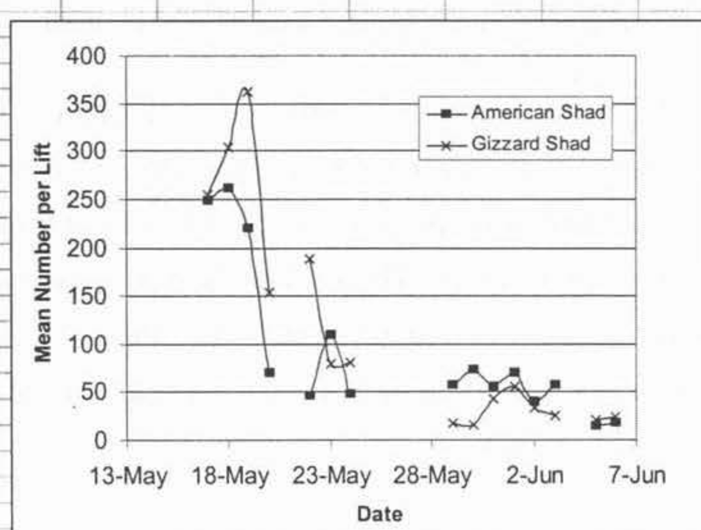
Results

Fish Lift Data

The numbers of American and gizzard shad contained in each individual fish lift are provided in the Appendix A tables. Summary mean values per day are shown in Table 3, with accompanying graphic.

Table 3. Mean Numbers of Shad per Lift

	Average Number of fish in Lift	
	American Shad	Gizzard Shad
17-May	248	254
18-May	261	303
19-May	220	362
20-May	70	154
21-May		
22-May	46	188
23-May	109	79
24-May	47	81
25-May		
26-May		
27-May		
28-May		
29-May	56	18
30-May	73	17
31-May	56	43
1-Jun	70	56
2-Jun	40	34
3-Jun	57	25
4-Jun		
5-Jun	15	20
6-Jun	18	24



Monitoring Acoustic System Data

An example of the acoustic patterns of fish abundance and distribution in the Holtwood Dam Fish Bypass Intake Canal is shown in Figure 4. This data set was collected on April 21, 2005, and represents about 3 minutes of data from one of the scientific measurement transducers.

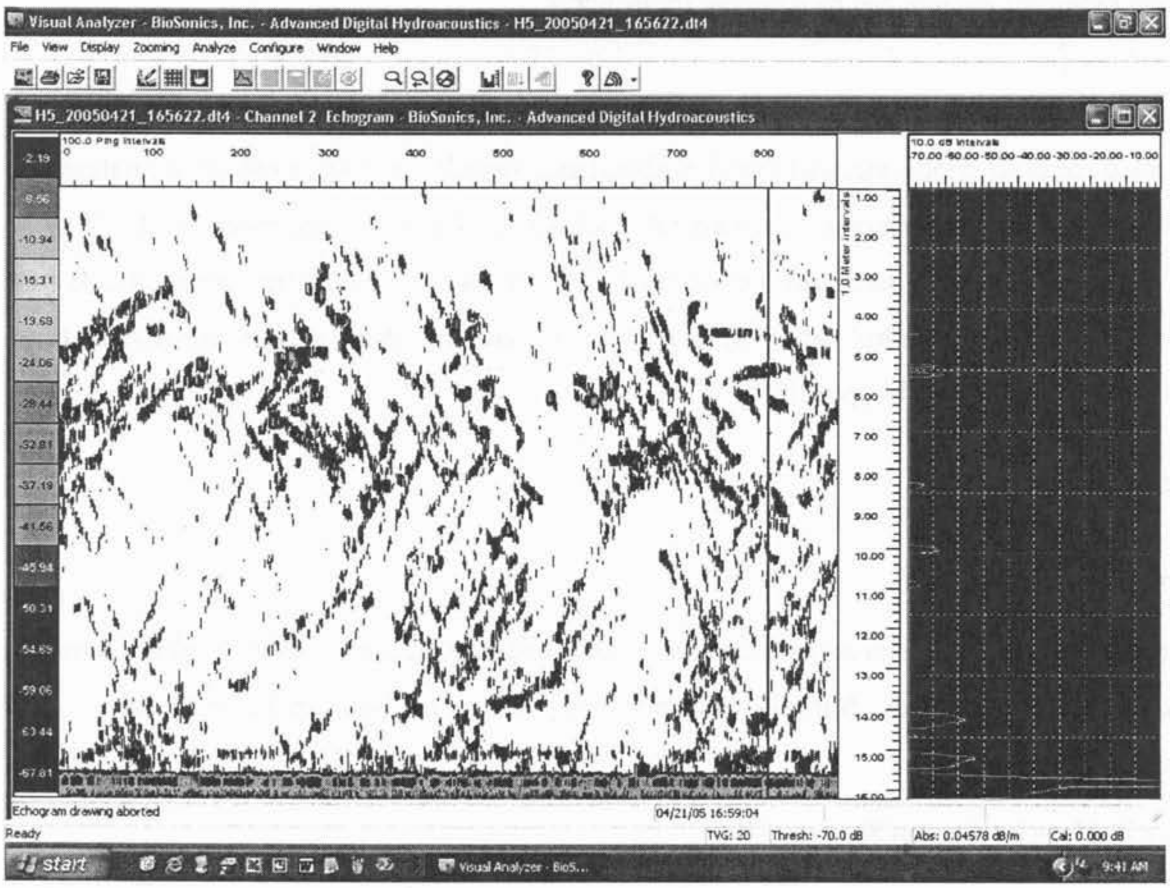


Figure 4. Echogram of Fish in Bypass Channel (April 21, 2005)

To orient the viewer, this figure contains several features. The color bar represents calibrated signal intensity of acoustic returns. The panel to the left is called an echogram, and is a time series of individual acoustic ‘pings’ or returns. The numerical scale between the panels represents range in meters. The panel on the right is a digital oscilloscope showing the instantaneous acoustic return for an individual ping. Normally, the range scale would indicate depth, but since the transducer is aimed horizontally, the scale represents the distance in meters from the transducer.

The transducer is mounted near the outlet gate of the B bypass channel. The intermittent red echo observed at a range of about 15.5 meters is the signal from the crowder doors, which were closed at the time. The patterns on the echogram are produced by fish moving about in the bypass channel. A variety of behaviors are observed. Some targets produce a diagonal line moving from lower left to upper right. These signatures represent individual fish moving rapidly toward the transducer (and away from the crowder gate). Other patterns are observed moving diagonally from upper left to lower right. These targets are moving toward the gates. Other targets are observed milling about in the channel.

During the time that this data segment was collected, there was no flow through the channel. When flow was begun, the acoustic monitoring system detected a significant amount of entrained air in the flowing water. The effects of this entrained air including masking some of the echoes returning from fish targets. This masking effect is heavier at longer ranges, as the acoustic beam increases in volume with range.

Fish Target Strength Data

A sample of target strength (TS) data is provided in the following figure.

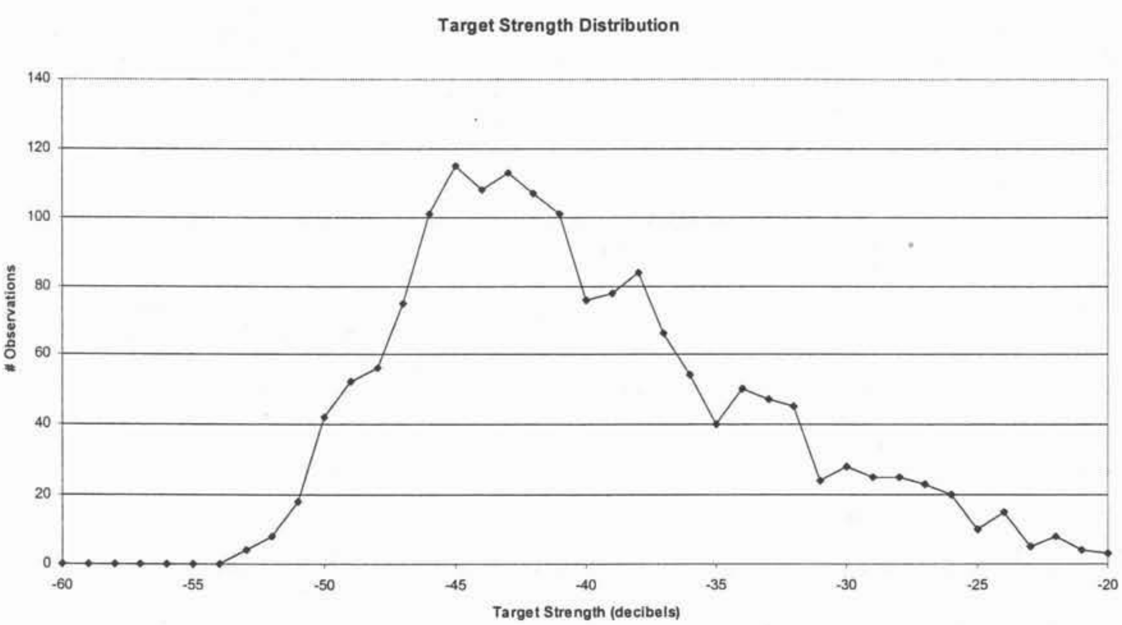


Figure 5. Target Strength Distribution of Fish in Holtwood Dam Intake Canal

Target strength is a measure of the acoustic size of individual fish, and is normally obtained in dorsal aspect (looking down on the fish). In this study, the transducers were aimed horizontally. Additionally, the fish were acoustically observed to be swimming in all directions, thus providing TS values from a wide variety of aspects ranging from side aspect to head or tail aspect. Because the fish appear to be swimming toward or away from the transducer for a higher proportion of the sample (see Figure 4), the data suggest that the side aspect TS may be in the range of –40 to –30 db, while the lower head or tail aspect TS values may be in the range of –50 to –40 dB. Given the above distribution, the abundance index provided by the echo integration process is about 1000 times greater than the actual fish density.

Fish Abundance Time Series, May 17, 2005

Figures 6 through 23 present the acoustic abundance estimates for each treatment and control test completed on May 17, 2005. Riverine terminology will be used to identify orientation – left bank implies the left side of the intake canal as one looks down current. Fish densities observed on Transducer 1 will therefore be on the left side when looking down current.

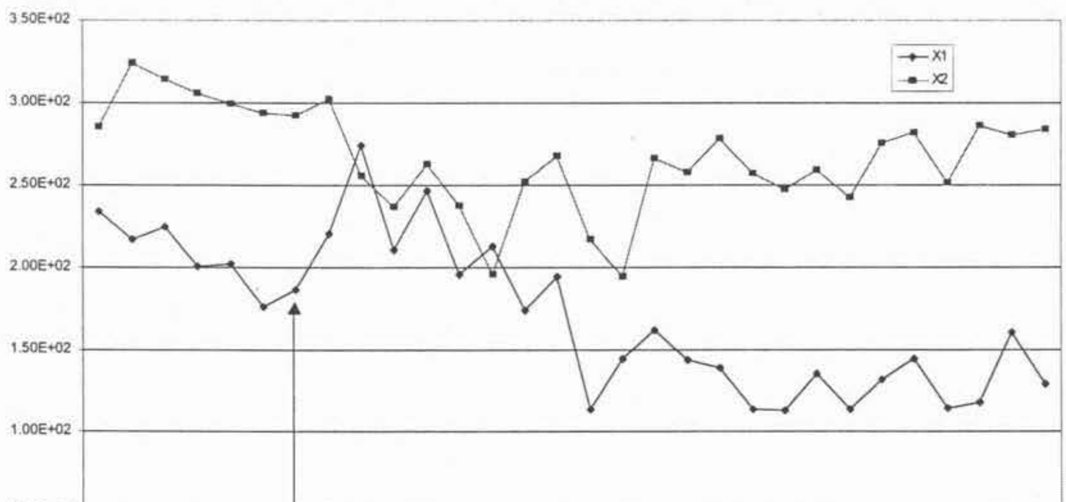


Figure 6. May 17, Test 1, Sound Pulse at 09:05

The crowder action is initiated immediately after the deterrent sound is pulsed. Fish abundance increases on the left side, and fluctuates on the right side. Total abundance stabilizes at a slightly lower level on both sides after about 12 minutes. Taken by itself, this graph suggests that fish activity increases significantly after the deterrent event.

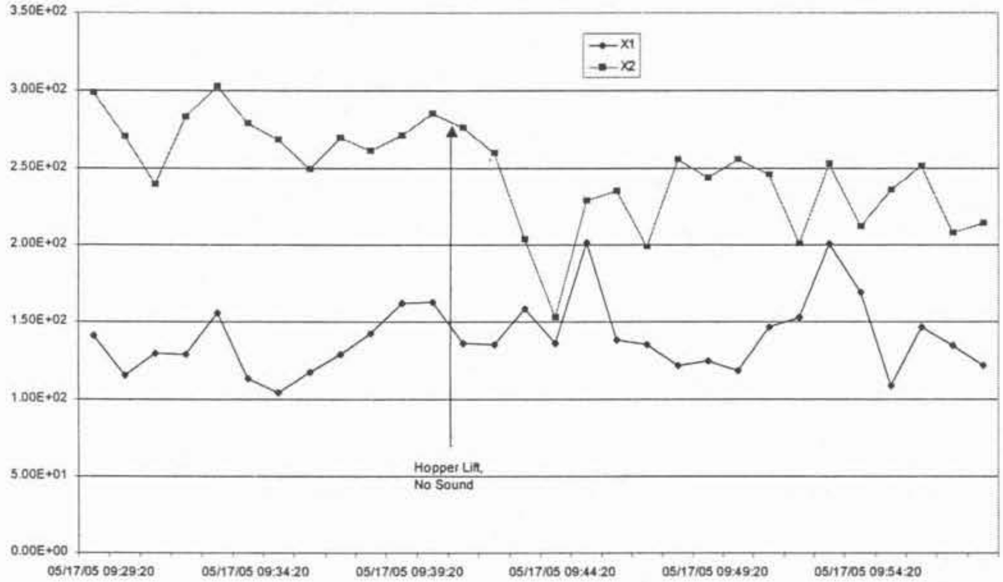


Figure 7. May 17, Control 1, Hopper Lift at 09:41

The fish hopper lift cycle is initiated at 09:41 without a preceding deterrent event. Fish abundance drops on the right bank and increases on the left bank for one minute. Overall abundance appears to drop slightly on the right bank following the removal of fish. This graph suggests that the fish respond to the activation of the crowder.

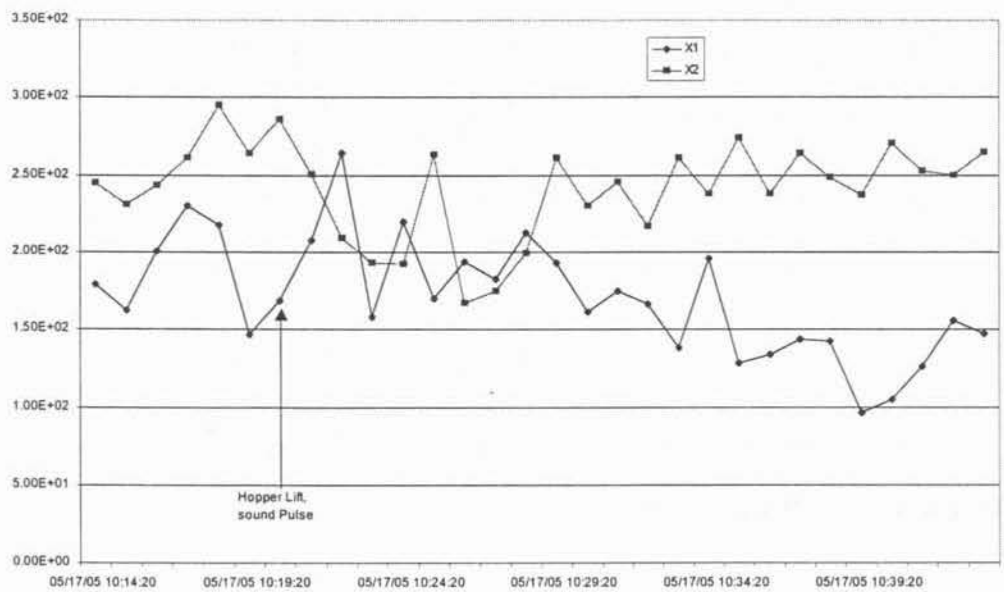


Figure 8. May 17, Test 2, Sound Pulse at 10:20

Test 2 indicates increased movement following the deterrent sound event. A pattern of decrease on the right side and increase on the left side is observed.

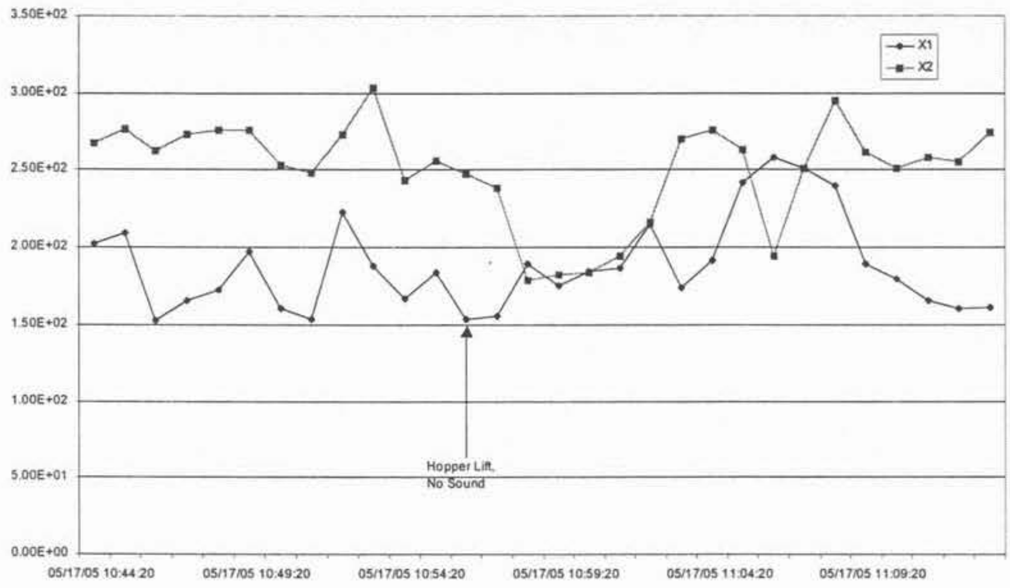


Figure 9. May 17, Hopper Lift at 10:56

Fish abundance decreases on the right bank about 1 minute after the lift cycle is initiated. Fish cannot move into the hopper after a cycle is initiated, therefore abundance changes suggest movement into and out of the intake canal or side to side.

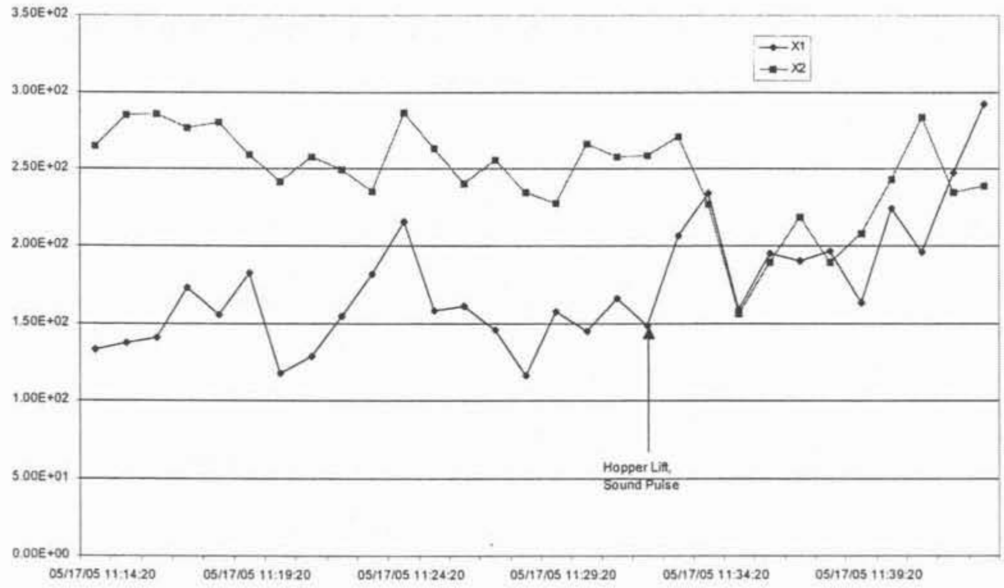


Figure 10. May 17, Test 3, Sound Pulse at 11:32

Fish abundance increases on the left side and decreases on the right side immediately after the deterrent sound is triggered.

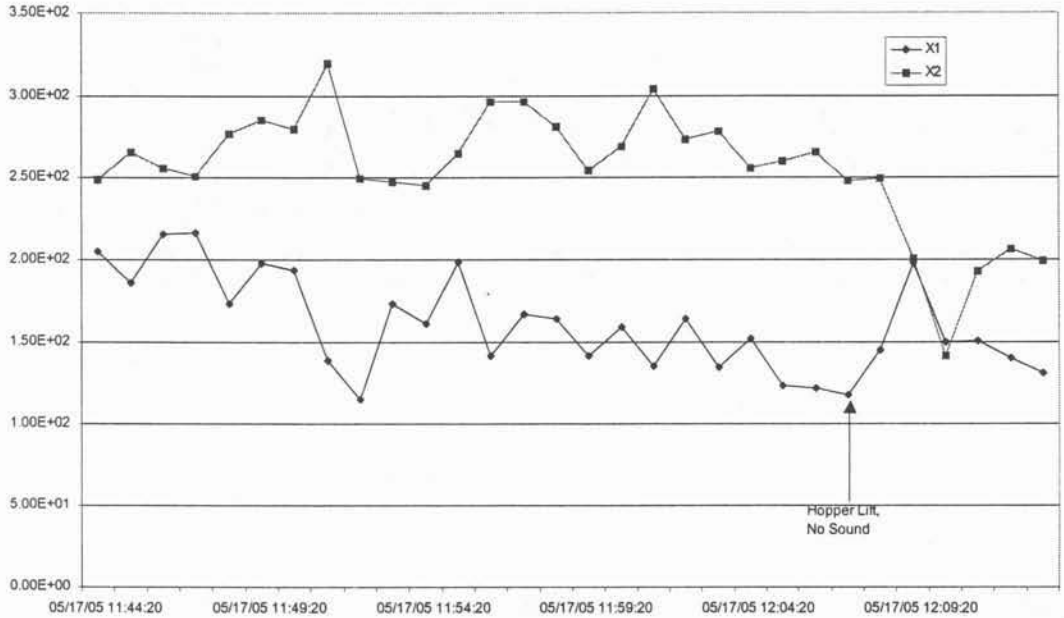


Figure 11. May 17, Hopper Lift at 12:07

The fish lift is cycled at 12:07 without a preceding deterrent sound pulse. Fish abundance immediately decreases on the right bank and increases on the left bank, strongly suggesting sideways movement.

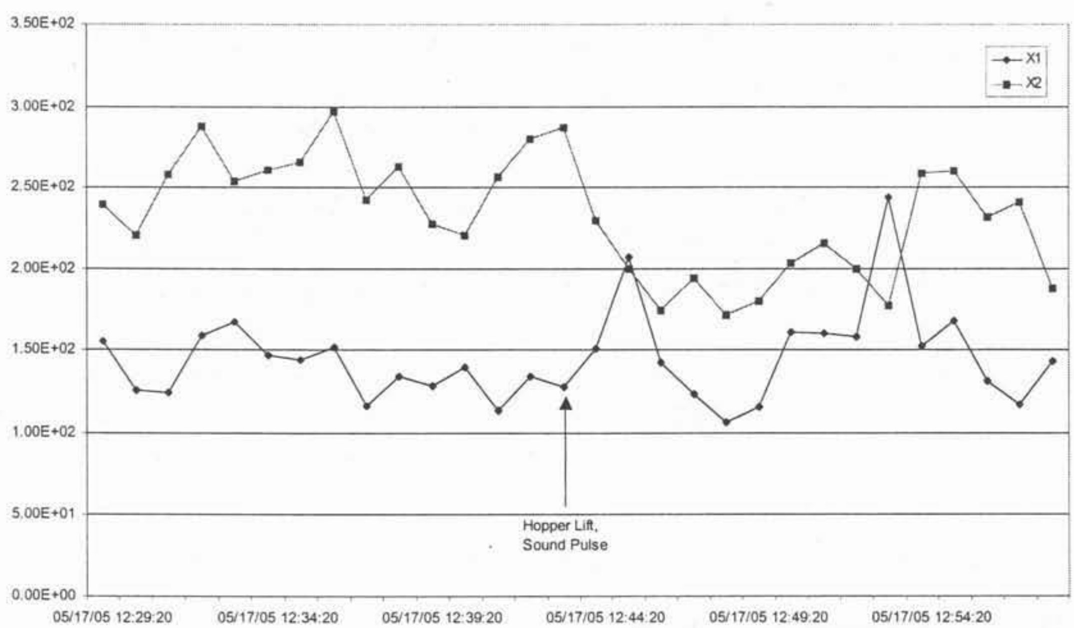


Figure 12. May 17, Test 4, Sound Pulse at 12:43

Following the deterrent pulse at 12:43, abundance decreases along the right bank and increases along the left bank.

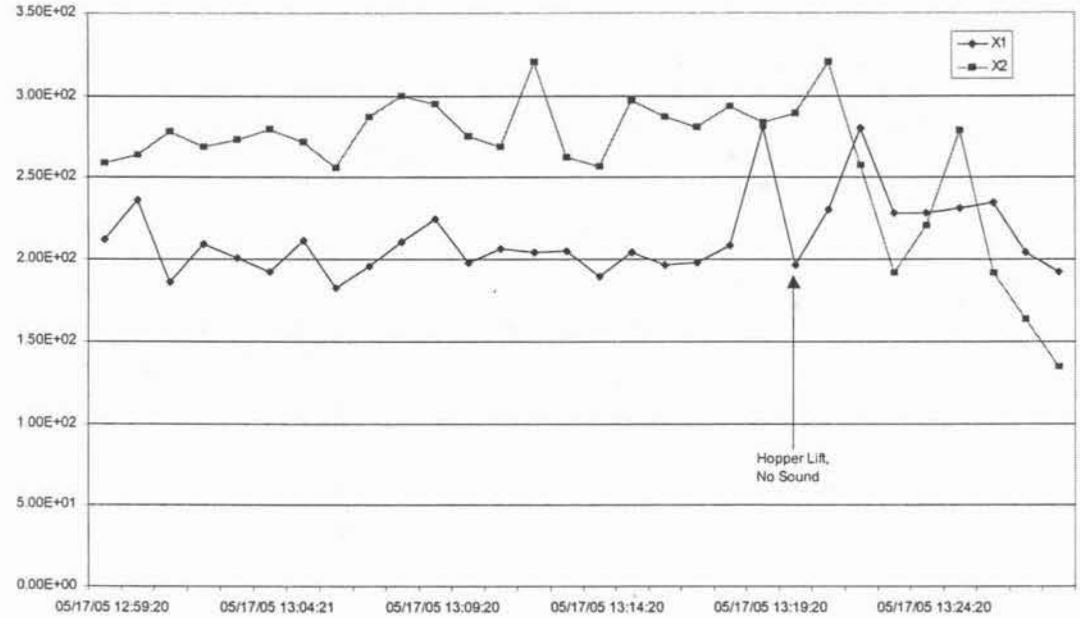


Figure 13. May 17, Hopper Lift at 13:20

Fish abundance decreases on the right bank and increases on the left side of the intake canal when the lift cycle is initiated at 13:20.

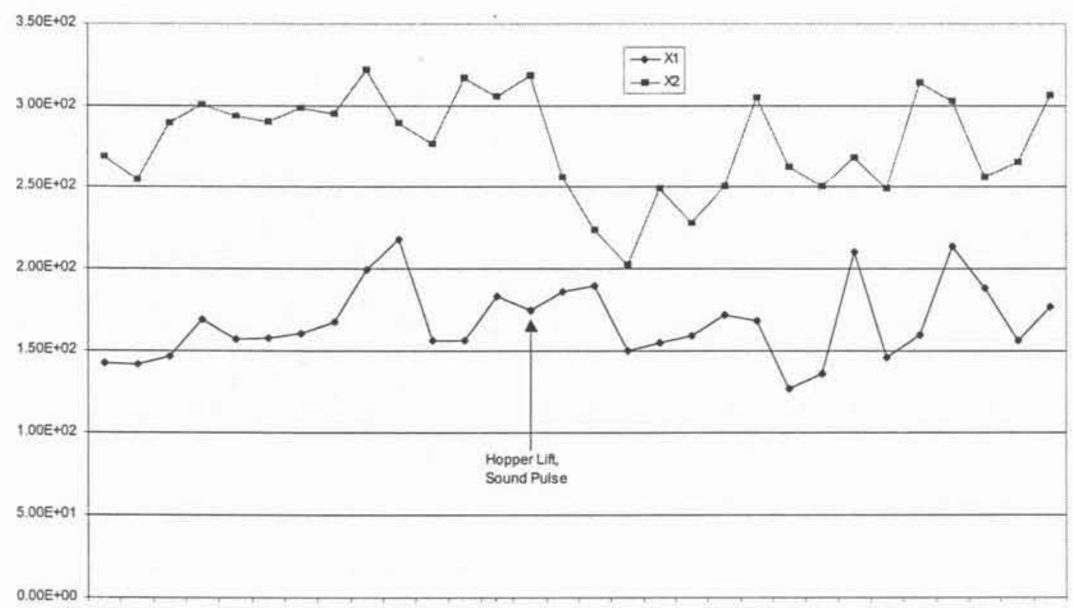


Figure 14. May 17, Test 5, Sound Pulse at 13:56

Right bank fish abundance decreases when the deterrent sound source is pulsed; no change is observed on the left side.

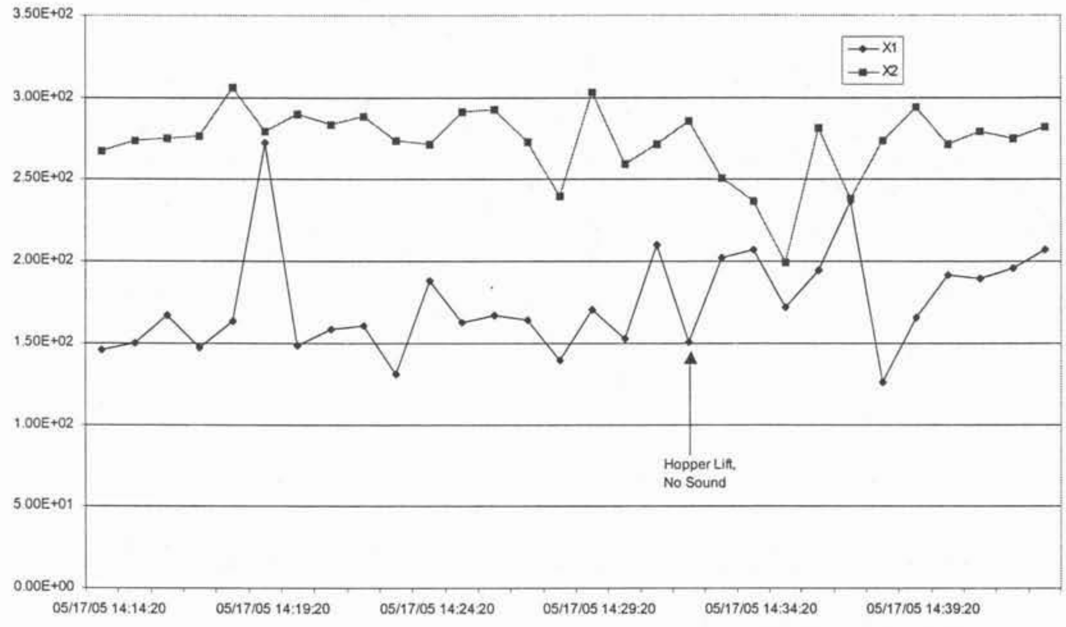


Figure 15. May 17, Hopper Lift at 14:32

Fish abundance increases gradually on the right bank side after initiation of a lift cycle at 14:32, while the left bank abundance remains variable.

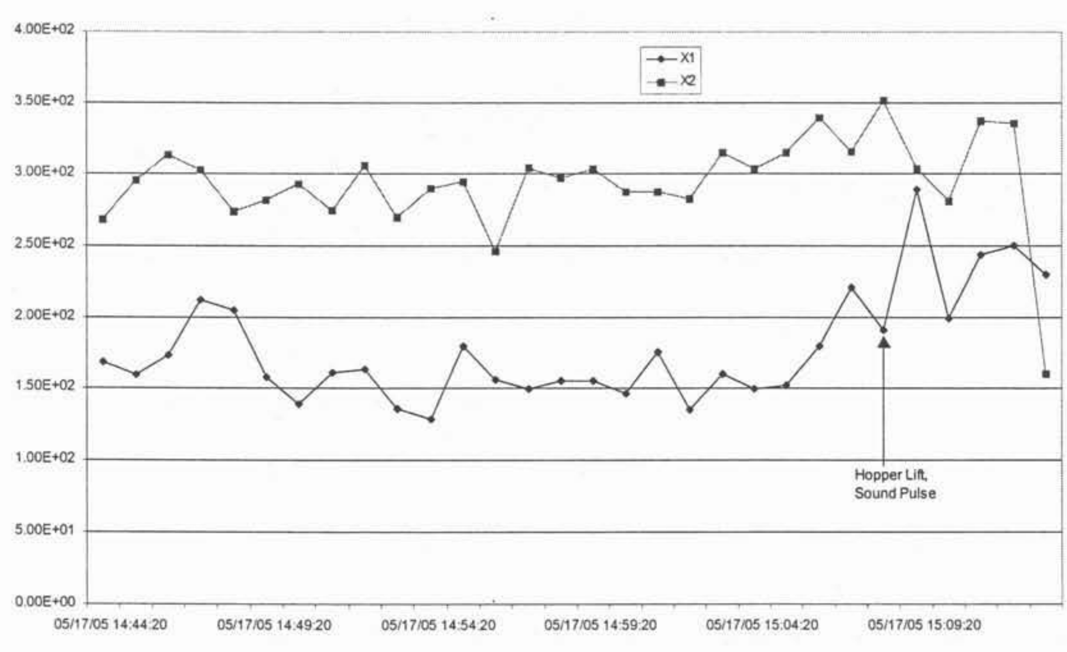


Figure 16. Test 6, Sound Pulse at 15:07

Fish abundance decreases on the right side and increases on the left side. This condition is only maintained for one minute.

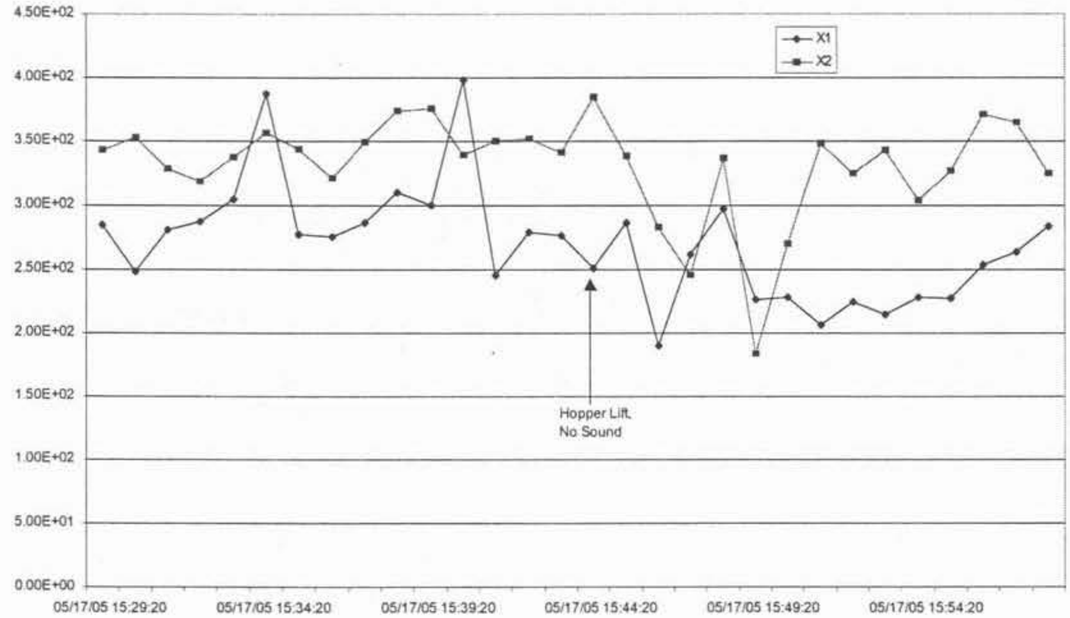


Figure 17. May 17, Hopper Lift at 15:44

Fish abundance decreases on both sides of the intake canal within a minute of the lift cycle, and shows considerable variability. Abundance remains lower on the left side for several minutes, but increases much sooner on the right side.

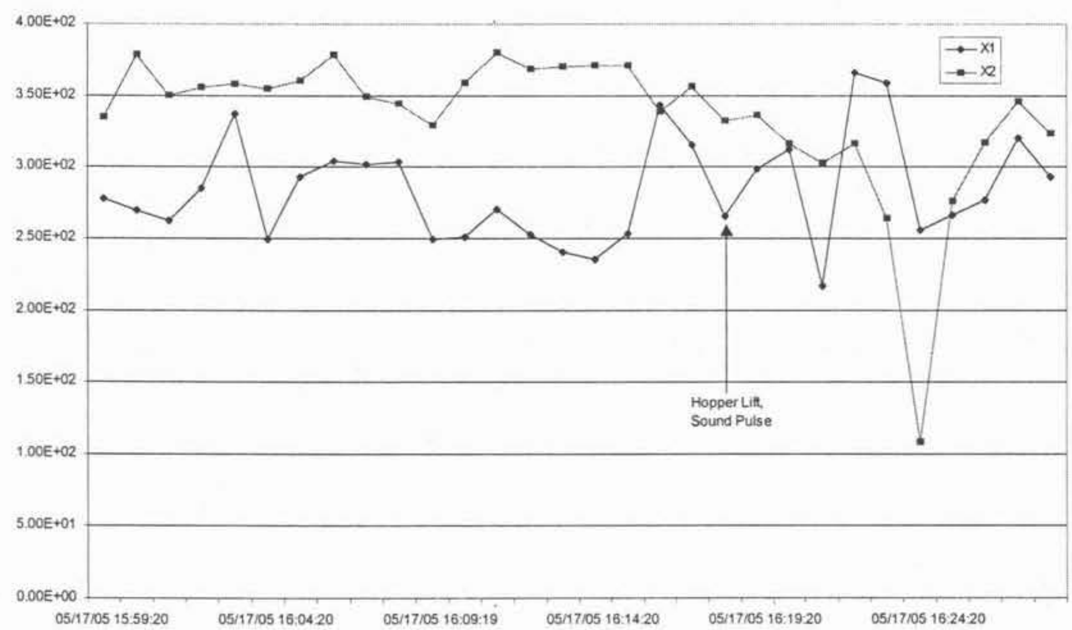


Figure 18. May 17, Test 7, Sound Pulse at 16:18

This sound deterrent test is characterized by highly fluctuating densities on the left side of the intake canal and decreasing levels of abundance on the right side.

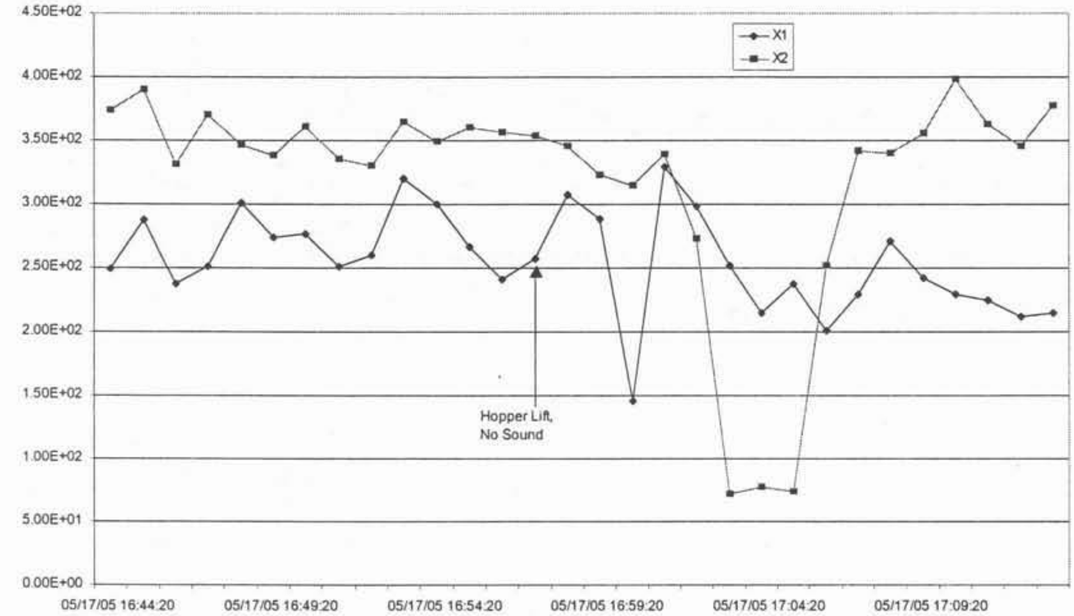


Figure 19. May 17, Hopper Lift at 16:57

As observed in the previous test, this fish lift is characterized by highly fluctuating densities on the left side of the intake canal and decreasing levels of abundance on the right side.

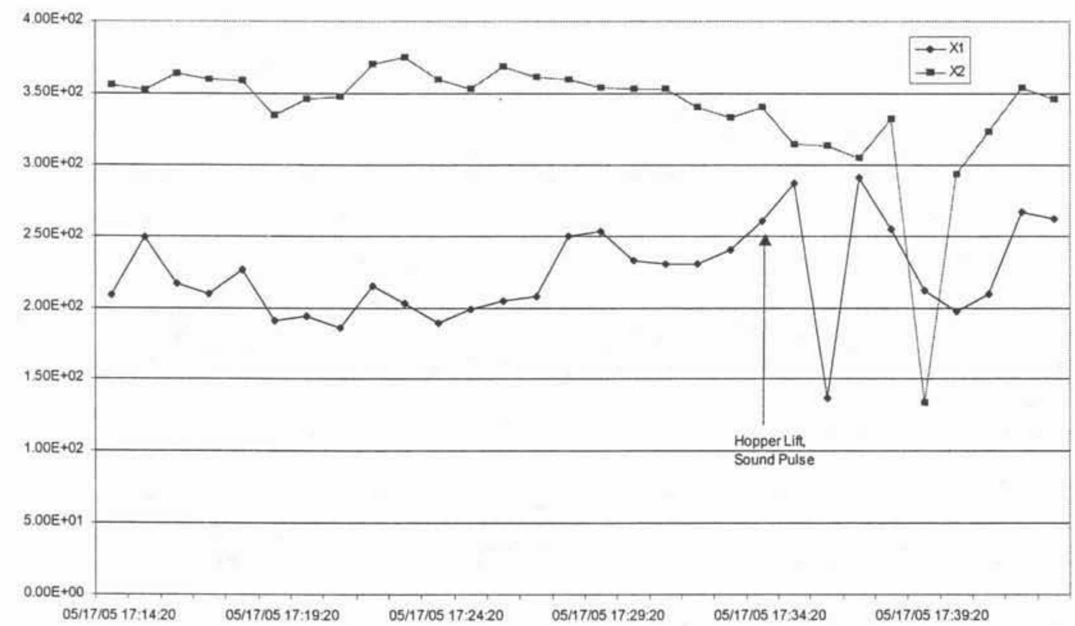


Figure 20. May 17, Test 8, Sound Pulse at 17:33

As observed in the previous test, the response to the sound deterrent is characterized by highly fluctuating densities on both sides of the intake canal.

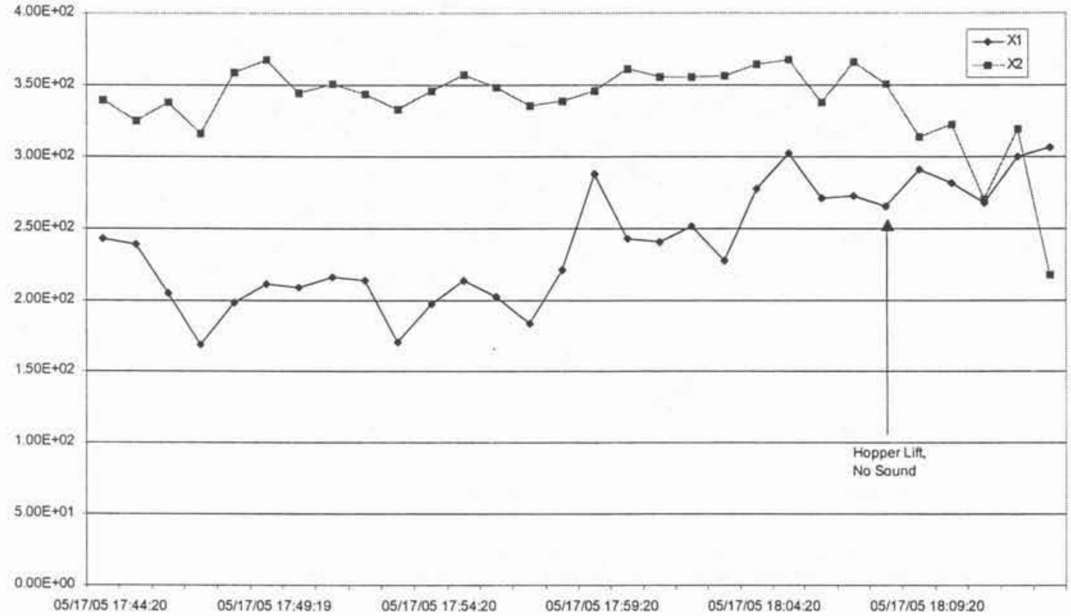


Figure 21. May 17, Hopper Lift at 18:08

Following the activation of the fish lift at 18:08, the fish abundance decreases on the right side of the canal.

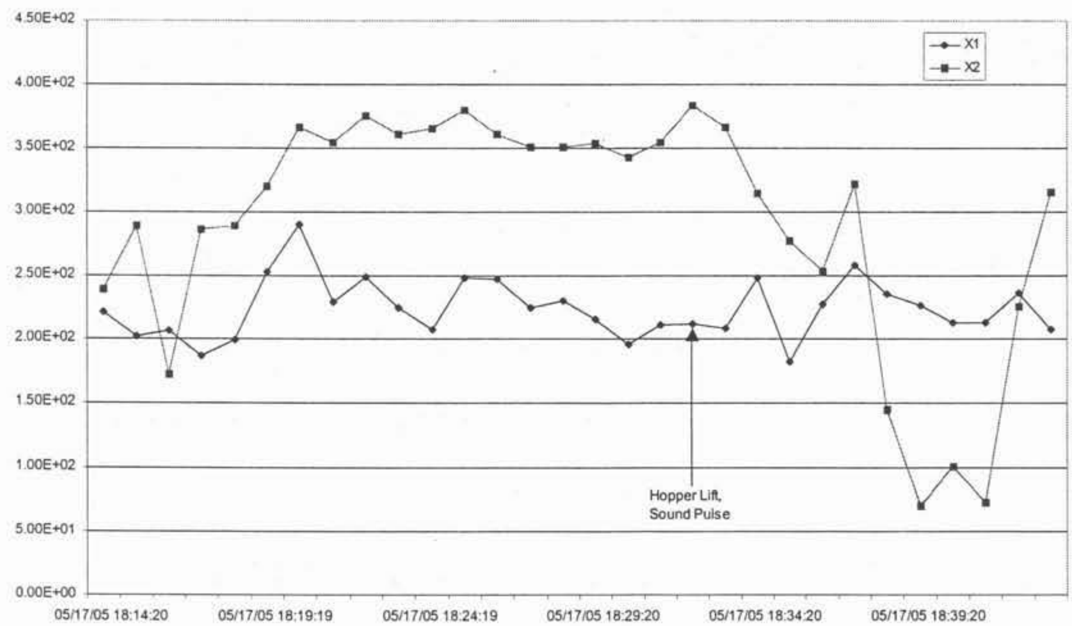


Figure 22. May 17, Test 9, Sound Pulse at 18:32

Right side fish abundance decreased at the onset of the deterrent sound pulse and dropped significantly for several minutes.

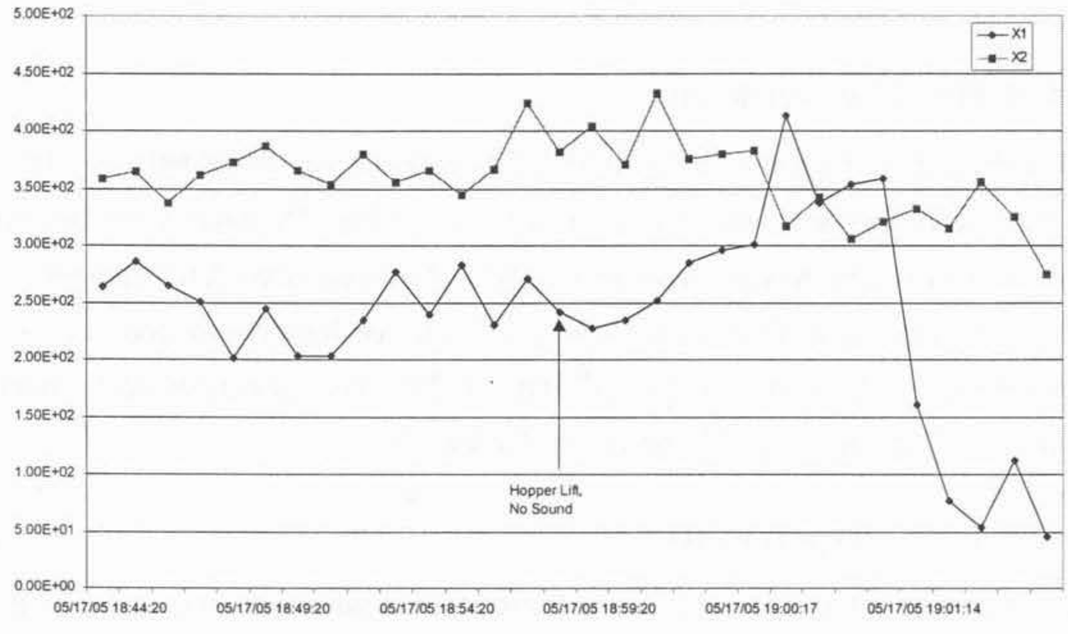


Figure 23. May 17, Hopper Lift at 18:58

No significant changes in fish abundance are correlated with this fish lift event.

Summary of May 17 Experiments

The average number of fish in a lift following a deterrent sound pulse was 511 fish, while the average number in a control lift was 492 fish. The time series of density plots suggest that fish in the intake canal are startled by the deterrent sound. The data do not suggest a directed movement, but instead indicate an increase in activity level as fish appear to move in all directions in an accelerated manner. Several of the graphs indicate that the activity of the crowder stimulates fish activity in a manner similar to the deterrent source, yet with a less instantaneous response.

NOTE: Fish abundance time series graphs are also available for May 23 and June 2, 2005 (26 graphs) from PA Fish and Boat Commission, 1735 Shiloh Road, State College, PA 16801.

Summary of May 23 Experiments

On May 23rd, the average number of fish in a lift following a deterrent sound pulse was 181 fish, while the average number of fish in a control lift was 195 fish. The experiments this day indicated that fish movement was not as strongly correlated with either the deterrent sound source or the fish lift timing as observed in the May 17th data. Both water flow and river temperature were relatively similar for May 17th and May 23rd. The intensity of the deterrent sound source was 127 dB for May 17th and 110 dB for May 23rd.

Summary of June 2 Experiments

The average number of fish in a lift following a deterrent sound pulse was 76 fish, while the average number of fish in a control lift was 71 fish. The experiments from 2 June indicated that fish movement was as strongly influenced by the operation of the lift mechanism as it was by the deterrent sound source. Both water flow and river temperature were relatively similar for May 17th, May 23rd, and June 2nd study periods. The intensity of the deterrent sound source was 127 dB for May 17th, 110 dB for May 23rd, and 45 dB on June 2. Sound pulse duration was 10 seconds on May 17th, and 20 seconds on May 23rd and on June 2.

Summary of Deterrent Sound Study

The original block design proposed for the Holtwood Dam Deterrent Sound Study was degraded by operational constraints imposed by river flow and generational requirements, as well as by operational failures of the crowder doors. The data do not provide a clear indication of which pulse duration setting or deterrent gain settings were optimal to optimize fish passage through the system. The fish responses to the deterrent source do appear stronger in the May 17th data set, which suggests that the higher gain value of 127 dB might be more effective in initiating a startle response.

The fish abundance time series plots suggest that fish activity is stimulated by several factors, among them flow, activation of the fish lift, and the deterrent sound source. Reaction to lift or crowder activity is more gradual than the fish response to the deterrent sound events. Comparison of fish passed by the lift system with deterrent on and off does not indicate a difference in passage efficiency. The data suggest that fish can be stimulated but not necessarily guided. Fish studies at New York Power Authority facilities showed that blueback herring could be guided only if a clear gradient of deterrent sound was provided. In the constrictive environment of the Holtwood Dam fish bypass intake channel, it may be unlikely that a gradient can be established and maintained without using considerable care in placing and driving the deterrent system transducers.

Recommendations

The results from this study clearly indicate that migrating shad can be stimulated to activity by the use of ultrasonic sound. The results also suggest that other factors stimulate the fish, such as flow and the operation of the crowder or lift mechanisms. The effects of these individual factors can be determined by designing a study that controls their effects. For instance, responses to deterrent sound sources could be isolated from those due to flow by reducing flow and stimulating fish accumulated in the intake canal.

The ability to create gradients of sound is critical to move fish in a specific direction. This ability is straightforward in open water, but more difficult in confined spaces where concrete walls can refract the sound waves. This study confirms that fish can be stimulated to activity. The following model suggests how the findings from this study might be used to improve the fish passage efficiencies at Holtwood Dam.

A future approach might consider focusing on the following:

- Enhance the ability of fish to find the entrances to the intake channel. Techniques would include operational changes in the generation of electricity, specifically choosing turbines distant from the bypass channel. The use of deterrent sound sources in the tailrace or slightly further downstream might be used to guide fish to and along the right bank to the inlet of the bypass canal.

- Movement of fish in the intake canal could be stimulated by use of deterrent sound sources. Movement in itself does not benefit the fish unless it is directed movement. One scheme to direct fish is to put a series of angled or V-shaped screens or "fykes" in the intake canal at various distances. Fish could easily pass through openings or slots in the screens if they were moving up current, but would have difficulty returning through the openings to move down current. This scheme would be similar in concept to a fish ladder, and stimulation to move would be provided both by flow and by deterrent sound sources. The screens could easily be lifted out for storage or maintenance, and would have no moving parts to fail.

Appendix A. Holtwood Dam Data Tables

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
1	17-May	0835 - 0840	9	9	Holt035.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Doors Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0905	10 Seconds	0905	0912	459	157
		0941	0950	252	98
1020	10 Seconds	1020	1028	413	483
		1056	1103	410	378
1132	10 Seconds	1133	1140	378	324
		1207	1215	325	344
1243	10 Seconds	1243	1255	239	258
		1320	1328	238	338
1356	10 Seconds	1357	1404	253	284
		1432	1439	210	185
1507	10 Seconds	1507	1515	93	223
		1544	1551	219	212
1618	10 Seconds	1618	1625	184	217
		1657	1704	263	370
1733	10 Seconds	1734	1741	133	228
		1808	1815	172	155
1832	10 Seconds	1832	1840	172	102
		1858	1907	45	217

COMMENTS: 1000 h: Adjusted Gate A up slightly to improve attraction flow. 1305 h: Plant dropped to 9 Units for maximum efficient. 1505 h: Units 1, 2, and 7 off, tailrace lower, Adjusted Gate A down.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
2	18-May	0830 - 0840	5	5	Holt0310.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Doors Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
		0908	0916	454	343
0945	20 Seconds	0946	0954	332	402
		1022	1030	134	244
1059	20 Seconds	1100	1107	178	356
		1136	1144	217	394
1212	20 Seconds	1212	1221	379	383
		1249	1257	362	327
1325	20 Seconds	1326	1334	346	356
		1404	1411	145	141
1442	20 Seconds	1443	1451	59	82

COMMENTS: 1038 h: Adjusting Gate A up to improve the attraction flow. 1325 h: Only three units operating lowering Gate A. 1500 h: Ennded today's study due to low tailrace level. If Gate A would be lowered any more the transducers would be out of the water.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
3	19-May	0720 - 0730	5	4	Holt0315.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Doors Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0804	30 Seconds	0805	0816	288	867
		0841	0849	316	420
0917	30 Seconds	0918	0927	322	496
		0955	1002	275	370
1032	30 Seconds	1033	1041	282	250
		1106	1114	79	166
1144	30 Seconds	1144	1152	24	134
		1220	1230	26	368
1257	30 Seconds	1258	1307	365	185

COMMENTS: Sound study ended early due to crowder door problems. The catch just started to pick up again when problem was encountered.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
4	20-May	0920 - 0930	4	4	Holt0315.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
1100	30 Seconds	1101	1106	184	171
		1136	1140	192	209
1206	30 Seconds	1206	1211	94	206
		1545	1549	13	101
1615	30 Seconds	1615	1619	34	177
		1645	1651	15	114
1716	30 Seconds	1717	1721	10	112
		1747	1752	19	141

COMMENTS: Same configuration as 19 May, except the the crowder doors are wide open due to repairs. Operating in the Fast Fish Mode - Lower screen/Raise hopper. Crowder is not being used until repairs are completed. 1150 h: Hydroacoustic computer locked up, turned computer off and on to reboot at 1157 h. 1341 h: the crowder reapirs will be delayed, but doors are closed. I turned off hydroacoustics for now - will restart ASAP.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
5	22-May	0809 - 0815	8	8	Holt0515.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0859	30 Seconds	0900	0905	46	147
0929	30 Seconds	0930	0936	31	220
		0100	1005	29	327
		1030	1035	49	231
1059	30 Seconds	1100	1105	52	220
		1130	1135	85	154
1159	30 Seconds	1200	1205	56	201
		1230	1235	38	264
1259	30 Seconds	1300	1305	19	203
		1330	1338	7	229
1359	30 Seconds	1400	1405	33	216
		1430	1435	76	178
1459	30 Seconds	1500	1505	80	136
		1535	1538	38	85
1559	30 Seconds	1600	1605	64	101
		1630	1635	39	103

COMMENTS: Fast Fish Mode: No Crowder - Crowder Doors are wide open. 1410 h: Plant went down from 10 to 6 units. Tailrace level dropping. Lowered Gate A twice. 1640 h: End of sound study for today due to low tailrace. I need to lower Gate A more which may leave the transducers high and dry. 1650 h: Turned off the hydroacoustic equipment.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
6	23-May	0825 - 0830	8	8	Holt0510.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0901	20 Seconds	0902	0906	10	88
		0930	0935	12	37
0959	20 Seconds	1000	1004	49	78
		1030	1034	61	34
1059	20 Seconds	1100	1104	79	44
		1130	1134	140	62
1200	20 Seconds	1201	1206	110	101
		1230	1235	183	117
1259	20 Seconds	1300	1305	169	103
		1330	1335	173	110
1359	20 Seconds	1400	1405	136	97
		1430	1435	164	111
1459	20 Seconds	1500	1505	145	113
		1530	1535	145	93
1559	20 Seconds	1600	1605	87	35
		1630	1635	84	36

COMMENTS: Tailrace level fluctuating a lot today. I made several adjustments to Gate A to maintain proper attraction flow. Stopped the study for the day after Lift #16 due to a thunderstorm in the making.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
7	24-May	0815 - 0820	8	8	Holt055.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
		0900	0905	12	118
0929	10 Seconds	0930	0935	14	124
		1000	1005	42	33
1029	10 Seconds	1030	1035	43	62
		1100	1105	40	77
1130	10 Seconds	1130	1135	46	86
		1200	1205	61	65
1230	10 Seconds	1230	1235	91	97
		1300	1305	43	198
1329	10 Seconds	1330	1335	92	71
		1400	1405	61	47
1430	10 Seconds	1430	1435	31	39
		1500	1505	49	84
1529	10 Seconds	1530	1535	58	87
		1600	1605	38	57
1629	10 Seconds	1630	1635	29	45

COMMENTS: Hydroacoustics turned on at 0854 h. Hydroacoustics turned off at 1645 h. The tailrace elevation went up and down constantly today. I had to addjust Gate A several times to compensate.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
8	29-May	0800 - 1200	3	3	Holt045.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
1159	10 Seconds	1200	1205	71	29
		1300	1305	57	20
1358	10 Seconds	1359	1404	59	19
		1500	1505	68	15
1559	10 Seconds	1600	1605	37	14
		1700	1705	45	8

COMMENTS: Had wanted to start testing at 0830 h, but the hydroacoustic computer would notboot up. Was not able to start until 1150 h. The new computer did not have Holtwood1.configuration, so I edited the default setting. The screen is not showing the crowder area even with one of the doors closed. (I figured out the reason the crowder was not showing up on the computer. I needed to extend the range from 15 to 25 meters.) Today's study was limited to three lifts limited to three lifts per scenario (sound vs. no sound) due to low generation until 1100 h and the restriction of one lift per hour due to problems with the hopper hoist.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
9	30-May	0800 - 0855	4	4	Holt0410.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0845	20 Seconds	0855	0900	78	17
		1000	1005	25	8
1059	20 Seconds	1100	1105	33	2
		1156	1201	43	15
1259	20 Seconds	1300	1305	17	5
		1400	1405	202	29
1459	20 Seconds	1500	1505	127	37
		1600	1605	59	19

COMMENTS: Barely enough water to run today's study. Wate level is just at the top of the Spooker; the transducer plate/hydroacoustic transducers are about 12 inches below the surface. 1250 h: More generation is on its way - 9 units in operation at 1300 h. 1300 to 1310 h: raised Gate A and increased valve settings to adjust for the higher generation. NOTE: Only one crowder door open today.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
10	31-May	0800 - 0859	5	5	Holt0415.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
		0900	0905	12	20
0959	30 Seconds	1000	1005	44	17
		1100	1105	48	21
1159	30 Seconds	1200	1205	89	33
		1300	1305	37	54
1359	30 Seconds	1400	1405	88	78
		1500	1505	126	56
1559	30 Seconds	1600	1605	49	38
		1700	1705	47	58
1759	30 Seconds	1800	1805	21	50

COMMENTS: Only one crowder door open, there appears to be more distortion due to water passing through the closed crowder door. Will try tomorrow to open the crowder door prior to start up.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information					
Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
11	1-Jun	0800 - 0859	5	5	Holt0215.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0859	30 Seconds	0900	0905	19	117
		1000	1005	82	52
1059	30 Seconds	1100	1105	53	44
		1200	1205	139	62
1259	30 Seconds	1300	1305	97	73
		1400	1405	120	65
1459	30 Seconds	1500	1505	88	50
1559	30 Seconds	1600	1605	34	39
		1700	1705	50	32
		1800	1805	17	24

COMMENTS: Both crowder doors opened today. I went out of sequence on the lift at 1559 h (it was not supposed to be conducted using sound). I tried to the correct the error by doing the last two lifts without sound to provided an equal number of lifts with and without sound.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
12	2-Jun	0800 - 0859	5	5	Holt0210.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0859	20 Seconds	0900	0905	67	58
		1000	1005	22	36
1100	20 Seconds	1101	1106	25	31
		1200	1205	51	34
1259	20 Seconds	1300	1305	44	24
		1400	1405	87	47
1459	20 Seconds	1500	1505	46	33
		1600	1605	22	28
1659	20 Seconds	1700	1705	23	31
		1800	1805	12	16

COMMENTS: Hydroacoustics turned on at 0854 h. Tailrace level fluctuated a lot in the morning, therefore I needed to adjust Gate A several times. Equipment was turned off at 1838 h.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information

Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
13	3-Jun	0815 - 0859	4	4	Holt025.cfg

Individual Lift Data

Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
		0900	0905	70	71
0959	10 Seconds	1000	1005	37	75
		1100	1105	90	10
1159	10 Seconds	1200	1205	52	5
		1300	1305	99	16
1359	10 Seconds	1400	1405	27	11
		1500	1505	44	4
1559	10 Seconds	1600	1605	37	6

COMMENTS: Both crowder doors are wide open. Rainy weather today. Turned on the hydroacoustic equipment at 0858 h and turned it off at 1622 h. During the lift at 0959 h the pulse sound twice because the crowder screen was not in the correct position when the sound was pulsed the first time. Ended the study after the 1559 h lift due to heavier periods of rain that could possibly damage the spooker equipment and the need to close everything up for the day.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information					
Test Day #	Today's Date	Clean out time*	# lifts / sound	# lifts / no sound	Scenario
14	5-Jun	0820 - 0900	3	3	Highest Volume

Individual Lift Data					
Time* of Sound Pulse	Sound Pulse Duration (sec)	Time* Crowder Screen Closed	Hopper Dump Time*	#Am. Shad Dump to Dump	#Gizz. Shad Dump to Dump
0859 - 0900	30 Seconds	0901	0906	4	21
		1000	1005	3	65
1059	30 Seconds	1100	1105	3	10
		1200	1205	17	11
1259	30 Seconds	1300	1305	49	6
		1600	1605	14	7

COMMENTS: Hydroacoustics was turned on at 0853 h and turned off at 1320 h due to the plant tripping off. Lost nearly all generation. I stopped the sound study because the water level was below the transducer level. Planned to re-start the study if the water level rises in the tailrace. Re-started hydroacoustics at 1513 h as the water level in the tailrace began rising with the plant coming back on line. Stopped the sound study at 1636 h due to problems with plant generation.

* Military/24-hr Clock

2005 PFBC HOLTWOOD SOUND STUDY DATA SHEET

Daily Information					
Test Day #	**Today's Date**	**Clean out time***	**# lifts / sound**	**# lifts / no sound**	**Scenario**
15	6-Jun	0820 - 0859	4	4	Full Volume

Individual Lift Data					
Time* of Sound Pulse	**Sound Pulse Duration (sec)**	**Time* Crowder Screen Closed**	**Hopper Dump Time***	**#Am. Shad Dump to Dump**	**#Gizz. Shad Dump to Dump**
		0905	0910	13	9
0959	60 Seconds	1000	1005	8	46
		1100	1105	30	31
1159	60 Seconds	1200	1205	5	8
		1300	1305	9	29
1359	60 Seconds	1400	1405	24	19
		1500	1505	39	9
1559	60 Seconds	1600	1605	13	38

COMMENTS: Last day of the sound study. Tailrace level fluctuated a lot in the morning and remained fairly steady through the atfernoon. I used was the highest volume along with a pulse of 60 seconds. Fish density has dropped noticably.

* Military/24-hr Clock

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, their stocks have increased significantly in the lower Susquehanna River. The Maryland Department of Natural Resources (DNR) is committed to restoring these species in the upper Chesapeake Bay to sustainable, self-producing populations.

METHODS AND MATERIALS

I. Adults

a. 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 26 April through 21 May 2005. Two rods were fished simultaneously, with each rod rigged with two shad darts and lead weight added, when necessary, to achieve proper depth. 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.

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.

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 used American shad captured in the tailrace by hook and line 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 and identified to species and enumerated by experienced Normandeau technicians. American shad possessing a tag were counted and the tag color noted. Hourly catch logs by species were then produced by

Normandeau personnel and distributed to DNR personnel. 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 (1980-2005) 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 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. Since the number of interviews and river flow significantly influenced CPUE estimates, conclusions drawn from these indices should be considered somewhat tenuous.

b. 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 and is therefore higher than the non-spawning population.

II. 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 and fork length measurements recorded for American and hickory shad.

RESULTS

I. Adults

a. American shad

Sex and Age Composition

The 2005 male-female ratio for Conowingo tailrace adult American shad captured by hook and line was 0.62:1. Of the 412 fish sampled by this gear, 386 were aged directly from their scales (Table 1). American shad not aged directly were assigned ages based on the 2005 age\length key.

Males were present in age groups 2-8 while females were found in age groups 4-8 (Table 1). The 2001 year-class of males (age IV) was the most abundant age group sampled, accounting for 43% of the total catch. For females, the 2000 (age V) and 1999 (age VI) cohorts were the most abundant age groups, accounting for 34% and 39%, respectively, of the total catch.

Repeat Spawning

The percentages of Conowingo tailrace repeat spawning American shad sampled by hook and line was 29.5% for males and 30.1% for females (Table 1). The arcsine-transformed proportions of Conowingo tailrace American shad repeat spawners (sexes combined) have been increasing since 1984 (r^2=0.68 P=0.002; Figure 3).

Relative Abundance

During east lift operations from 15 April to 17 May 2005, clerks counted 55,703 American shad passing the viewing window and included the following recaptures:

Tag Color	Year Tagged	Number Recaptured
Green	2005	78
Pink	2004	27
Orange	2003	04
Yellow	2003	02
Blue	2002	01
		Total tags = 112

Peak passage was on 11 May when 5,235 American shad were recorded.

In 2005, the west lift at Conowingo Dam operated from 27 April to 3 June. The 3,896 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 15 May when 625 American shad were recorded.

The Conowingo tailrace American shad relative population estimate in 2005 was 322,920 (95% confidence intervals 259,413-407,743; Table 2 and Figure 4). This estimate was adjusted for 3% tag loss as suggested by Leggett (1976).

Estimates of hook and line (1984-2005; Table 3) and fish lift (1980-2005) geometric mean CPUEs have increased linearly (hook and line: r^2=0.79, P<0.001 and fish lifts: r^2=0.81, P<0.001; Figures 5 and 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 three years (Tables 4 and 5). However, since catches are highly influenced by river flow, conclusions drawn from these indices should be considered somewhat tenuous.

b. 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=0.28, P=0.18; Table 6).

Mortality Estimates

Richardson (et al 2004) noted that ninety percent of hickory shad in Deer Creek spawned by age four and stocks generally consisted of few virgin fish. The oldest fish in their sample from Deer Creek 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 0.41. The average difference between the natural logs of the spawning group frequency, gave a Z of 0.51. In general, the resultant Z is attributed to natural mortality since there is no recreational or commercial fishery for hickory shad.

II. Juvenile American and Hickory Shad

Relative Abundance

Relative abundance of juvenile American shad in the Susquehanna River was very low with only one caught during the inriver summer seining, initiated in 2005. Young-of-the-year gizzard shad were the predominate fish caught.

DISCUSSION

Anadromous Species

1. American shad

a. Adults

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

All American shad commercial fisheries in the Atlantic ocean were closed on 31 December 2004. Since this fishery resulted in landings of mixed stocks in excess of 1 million lbs (ASMFC 1998) and there is no Chesapeake Bay American shad fishery, increases in relative abundances were expected. However, the three indicators (the tailrace relative estimates, hook and line geometric mean CPUEs and Conowingo Dam lift geometric mean CPUEs) showed significant decreases from the previous year.

Several factors contributing to this decline in abundance, include a cooler than average spring, poor recruitment and American shad harvested in the ocean as "bait". Because of the difficulty in identifying alosids, subadults may be caught as bycatch, appearing as bait in the various markets (pers. comm. K Hattala).

Data from two creel surveys targeting American shad in the Susquehanna River have also shown significant decreases in catch-per-hour during the last three years. Since estimates of relative abundances have fluctuated and river flows greatly influence catch, conclusions drawn from these creel CPUEs are considered somewhat tenuous.

b. Juveniles

Baywide juvenile American shad indices were much higher during the last five years compared to the previous 30 years, primarily driven by the upper Chesapeake Bay and Potomac River. In 2005, 115 juvenile American shad were captured at seven permanent sites by Maryland's juvenile striped bass seine survey (SBSS) during fourteen hauls and 129 juvenile

American shad were captured at the auxiliary sites. Juvenile American shad indices for the upper Chesapeake Bay based on the long-term data collected by SBSS have increased exponentially since 1980 (Figure 8; $r^2 = 0.32$ $P<0.001$). Results from OTC analysis completed on subsampled juvenile American shad from 2004, have shown all these fish to be non-hatchery. These strong juvenile indices have demonstrated sufficient spawning habitat and suitable water quality in these systems, while stocks in many other tributaries are minimal or unknown.

Sampling in the Susquehanna River for juvenile American shad in 2005 was unsuccessful. Reasons for the low catch rates include downriver migration soon after hatching, availability of food, salinity gradient, water temperature and predation.

2. Hickory shad

a. Adults

Hickory shad are difficult to capture because of their aversion to fishery independent (fish lifts and traps) and fishery dependent (commercial pound and fyke nets). Consequently, 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). Ninety percent of hickory shad in Deer Creek spawned by age four and stocks generally consisted of few virgin fish (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.

b. Juveniles

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

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Table 1. Numbers of adult American shad and repeat spawners by sex and age sampled from the Conowingo tailrace in 2005.

Conowingo Dam Tailrace

AGE	Male		Female		Total	
	N	Repeats	N	Repeats	N	Repeats
2	2	0	0	0	2	0
3	8	0	0	0	8	0
4	64	1	35	0	99	1
5	37	13	81	9	118	22
6	32	24	92	41	124	65
7	5	5	27	20	32	25
8	1	1	1	1	2	2
Totals	149	44	236	71	385	115
Percent Repeats	29.5%		30.1%		29.9%	

Table 2. Conowingo tailrace population estimate of adult American shad in 2005.

Chapman's Modification of the Petersen estimate

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

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

For the 2005 survey
C = 65,411
M = 389
R = 78

Therefore:

$$N = \frac{(65{,}411 + 1)(389 + 1)}{(78+ 1)} = 322{,}920$$

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

Using Chapman (1951):

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

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

$$\text{Upper } N = \frac{(65{,}411 + 1)(389 + 1)}{(62.5 + 1)} = 407{,}743$$

$$\text{Lower } N = \frac{(65{,}411 + 1)(389 + 1)}{(97.3 + 1)} = 259{,}413$$

Table 3. Conowingo Dam tailrace hook and line data, 1982-2005.

Year	Total Catch	Hours fished	CPAH[1]	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

[1] Catch-per-angler-hour

Table 4. Recreational creel survey data from the Susquehanna River below Conowingo Dam, 2001-2005.

Year	Number of Interviews	Total Fishing Hours	Total Catch of American Shad	Mean Number of American shad caught per hour
2001	90	202.9	991	4.88
2002	52	85.3	291	3.41
2003	65	148.2	818	5.52
2004	97	193.3	233	1.21
2005	29	128.8	63	0.49

Table 5. Summary of the spring American shad logbook data, 1999-2005.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of American shad Caught	Mean Number of American shad caught per hour
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

Table 6. Summary of the Deer Creek hickory shad logbook data, 1998-2005.

Year	Number of Returned Logbooks	Total Reported Angler Hours	Total Number of Hickory Shad Caught	Mean Number of Hickory Shad Caught per Hour
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

Table 7. Age structure of hickory shad from the Susquehanna River based on scales, 1998-2004.

Year	Number per Age Group						
	II	III	IV	V	VI	VII	VIII
1998	68	176	104	18	0	1	0
1999	45	351	98	4	2	0	0
2000	19	106	115	39	3	2	0
2001	11	121	72	31	4	0	0
2002	20	94	89	25	8	4	0
2003	1	22	30	21	4	1	1
2004	0	7	19	22	15	15	3
2005	Not yet done						

Figure 1. Location of the 2005 hook and line sampling in Conowingo Dam tailrace.

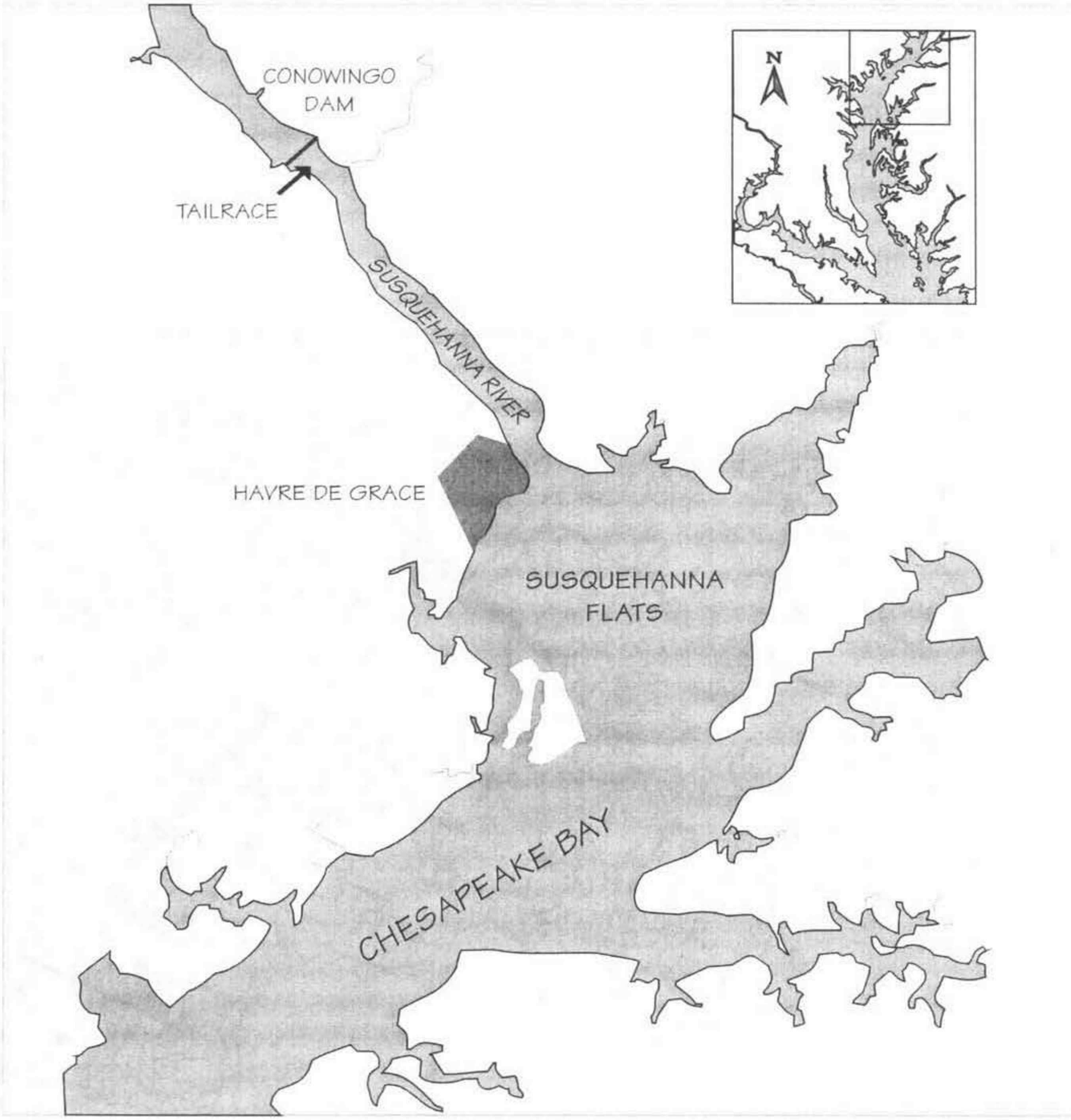


Figure 2. Distribution of the 2005 seine sites (black circles) on the Susquehanna River.

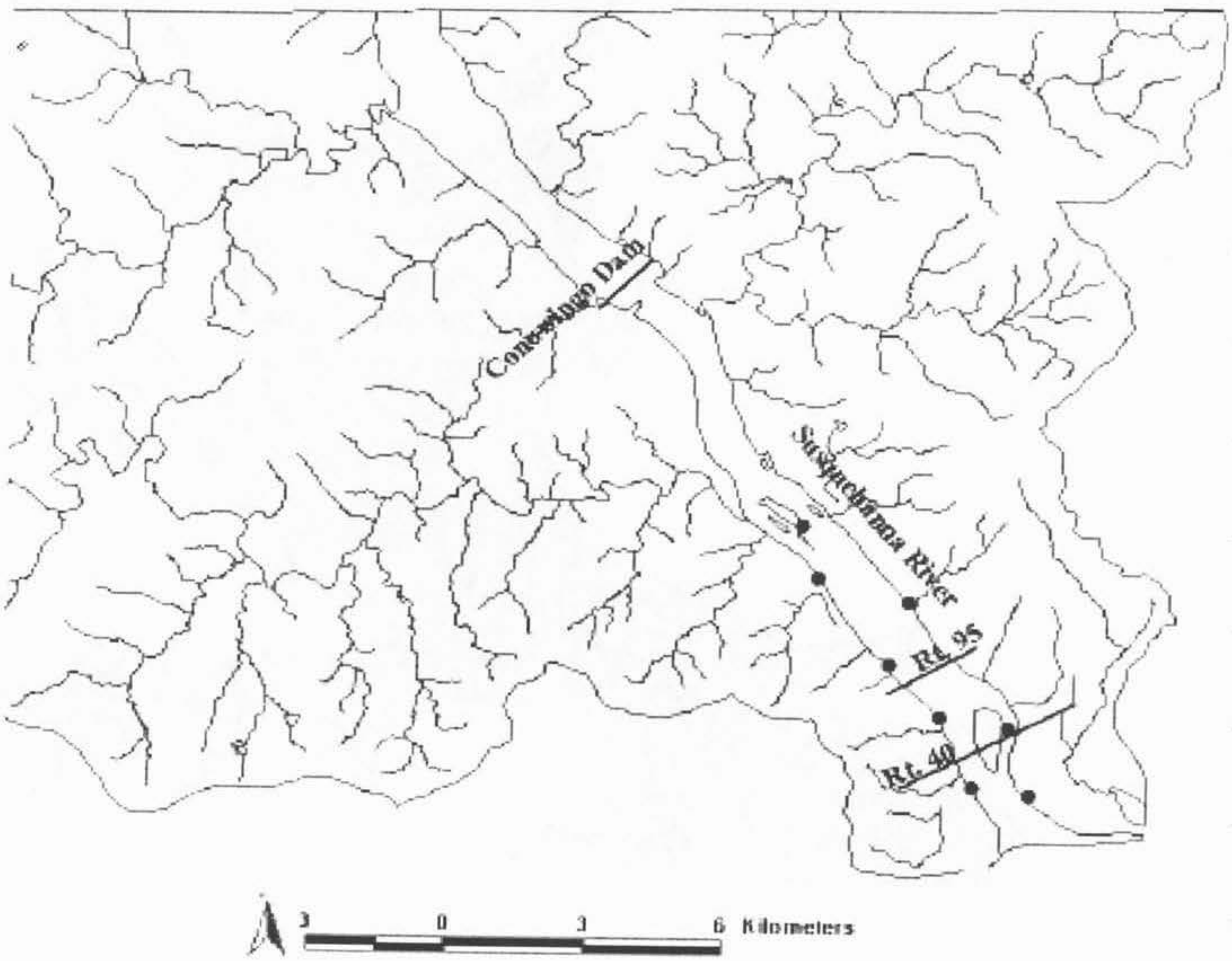


Figure 3. Trends in arcsine-transformed percentages of repeat spawning American shad (sexes combined) collected from the Conowingo Dam tailrace (1984-2005).

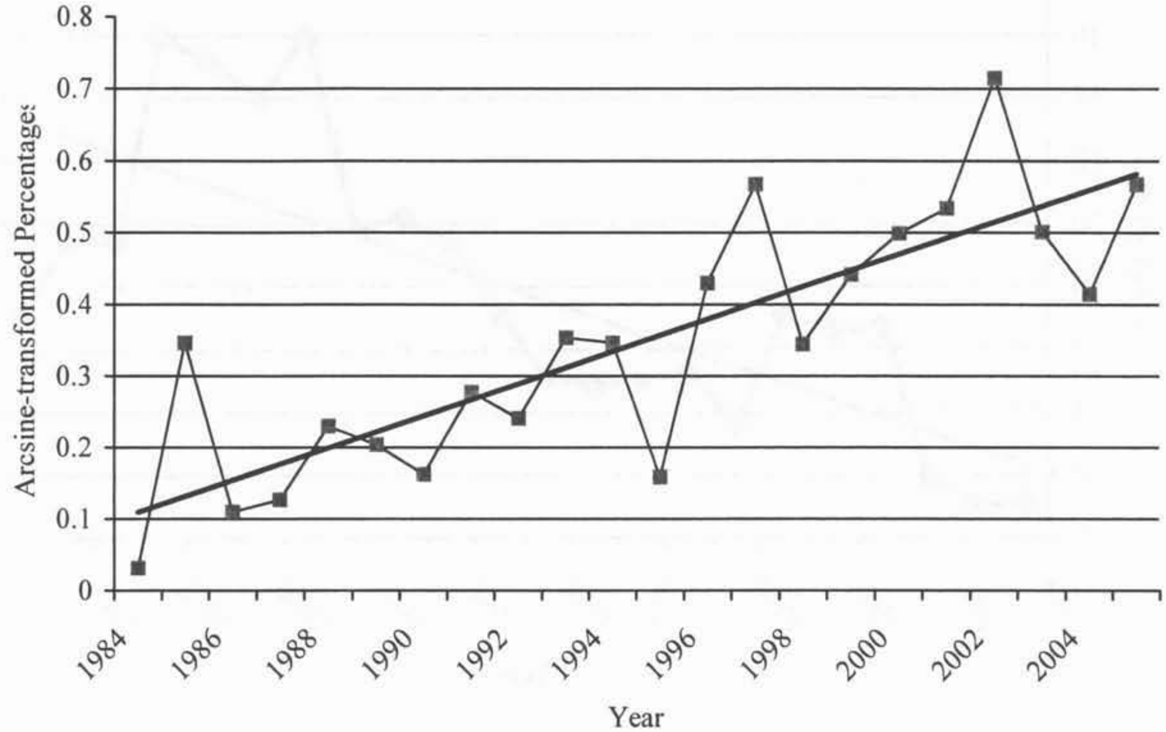


Figure 4. Conowingo Dam tailrace relative estimates of American shad abundance with 95% confidence intervals, 1984-2005.

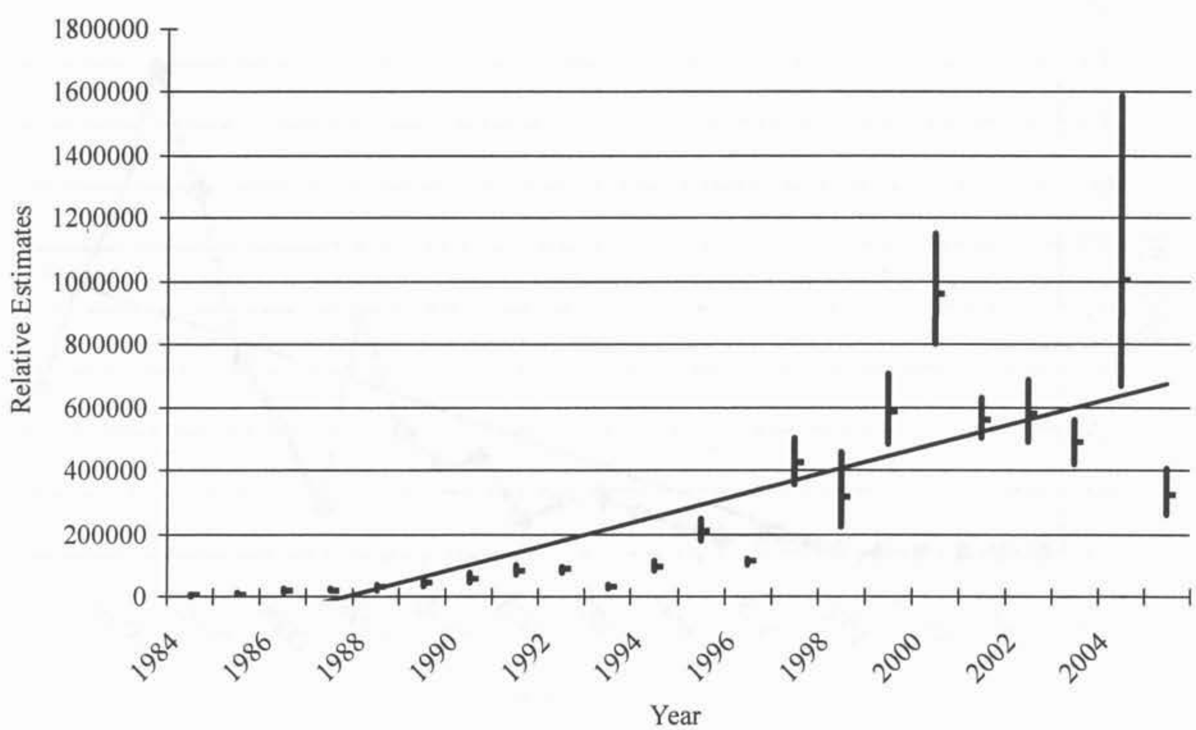


Figure 5. Geometric mean CPUE from Conowingo Dam tailrace hook and line sampling.

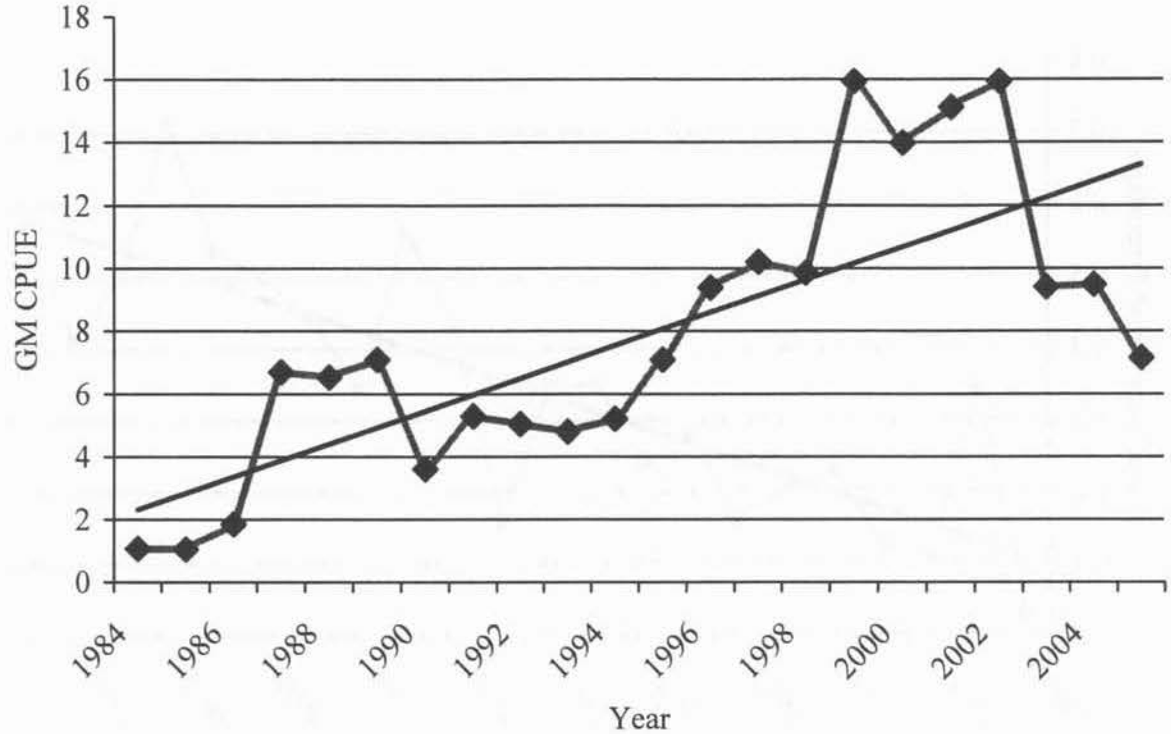


Figure 6. Geometric mean CPUE of American shad captured in east and west lifts at Conowingo Dam.

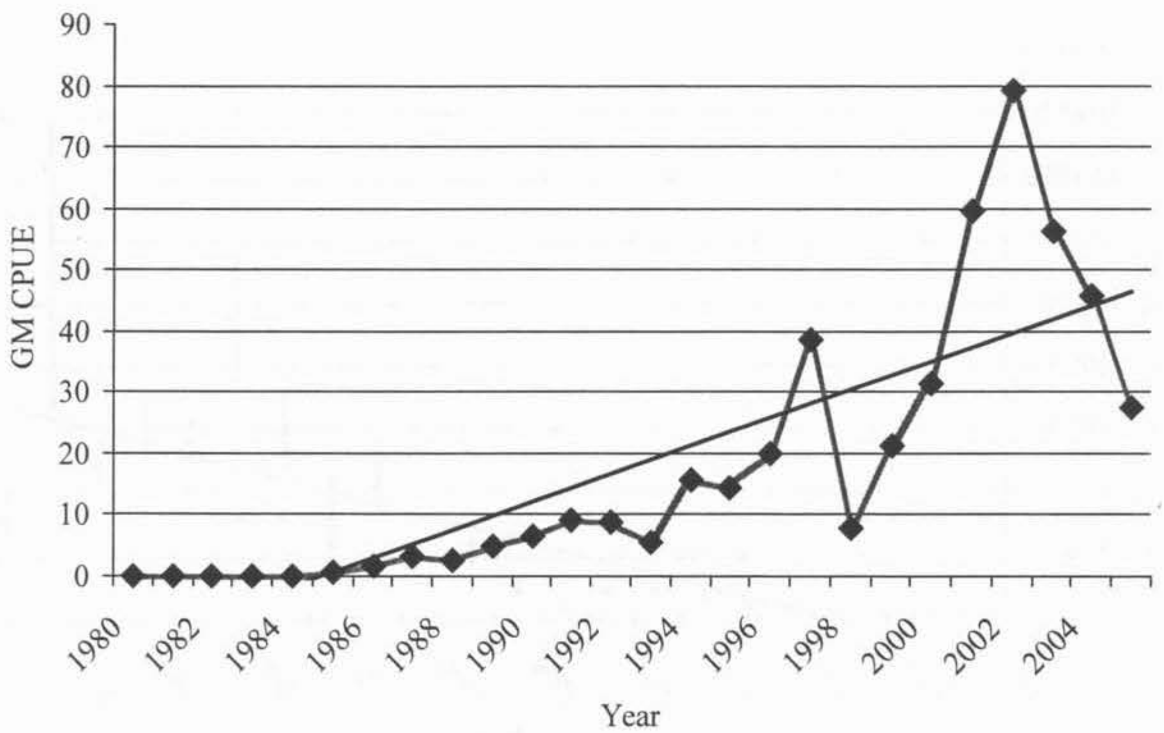
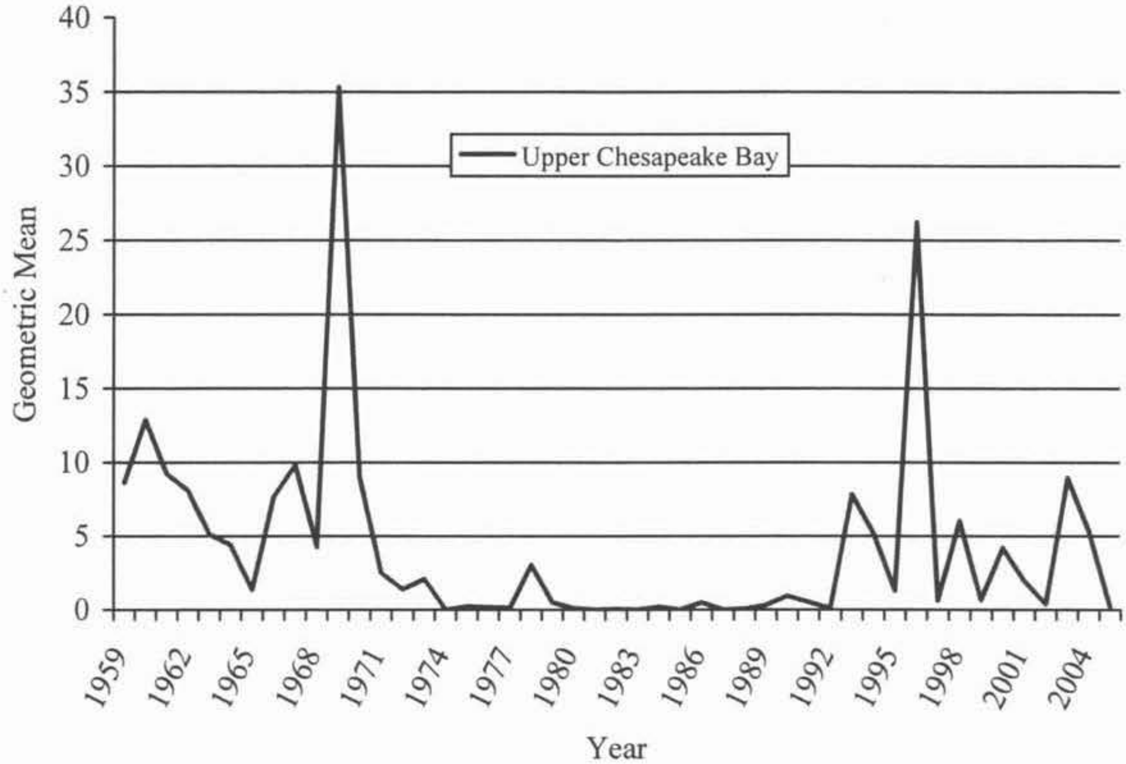


Figure 7. Upper Chesapeake Bay American shad juvenile indices based on the SBSS dataset, 1959-2005.



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