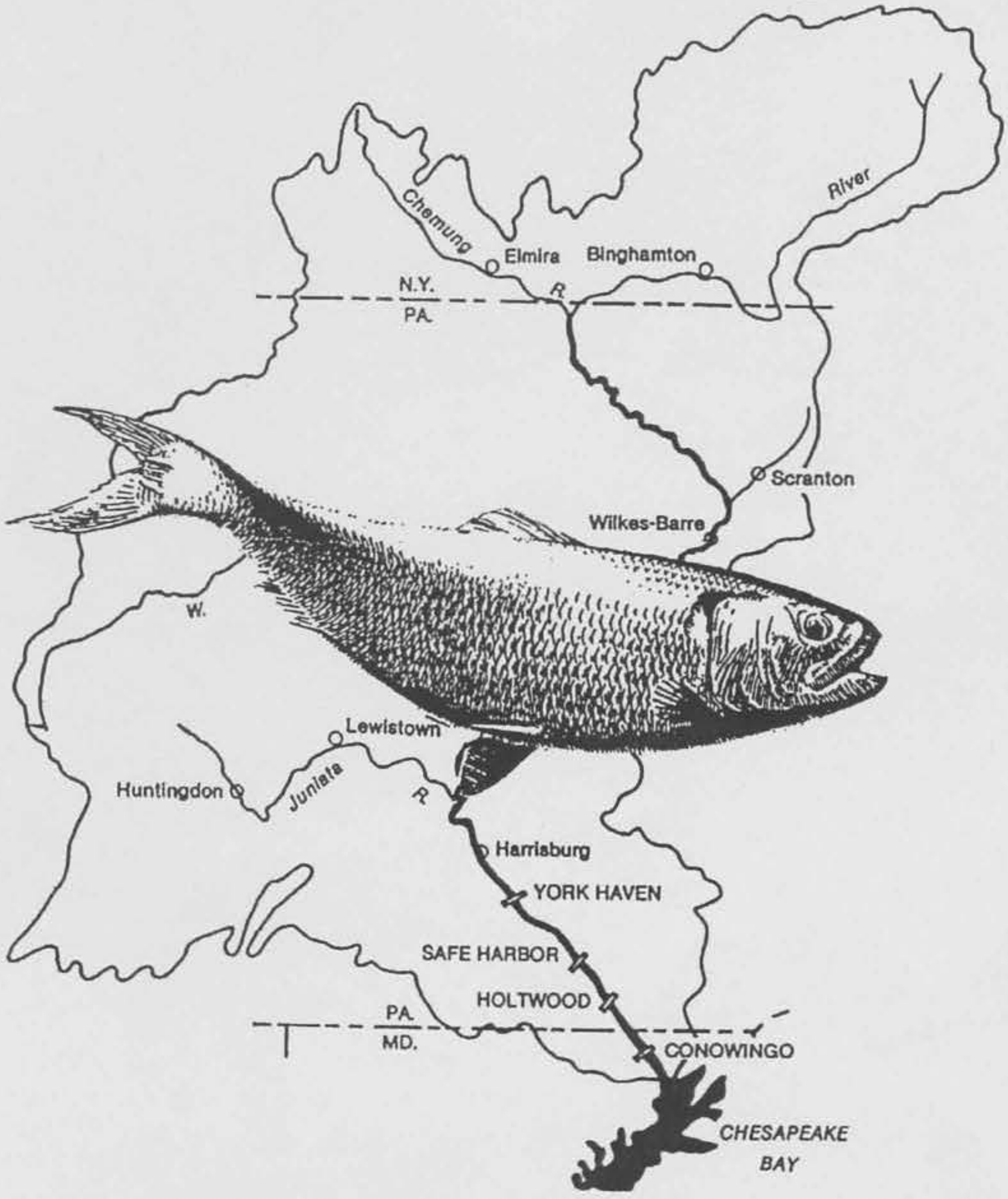
Restoration of American Shad to the Susquehanna River

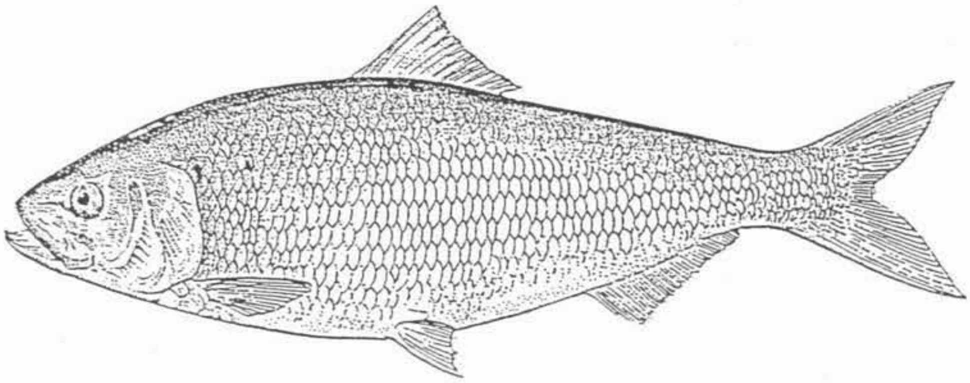
Annual Progress Report
2002



Susquehanna River
Anadromous Fish Restoration Committee

February 2003

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2002

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

MARYLAND DEPARTMENT OF NATURAL RESOURCES
NATIONAL MARINE FISHERIES SERVICE
NEW YORK DIVISION OF FISH, WILDLIFE AND MARINE RESOURCES
PENNSYLVANIA FISH AND BOAT COMMISSION
SUSQUEHANNA RIVER BASIN COMMISSION
UNITED STATES FISH AND WILDLIFE SERVICE

FEBRUARY 2003

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EXECUTIVE SUMMARY

This 2002 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. This program, much of it funded by hydroelectric project operators, is aimed at rebuilding anadromous American shad and river herring stocks based on hatchery releases and natural reproduction of adult fish directly passed at 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 2002 was characterized by relatively high and fluctuating river flows (35-190k cfs) which led to spilling on most days at Holtwood. The Conowingo East lift began operations on April 8 and shad appeared in abundance on April 12. From that date until May 14, 88,027 shad were passed. All projects shutdown for high water during May 15-22, and Conowingo passage from May 23 through June 7 amounted to an additional 19,974 shad. One-half the entire season run (54,235 fish) passed Conowingo during the 8-day period May 6-13 at water temperatures of 60-66°F.

For the season the East lift operated 49 days, made 560 lifts and passed 656,894 fish representing 31 taxa. Only three species comprised 99% of all fish passed: gizzard shad (513,794), American shad (108,001) and white perch (29,404). Other alosids included only 2,037 blueback herring, 74 alewives and 6 hickory shad. Maryland DNR tags observed here totaled 195, most of which were year 2002 fish tagged in the tailrace.

The Conowingo West lift operated on 31 days from late April through early June, fishing for 147 hours and making 417 separate lifts. Total catch amounted to 419,103 fish including 339,292 gizzard shad, 65,031 white perch, 9,347 American shad, 428 blueback herring, and 141 alewives. Sex ratio in the American shad run was 1.2 : 1.0 favoring males. Every 50th shad collected throughout the season was killed for otolith analysis and a scale sample. Shad used for spawning trials includes 1,350 delivered to USFWS-Lamar, 305 provided to Maryland DNR, and 1,000 kept on-site at Conowingo Dam. Herring were not stocked upstream in 2002.

The tailrace lift at Holtwood operated on 35 days during April 15 through June 7, fishing for 207 hours and making 275 lifts. The spillway lift operated on 27 days making 200 lifts in 154 hours.

High river flows forced shutdown of Holtwood fish lifts on May 2-5 and May 14-26. A total of only 17,522 American shad were passed in 2002 - 9,618 at the tailrace and 7,904 at the spillway. Other fish in combined Holtwood collections included 107,600 gizzard shad, 13 bluebacks and 10,150 others. Peak passage day for American shad was May 10 (2,978 fish). Shad passage rate at Holtwood in 2002 was only 16.2% of those passed at Conowingo East lift, a substantial decline from the record 56.8% seen in 2001, and the poorest year on record.

The Safe Harbor fish lift operated for 221.5 hours during 35 days between April 17 and June 13 and made 315 lifts. Operations were suspended during May 15-27 due to high water (Holtwood shutdown) and total fish passage for the season was 135,720 fish including 11,705 American shad and 98,138 gizzard shad. Peak day of American shad passage was May 13 (2,021). Safe Harbor passed almost 67% of the shad passing Holtwood.

Fish ladder operations at York Haven's East Channel Dam occurred on 31 days between April 29 and June 11. Shad were observed passing the site on 28 days and peak passage occurred on June 2 (208 fish). For the season, total fish passage at York Haven amounted to 145,935 fish including 100,779 gizzard shad, 1,555 American shad (13.3% of Safe Harbor total), and 43,601 others (25 species). Most American shad (95%) passed York Haven during two 9-day periods, interrupted by a high flow event. Some 618 (40%) passed between May 6-14, and 855 (55%) passed during May 31 through June 8.

No pound nets were set in upper Chesapeake Bay and Maryland DNR collected shad for tag and release only by angling in the Conowingo tailrace. Total catch was 812 shad of which 780 were tagged and released. Using recapture (tag sightings) primarily from the East lift, a shad population index was calculated for the Conowingo tailrace of 555,597, essentially unchanged from 2001. Scale analysis from angling samples showed that most males were aged 4-6 with 21.5% repeat spawning (compared to 25.6% in 2001), and most females were ages 5-7 with a program record 48% repeat spawners (compared to 27.1% last year).

Based on analysis of 182 readable otoliths from adult shad taken at Conowingo West lift, 120 (66%) were of hatchery origin and 62 (34%) were wild. The majority of hatchery fish (87 or 72.5%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River or mainstem Susquehanna below Sunbury. Most others (26 fish - 22%) carried various triple marks and the remainder were double (2), quadruple (4), and quintuple (1) marked. 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 almost fully recruited year-classes of 1986-1996, it took an average 212 stocked larvae, 133 stocked fingerlings, and/or 0.64 transplanted or passed adults to produce each adult return to Conowingo Dam.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River and PFBC completed Delaware River egg collections. The Hudson River produced 18.51 million eggs with 62% viability. Delaware River collections were hampered by adverse weather and flow conditions and produced only 2.04 million eggs with 41% viability. In a second year attempt at tank spawning at Conowingo Dam, Normandeau Associates setup a second tank, completed 20 spawning trials using 1,000 fish (340 females) to produce 7.08 million eggs of which only 10.1% were viable. In a fifth year tank-spawning effort at Lamar (USFWS Northeast Fishery Center), 1,350 adult shad were delivered from the West Lift during April 23 through June 7. Approximately 8 million eggs were delivered to Van Dyke with 10.3%.

In addition to reduced egg viability from suppliers (38.8% overall), Van Dyke Hatchery experienced unusual post-hatch mortality problems which later was attributed to chemically treated foam bottoms used in the Van Dyke incubation jars. Total production in 2002 was 2.676 million fry (compared to an average 10 million during 1982-2001) of which 2.589 million were stocked in the Susquehanna drainage as follows: 2.12 million in the Juniata River; 21,000 in the North Branch (PA); 359,100 in the North Branch and Chemung rivers (NY); 50,000 in the West Branch; and 36,000 in three lower river tributaries. The PFBC also reared and stocked 85,000 shad fry for the Lehigh River and 2,000 for the Schuylkill River. Lamar stocked about 51,000 shad fry into Bald Eagle Creek, a tributary to the West Branch. All fish were distinctively marked with tetracycline.

Juvenile shad collections were very weak in 2002 as a result of near record low hatchery stocking and small numbers of adults passing Safe Harbor and York Haven fishways. The usually productive haul seine at Columbia, PA produced no shad in 15 weeks of effort (84 hauls). Push netting and electrofishing also produced no shad. A total of 68 juvenile shad were taken with lift net at Holtwood's inner forebay on four dates between October 15-27. Peach Bottom screens produced 18 shad, 2 bluebacks, and 5 alewives, while intake strainers at Conowingo provided 6 shad and 4 alewives. During July-September seine sampling in the upper Chesapeake Bay, Maryland DNR collected 49 juvenile shad.

Otoliths from a total of 86 juvenile shad were examined for hatchery marks from combined collections made at and above Conowingo Dam. Of these, 78% were hatchery marked with the majority of those (54%) carrying marks indicating that they were stocked at various locations in the Juniata River. Most of the remaining hatchery fish examined came from stockings in the North Branch in New York and the Chemung River (44%) with only one fish from the West Branch and none from the North Branch (PA) or the three stocked tributaries. In terms of relative survival from stocking site to recovery, the two New York release areas (both Hudson source eggs) produced the best results followed by the West Branch, Juniata (Susquehanna eggs), and Juniata (Hudson eggs).

Fish passage facility operations, 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, shad netting above Conowingo Dam, and otolith mark analysis were funded by the PA Fish and Boat Commission. Maryland DNR funded the adult shad population assessment, stock analysis, and juvenile shad seining in the upper Chesapeake Bay. USFWS covered most costs associated with tank spawning and production at Lamar. Costs related to Conowingo West fish lift operations including trucking of shad to Lamar and tank spawning were paid from a SRAFRC contributed funds account administered by USFWS. This account also paid for hormones used at Lamar and Conowingo for tank spawning. Contributions to the special account in 2002 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 IN SPRING 2002

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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 has been to monitor fish populations below Conowingo Dam and transport pre-spawned migratory fishes upriver.

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

With the completion of fishways at Holtwood, Safe Harbor, and York Haven dams, the East lift has been operated to pass fish directly into Conowingo Pond since spring 1997. Objectives of 2002 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 512 MW and a hydraulic capacity of 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, 7,500, and 5,000 cfs were maintained from 1 to 30 April, 1 to 31 May, and 1 to 7 June, respectively.

Fishway Operation

East lift operation began on 8 April and generally operated on an every day basis after 12 April. Operations were suspended on 27 April due to a hopper shieve wheel bearing seizure. Lift operation resumed on a daily basis on 30 April. Operations were again suspended from 15 through 22 May due to high river flow conditions. Operations resumed 23 May with continuous operation until the season ended on 7 June. The lift was operated a total of 49 days during the 2002 season. 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 the East lift operation in 2002 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. Entrance C was used to attract fishes during the entire 2002 season. Entrance A was used once on 12 April.

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 656,894 fish of 30 species and 1 hybrid was passed upstream into Conowingo Pond. Gizzard shad (513,794), American shad (108,001), and white perch (29,404) were the dominant species passed, comprising 78%, 16%, and 4% respectively of the season total; the three species together accounted for 98% of the total fish passed. Other common fishes included blueback herring (2,037), striped bass (913) and smallmouth bass (597). Alosids (American shad, hickory shad, blueback herring, and alewife) comprised nearly 17% of the total catch. Peak passage occurred on 4 May when 40,234 fish, (94% gizzard shad), were passed.

American Shad Passage

The East lift collected and passed 108,001 American shad (Table 1). The first shad was passed on 10 April. Collection and passage of shad varied daily with 50% (54,235) of the shad collected and passed during the eight day period between 6 and 13 May. The lift collected and passed over 10,000 American shad on three separate days. On 30 of the 49 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on 8 May when 12,323 American shad were passed.

American shad were collected at water temperatures of 52.5 to 77.0°F and at natural river flows of 28,500 to 97,200 cfs (Table 2 and Figure 1). The average daily river flow on those days when American shad passage exceeded 1000 fish was approximately 44,000 cfs. The average daily river flow during the operational season was 47,055 cfs. The hourly passage of

American shad for the East lift is given in Table 3. Peak hourly passage of shad (15,024) occurred between 1300 to 1359 h. Generally, shad passage was steady, all hour periods from 1100 to 1859 h had passage greater than 9,000 shad.

Other Alosids

A total of 74 alewife was collected and passed (Table 1). The majority of alewife (47) passed on 17 and 18 April. Six hickory shad were collected and passed in spring 2002. A total of 2,037 blueback herring was collected and passed (Table 1). Most blueback herring (92%) were passed on 1 June at a water temperature of 75.0°F and river flow of 36,700 cfs.

SUMMARY

Low river flows and water temperatures above 50°F allowed East fish lift operations to commence on 8 April. Despite the unexpected occurrence of high river flows during the historical peak shad passage period, the East lift successfully passed 108,001 American shad by the season's end. The total number of American shad passed during the 2002 season was the third highest passage total since East lift operations began in 1991 and the third consecutive year in which American shad passage has surpassed 100,000 fish (Table 4).

A total of 1,242 American shad lift mortalities, (1% of the total shad passed), were observed this season, similar to the lift mortalities observed in previous years and less than values observed during trap and transport operations.

One modification was made prior to the start of the 2002 season. A 30 inch diameter fiberglass elbow was attached to the hopper extension chute in the trough. The new chute modification allows fish to enter the trough center stream. Fish viewing conditions were similar to those encountered in 2001 despite the occurrence of high spring river flows. Decent water clarity allowed technicians to view well over 22 inches of the viewing area throughout most of the season. Visual counting accuracy was maximized by utilizing two people during periods of increased fish passage and/or poor viewing conditions.

RECOMMENDATIONS

1. 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.

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. Inspect all cables and limit switches to meet design specifications, and continue to evaluate effectiveness of modifications.

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

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2002. No operation on April 9, 11, 28, 29, and May 15-22.

Date:	*08 Apr*	*10 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*
Hours of Operation:	*4.2*	*5.8*	*7.5*	*7.5*	*7.8*	*7.8*	*10.5*	*6.3*
Number of Lifts:	*5*	*6*	*8*	*8*	*8*	*8*	*8*	*7*
Water Temperature (°F):	*51.0*	*52.0*	*54.0*	*56.0*	*58.0*	*64.0*	*63.0*	*66.0*
American shad		64	1,523	2,127	2,968	1,315	2,599	411
Blueback herring							1	
Alewife			1					24
Gizzard shad	3,823	174	6,759	3,908	239	4,948	7,423	18,803
Hickory shad			5	1				
Sea lamprey	3		5		2	2	5	13
Rainbow trout								
Brown trout			1					
Splake								
Carp						1		
Spottail shiner								
Creek chub							1	
Quillback								
White sucker			1	5	3		1	1
Shorthead redhorse			1	1	1	7	3	12
White catfish								
Brown bullhead								
Channel catfish							1	2
White perch								9
Striped bass								2
Rock bass								1
Redbreast sunfish								
Green sunfish					1			1
Pumpkinseed	1			1				1
Bluegill	11	4				2		
Smallmouth bass			4	8	7	7	9	23
Largemouth bass			1	2	1	3		
Yellow perch						1	2	1
Walleye				1		4	3	4
Tessellated darter								1
Atlantic needlefish								
TOTAL	***3,838***	***242***	***8,301***	***6,054***	***3,222***	***6,290***	***10,048***	***19,309***

Table 1

Continued.

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*
Hours of Operation:	*7.8*	*7.9*	*7.6*	*7.5*	*6.3*	*4.7*	*7.8*	*9.8*
Number of Lifts:	*8*	*7*	*8*	*13*	*8*	*7*	*13*	*13*
Water Temperature (°F):	*67.0*	*72.0*	*71.0*	*69.0*	*69.0*	*68.0*	*64.0*	*62.0*
American shad	96	82	1,060	5,299	274	136	3,746	1,829
Blueback herring				4			2	
Alewife	23	1	2		2			1
Gizzard shad	15,577	20,559	16,888	19,876	12,481	8,420	16,210	8,021
Hickory shad								
Sea lamprey	10	23	16	23	22	6	10	13
Rainbow trout					1			1
Brown trout							1	
Splake				2				
Carp	2	9	2	2	3	1		
Spottail shiner								
Creek chub								
Quillback			2	1	2	2		
White sucker					1	1		1
Shorthead redhorse	8	7	1	1	2		1	5
White catfish								
Brown bullhead	1							
Channel catfish	3	4	3	1	7	1		
White perch	55	933	81	128	919	68	33	78
Striped bass	1	6		12	95	6	37	33
Rock bass	3	4	2		1		2	
Redbreast sunfish	2					2		
Green sunfish		1						
Pumpkinseed								
Bluegill	5			3	1		1	4
Smallmouth bass	33	62	4	12	16	7	4	3
Largemouth bass		1			2			1
Yellow perch	1	6	1	17	8	7	14	88
Walleye	8	2			1		1	
Tessellated darter								
Atlantic needlefish								
TOTAL	***15,828***	***21,700***	***18,062***	***25,381***	***13,838***	***8,657***	***20,062***	***10,078***

Table 1

Continued.

Date:	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*
Hours of Operation:	*9.9*	*8.2*	*0.0*	*0.0*	*10.3*	*9.3*	*9.8*	*8.0*
Number of Lifts:	*11*	*7*	*0*	*0*	*14*	*11*	*13*	*10*
Water Temperature (°F):	*61.0*	*60.0*	*16.0*	*62.0*	*59.0*	*61.0*	*60.0*	*60.0*
American shad	1,100	2,695	394	14	1,255	646	597	121
Blueback herring						1	3	3
Alewife	9	5			6			
Gizzard shad	3,861	5,800	18		16,162	7,899	13,780	8,097
Hickory shad								
Sea lamprey	5	2	1		12	2	4	4
Rainbow trout							2	
Brown trout								
Splake								
Carp	1							
Spottail shiner								
Creek chub								
Quillback								
White sucker					1			
Shorthead redhorse						2	3	
White catfish								
Brown bullhead								
Channel catfish							1	
White perch	24	2	1	1	3,112	13,172	171	6
Striped bass	48	13	6		49	16	3	17
Rock bass					1		1	
Redbreast sunfish								
Green sunfish		1		1				
Pumpkinseed								
Bluegill					3	2		
Smallmouth bass	6	1			15	3	14	6
Largemouth bass	2							
Yellow perch	9	7			30	2	1	1
Walleye						2		
Tessellated darter								
Atlantic needlefish								
TOTAL	***5,065***	***8,526***	***420***	***16***	***20,646***	***21,747***	***14,580***	***8,255***

Table 1

Continued.

Date:	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*11 May*
Hours of Operation:	*10.8*	*9.5*	*9.5*	*9.8*	*10.3*	*9.8*	*10.6*	*11.0*
Number of Lifts:	*17*	*13*	*15*	*15*	*23*	*18*	*19*	*22*
Water Temperature (°F):	*60.0*	*59.0*	*60.0*	*61.0*	*62.0*	*61.0*	*64.0*	*64.0*
American shad	1,689	1,224	2,711	4,047	12,323	4,683	4,245	11,595
Blueback herring	11	1	4	2		14		2
Alewife								
Gizzard shad	38,006	12,643	22,088	18,567	10,316	16,014	16,985	18,416
Hickory shad								
Sea lamprey	17	7	14	15	16	2	6	14
Rainbow trout	1			1		2		
Brown trout		1				1		1
Splake								1
Carp			1			4	6	1
Spottail shiner								
Creek chub								1
Quillback		1	7	6	2	19	7	3
White sucker								
Shorthead redhorse	14	4	8	29	16	17	56	8
White catfish								
Brown bullhead		1				1	1	1
Channel catfish	7	6	1	1	1			3
White perch	464	258	528	332	375	3,081	4,298	292
Striped bass	12	11	29	13	9	28	15	8
Rock bass						5	3	5
Redbreast sunfish							2	
Green sunfish								
Pumpkinseed	1					1		
Bluegill		3	1	1	1	7	3	4
Smallmouth bass	10	6	10	19	7	36	11	28
Largemouth bass	2	3			1		1	
Yellow perch		4	1	1	1	7	6	6
Walleye			3			8	6	2
Tessellated darter								
Atlantic needlefish								
TOTAL	***40,234***	***14,173***	***25,406***	***23,034***	***23,068***	***23,930***	***25,651***	***30,391***

Table 1

Continued.

Date:	*12 May*	*13 May*	*14 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours of Operation:	*10.4*	*8.3*	*8.7*	*4.5*	*8.0*	*10.0*	*9.8*	*10'0*
Number of Lifts:	*22*	*12*	*13*	*6*	*14*	*13*	*16*	*11*
Water Temperature (°F):	*64.0*	*66.0*	*65.0*	*57.0*	*59.0*	*63.0*	*62.0*	*64.0*
American shad	11,142	3,492	525	1	292	1,765	3,046	1,896
Blueback herring	1				1		27	74
Alewife								
Gizzard shad	18,770	10,453	12,518	11,100	28,325	7,661	7,203	5,665
Hickory shad								
Sea lamprey	19	5	5		2			
Rainbow trout								5
Brown trout			1					
Splake								1
Carp			7	1	1	3	89	4
Spottail shiner								
Creek chub								
Quillback	6	13	11		1	11	12	10
White sucker	1							
Shorthead redhorse	5	6	13		3	13	16	26
White catfish			1					
Brown bullhead			1					
Channel catfish	8	1	38	86	6	4		1
White perch	538	297	54		4	20	1	
Striped bass	9	46	53	3	6	8	6	2
Rock bass	5							1
Redbreast sunfish	1	3	1					2
Green sunfish								
Pumpkinseed		2	1	1				1
Bluegill	1	3	3	1		4	1	3
Smallmouth bass	43	10	5	8	46	10	19	20
Largemouth bass				2			2	1
Yellow perch	3	8			2		1	2
Walleye	6	7	8	3	6		1	4
Tessellated darter								
Atlantic needlefish								
TOTAL	***30,558***	***14,346***	***13,245***	***11,206***	***28,695***	***9,499***	***10,424***	***7,718***

Table 1

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*
Hours of Operation:	*9.0*	*7.5*	*10.0*	*8.3*	*8.8*	*8.3*	*8.3*	*8.2*
Number of Lifts:	*16*	*11*	*12*	*9*	*14*	*8*	*9*	*10*
Water Temperature (°F):	*65.0*	*65.0*	*66.0*	*69.0*	*75.0*	*76.0*	*77.0*	*76.0*
American shad	3,197	1,352	1,907	1,305	2,569	756	312	665
Blueback herring		1	1	5	1,876			
Alewife								
Gizzard shad	8,333	7,181	4,518	4,744	5,893	1,314	4,556	1,915
Hickory shad								
Sea lamprey				11				
Rainbow trout	1			3		2		1
Brown trout		1	1	1		2	1	
Splake								
Carp		2	3	4	3	1	3	3
Spottail shiner						1		
Creek chub								
Quillback	14	2	1	6	12	2	9	170
White sucker								
Shorthead redhorse	2		1					
White catfish								
Brown bullhead								
Channel catfish	2	1	1	2			2	1
White perch	28	17	6	2	3	6	1	
Striped bass	21	10	15	21	14	37	25	47
Rock bass	1	3		2			1	
Redbreast sunfish		1			2		20	7
Green sunfish								
Pumpkinseed					2		1	
Bluegill	3	12		1	1	7	12	7
Smallmouth bass	23	6	13	6	5	2	2	4
Largemouth bass			4	1			3	2
Yellow perch	1			6	2	1	3	4
Walleye	3	1			1	2		
Tessellated darter								
Atlantic needlefish								
TOTAL	***11,629***	***8,590***	***6,471***	***6,120***	***10,383***	***2,133***	***4,951***	***2,826***

Table 1

Continued.

Date:	*05 Jun*	*06 Jun*	*07 Jun*	***Total***
Hours of Operation:	*7.5*	*7.5*	*6.3*	***440.7***
Number of Lifts:	*7*	*7*	*7*	***560***
Water Temperature (°F):	*76.0*	*77.0*	*76.0*	
American shad	406	320	185	**108,001**
Blueback herring	1	1	1	**2,037**
Alewife				**74**
Gizzard shad	216	458	210	**513,794**
Hickory shad				**6**
Sea lamprey				**316**
Rainbow trout				**20**
Brown trout				**12**
Splake				**4**
Carp	2	8	5	**172**
Spottail shiner				**1**
Creek chub				**2**
Quillback	4	2	62	**400**
White sucker				**16**
Shorthead redhorse				**292**
White catfish				**1**
Brown bullhead				**6**
Channel catfish	1	2	1	**199**
White perch	1	1	4	**29,404**
Striped bass	38	46	37	**913**
Rock bass				**41**
Redbreast sunfish	4		4	**51**
Green sunfish				**5**
Pumpkinseed			1	**14**
Bluegill	6		9	**130**
Smallmouth bass	1	1	2	**597**
Largemouth bass			3	**38**
Yellow perch	1	2		**258**
Walleye		1		**88**
Tessellated darter				**1**
Atlantic needlefish			1	**1**
TOTAL	***681***	***842***	***525***	**656,894**

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 2002. No operation on April 9, 11, 28, 29, and May 15-22.

Date	American Shad Catch	MD DNR Recaptures*	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
08 Apr	0	*0*	39,500	51.0	30	10	C	310	21.50	106.9	0
10 Apr	64	*0*	33,500	52.5	30	7	C	310	20.0-22.0	107.8	0
12 Apr	1523	*0*	29,300	54.0	30	7	A then C	310	19.5-20.5	106.9	0
13 Apr	2127	*0*	29,400	56.0	25	7	C	310	18.5-22.0	106.8	0
14 Apr	2968	*0*	26,800	58.5	30	2	C	310	15.1-15.2	107.1	0
15 Apr	1315	*0*	34,000	63.5	25	8	C	310	21.0-22.5	107.7	0
16 Apr	2599	*0*	38,400	62.6	23	10	C	310	17.0-23.0	106.7	0
17 Apr	411	*0*	51,600	66.4	22	10	C	310	23.00	105.4	0
18 Apr	96	*0*	66,200	66.8	20	10	C	310	23.00	106.5	0
19 Apr	82	*0*	61,100	72.5	20	10	C	310	20.0-20.1	106.2	0
20 Apr	1060	*1PK*	53,300	70.7	29	10	C	310	20.00	108.3	0
21 Apr	5299	*1PK,1GR*	47,300	68.9	31	6	C	310	18.2-18.3	107.7	0
22 Apr	274	*0*	43,400	68.9	16	10	C	310	23.00	108.3	0
23 Apr	136	*0*	39,400	64.8	23	8	C	310	21.0-23.0	108.2	0
24 Apr	3746	*2PK*	35,900	63.9	25	7	C	310	21.5-22.0	107.0	0
25 Apr	1829	*1PK,2CH*	34,900	61.9	28	6	C	310	21.50	106.6	0
26 Apr	1100	*0*	31,600	61.2	30	6	C	310	17.7-18.4	107.6	0
27 Apr	2695	*2PK,1GR*	29,500	60.0	30	6	C	310	19.0-21.5	106.7	0
28 Apr**	394	*0*	30,400	60.0	30						0
29 Apr**	14	*0*	34,400	62.5	30						0
30 Apr	1255	*0*	42,300	59.0	20	11	C	310	22.0-23.0	106.7	0
01 May	646	*0*	66,900	60.7	20	10	A	310	23.00	106.2	0
02 May	597	*0*	73,000	59.8	20	11	A	310	23.5-24.0	106.3	0
03 May	121	*0*	72,600	60.0	19	11	C	310	22.0-23.5	105.7	0
04 May	1689	*1GR*	69,600	60.0	18	11	C	310	22.0-22.5	106.0	0
05 May	1224	*1GR*	66,200	59.4	25	11	C	310	22.5-24.0	107.8	0
06 May	2711	*4GR*	59,200	59.6	24	11	C	210	23.00	107.9	0

Table 2

Continued.

Date	American Shad Catch	MD DNR Recaptures*	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
07 May	4047	*1PK,3GR*	52,200	60.7	22	11	C	310	23.00	106.1	0
08 May	12323	*8PK,15GR,1OR*	45,200	61.7	24	11	C	310	21.0-22.5	106.6	0
09 May	4683	*1PK,5GR*	42,200	61.2	24	8	C	310	22.50	107.2	0
10 May	4245	*2PK,4GR*	42,200	63.9	27	11	C	310	22.0-23.0	107.6	0
11 May	11595	*14PK,16GR,1CH*	48,500	64.1	27	10	C	310	19.0-22.5	106.5	0
12 May	11142	*5PK,33GR*	54,000	64.4	26	11	C	310	19.5-23.5	106.8	0
13 May	3492	*2PK,12GR*	58,000	65.6	22	11	C	310	21.5-23.5	106.6	0
14 May	525	*1PK,2GR,1OR*	97,200	65.0	20	11	C	310	23.0	104.4	0
23 May	1	*0*	82,600	57.2	20	11	C	310	23.5	106.7	0
24 May	292	*0*	68,800	59.0	24	11	C	310	22.0-23.0	105.8	0
25 May	1765	*1GR*	59,000	62.6	26	11	C	310	21.0-23.5	107.6	0
26 May	3046	*2PK,4GR*	51,800	61.7	30	8	C	310	15.1-19.3	107.6	0
27 May	1896	*1PK,3GR*	46,400	63.5	32	11	C	310	20.0-23.5	107.0	0
28 May	3197	*3PK,6GR*	42,400	65.4	32	11	C	310	22.0-23.5	108.2	0
29 May	1352	*1PK,2GR*	37,200	65.3	25	10	C	310	21.0-23.0	108.0	0
30 May	1907	*1PK, 2GR*	37,200	66.2	28	9	C	310	21.0-22.0	106.6	0
31 May	1305	*2PK, 2GR,1OR*	36,700	68.9	24	10	C	310	20.0-23.5	108.4	0
01 Jun	2569	*3PK8GR*	36,700	75.2	30	11	C	310	17.0-23.0	107.3	0
02 Jun	756	*3GR*	36,000	76.1	30	7	C	310/252	14.1-22.5	107.6	0
03 Jun	312	*1GR*	35,200	76.9	30	10	C	310	21.5-22.5	107.5	0
04 Jun	665	*1PK,1GR*	32,400	76.1	30	9	C	310	19.5-22.0	106.6	0
05 Jun	406	*1GR,1OR*	30,500	75.6	30	10	C	310	19.0-23.0	105.6	0
06 Jun	320	*1GR*	28,500	77.0	30	10	C	310	17.5-23.0	107.1	0
07 Jun	185	*0*	29,900	76.3	30	4	C	310	13.9-16.9	106.1	0

* Tag color: PK=pink, GR=green, CH=chartreuse, OR=orange

** Lift not operated due to repairs, window counts only.

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2002. No operation on April 9, 11, 28, 29, and May 15-22.

Date:	*08 Apr*	*10 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*
Observation Time-Start:	*12:00*	*11:35*	*11:50*	*11:00*	*10:45*	*11:30*	*8:15*	*11:10*	*8:00*	*7:40*	*11:15*	*11:00*	*11:15*
Observation Time-End:	*16:30*	*17:30*	*19:00*	*19:00*	*19:00*	*19:00*	*19:00*	*18:00*	*16:30*	*16:00*	*19:00*	*19:00*	*17:45*
Military Time (hrs)													
0700 to 0759										2			
0800 to 0859							145		15				
0900 to 0959							143		12	2			
1000 to 1059					21		705		18	11			
1100 to 1159				142	122	38	274	268	8	6	2	111	110
1200 to 1259				27	102	65	269	37	13	14		448	42
1300 to 1359		2	34	103	466	176	118	23	4		4	1,002	17
1400 to 1459		6	83	187	395	227	25	10	4	5	6	1,129	31
1500 to 1559		14	304	354	533	131	18	15	12	42	87	738	37
1600 to 1659		20	333	404	539	128	41	20	10		300	486	21
1700 to 1759		22	315	350	359	202	391	38			276	854	16
1800 to 1859			454	560	431	348	470				385	531	
1900 to 1959													
Total	**0**	**64**	**1,523**	**2,127**	**2,968**	**1,315**	**2,599**	**411**	**96**	**82**	**1,060**	**5,299**	**274**

Date:	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*
Observation Time-Start:	*11:00*	*11:10*	*8:45*	*8:30*	*8:35*	*9:45*	*10:30*	*8:10*	*8:30*	*8:30*	*8:40*	*8:35*	*8:30*
Observation Time-End:	*16:30*	*19:00*	*19:00*	*18:45*	*16:45*	*11:45*	*12:30*	*19:00*	*18:15*	*19:00*	*17:00*	*19:30*	*18:30*
Military Time (hrs)													
0700 to 0759													
0800 to 0859			59	49	55			54		6	4	7	41
0900 to 0959			83	22	165	210		12	62	64	25	17	119
1000 to 1059			36	34	450	136	5	21	9	13	4		13
1100 to 1159	6	51	133	55	457	48	8	64	18	14			28
1200 to 1259	9	380	112	81	535		1	104	64	34	3		86
1300 to 1359	5	836	206	55	864			139	75	26	2	35	210
1400 to 1459	43	1,052	186	136	90			112	92	60	34	71	240
1500 to 1559	45	423	123	175	16			104	97	79	14	132	180
1600 to 1659	28	150	271	116	63			228	59	93	35	149	122
1700 to 1759		275	368	181				257	90	69		284	109
1800 to 1859		579	252	196				160	80	139		743	76
1900 to 1959												251	
Total	**136**	**3,746**	**1,829**	**1,100**	**2,695**	**394**	**14**	**1,255**	**646**	**597**	**121**	**1,689**	**1,224**

Table 3

Continued.

Date:	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*23 May*	*24 May*	*25 May*	*26 May*
Observation Time-Start:	*8:45*	*8:10*	*8:25*	*8:30*	*8:10*	*8:15*	*8:25*	*8:30*	*8:30*	*8:10*	*9:15*	*8:15*	*8:30*
Observation Time-End:	*19:00*	*19:00*	*19:15*	*18:45*	*19:40*	*20:00*	*19:30*	*18:00*	*17:30*	*13:15*	*16:30*	*18:20*	*18:15*
Military Time (hrs)													
0700 to 0759													
0800 to 0859	1	78	142	76	217	58	95	176	28	0		35	86
0900 to 0959	36	152	448	123	80	265	728	315	55			14	118
1000 to 1059	90	197	929	166	84	865	1,144	687	44			160	237
1100 to 1159	109	126	1,314	344	78	1,534	1,250	618	60	1		223	462
1200 to 1259	409	303	1,317	391	342	1,309	1,622	426	33		11	201	610
1300 to 1359	406	330	2,183	629	702	1,714	958	651	65		72	357	460
1400 to 1459	286	534	1,274	596	461	1,282	1,055	317	74		82	204	500
1500 to 1559	203	577	1,277	690	686	1,141	1,202	194	74		92	201	232
1600 to 1659	266	455	917	719	460	903	1,093	96	63		35	171	149
1700 to 1759	359	363	979	678	245	845	1,067	12	29			143	98
1800 to 1859	546	932	1,220	271	630	1,025	706					56	94
1900 to 1959			323		260	654	222						
Total	**2,711**	**4,047**	**12,323**	**4,683**	**4,245**	**11,595**	**11,142**	**3,492**	**525**	**1**	**292**	**1,765**	**3,046**

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*	*06 Jun*	*07 Jun*	
Observation Time-Start:	*8:15*	*8:30*	*8:00*	*8:20*	*8:00*	*8:00*	*8:25*	*8:15*	*8:00*	*8:00*	*8:30*	*8:00*	
Observation Time-End:	*18:30*	*18:00*	*19:00*	*19:00*	*17:00*	*17:30*	*16:45*	*17:15*	*17:00*	*16:15*	*16:15*	*15:00*	**Total**
Military Time (hrs)													
0700 to 0759													**2**
0800 to 0859	53	46	14	17	42	69	18		10	3	11		**1,710**
0900 to 0959	33	37		54	99	476	216	60	38	31	75	22	**4,411**
1000 to 1059	73	128		119	269	606	113	51	109	71	40	63	**7,721**
1100 to 1159	188	421	36	264	212	378	102	33	114	62	71	18	**9,981**
1200 to 1259	193	831	156	218	203	225	82	18	88	93	60	25	**11,592**
1300 to 1359	146	802	253	297	118	188	88	22	97	50	13	21	**15,024**
1400 to 1459	251	456	287	346	206	85	71	43	88	56	37	36	**12,851**
1500 to 1559	374	244	176	197	102	200	38	43	43	19	11		**11,689**
1600 to 1659	301	159	116	115	54	251	28	21	78	21	2		**10,089**
1700 to 1759	157	73	171	145		91		21					**9,932**
1800 to 1859	127		143	135									**11,289**
1900 to 1959													**1,710**
Total	**1,896**	**3,197**	**1,352**	**1,907**	**1,305**	**2,569**	**756**	**312**	**665**	**406**	**320**	**185**	**108,001**

Table 4

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2002.

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**

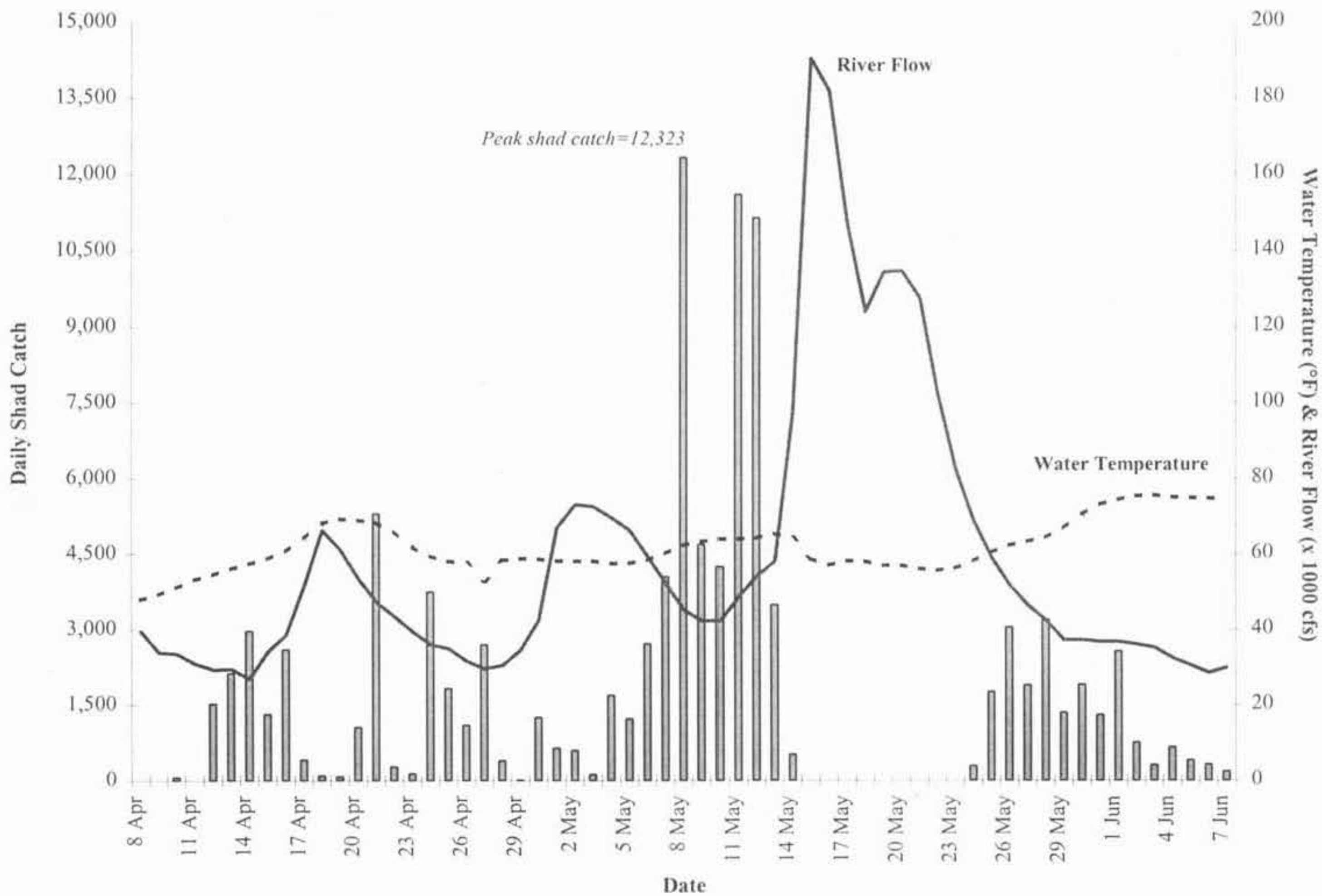

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo East Fish Lift, spring 2002. No operation on April 9, 11, 28, 29, and May 15-22.

Job I - Part 2

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2002

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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 2002 (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, to provide a lift operator, 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 in 2002 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 River Coordinator.

The objectives of Conowingo West lift operations in 2002 included collection and enumeration of shad, river herring, other migratory and resident fishes; provision of live adult shad broodfish to the USFWS Northeast Fishery Center at Lamar, PA and to Maryland DNR for tank spawning; 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 river herring were trucked and released in upstream waters though a couple hundred bluebacks were hauled to Octoraro Creek for a demonstration stocking.

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 flows at Conowingo were relatively modest (30-70 K cfs) during late April to mid-May; unusually high (60-190 K cfs) from mid- to late May; and average (30-40 K cfs) to the end of the operating season. West lift operations began on April 22 and, except for a high-water shutdown on May 14-27, proceeded every day through June 7. Total fishing effort over 31 operating days in 2002 included 417 lifts and a fishing time of 147 hours.

American shad collected in the trap were counted and either placed into holding or spawning tanks. Fish in excess of transport or on-site spawning needs were returned alive to the tailrace. Other species were identified and enumerated with all but a couple hundred blueback herring being returned to the tailrace. Live shad were delivered to USFWS Northeast Fishery Center (Lamar, PA) and provided to Maryland DNR for tank spawning. 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 ratio of shad in daily catches were recorded.

RESULTS

Figure 1 shows daily West lift shad catch, river flow and water temperatures for the 2002 season. Total catch at the West lift amounted to 419,103 fish of 35 taxa (Table 1). Gizzard shad and white perch comprised 96% of this total. Alosid catch included 9,347 American shad, 428 blueback herring, 141 alewives, and no hickory shad. Catch of American shad was split on either side of the shutdown period with 4,970 fish taken during April 22-May 13 (226 fish/day), and 4,377 taken during May 28-June 7 (486 fish/day). There was no well-defined peak period and the greatest catch day occurred on June 5 (1,754 shad). Most blueback herring (313) were collected on May 1-3 and stocked into Octoraro Creek on May 4. Daily operating parameters and catch by major species is shown in Table 2.

American shad transfers from the West lift included 1,350 fish delivered directly to USFWS-Lamar on 13 dates with only 24 mortalities (Table 3); and 305 shad provided on three dates to Maryland DNR for tank spawning (Table 4). Normandeau Associates used 1,000 shad at the lift for tank spawning (Job II, Part 3).

A total of 182 shad were sacrificed and provided to PFBC for otolith analysis and 57 Maryland

DNR tags were recovered of which 33 were hook and line tagged fish from the tailrace in 2002. Overall male to female sex ratio of shad in the West lift in 2002 was 1.2 to 1.0. Males averaged 481 mm in length and 1041 g, while females averaged 550 mm and 1618 g.

Discussion

In spring 2002, modest river flows persisted until mid-May followed by a 2-week high water event. Of the total American shad collected at the West lift in 2002, 53% were taken during the first 22 days of operation and 47% during the final 9 days after flows subsided. Lamar received 827 shad in 8 shipments prior to May 15 and 523 in 5 loads after May 28. Of the 20 spawning trials at Conowingo, 16 occurred before the mid-May flow event. Most shad collected in 2002 were released alive back to the tailrace.

West lift catch per effort of about 63.5 shad per fishing hour, 22 shad per lift, and 302 shad per day were at or near the highest capture rates recorded at this facility (Table 5). Operations and fish catch at the West lift during 1985-2002 are summarized in Table 6. Based on analysis of 182 adult shad otolith samples from Conowingo, hatchery-marked fish comprised 66% of the 2002 run, an increase from 62% the previous year. Most marked fish carried the single day tag indicating they were stocked into the Juniata River or mainstem Susquehanna above Clarks Ferry.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 2002.

Number of Days	31
Number of Lifts	417
Fishing Time (hours : minutes)	147:05:00
Number of Taxa	35
AMERICAN SHAD	9,347
BLUEBACK HERRING	428
ALEWIFE	141
GIZZARD SHAD	339,292
STRIPED BASS	2,086
White perch	65,031
American eel	144
Rainbow trout	3
Brown trout	7
Carp	225
Golden shiner	1
Comely shiner	2
Spottail shiner	3
Quillback	13
White sucker	8
Shorthead redhorse	317
White catfish	49
Yellow bullhead	2
Brown bullhead	26
Channel catfish	844
Rock bass	65
Redbreast sunfish	179
Green sunfish	4
Pumpkinseed	26
Bluegill	155
Smallmouth bass	390
Largemouth bass	12
White crappie	6
Black crappie	1
Yellow perch	122
Walleye	79
Atlantic needlefish	16
Sea lamprey	75
Splake	3
Creek chubsucker	1
Total	**419,103**

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 2002. No operation on May 14-27 and June 1-2.

Date:	22 Apr	23 Apr	24 Apr	25 Apr	26 Apr	27 Apr	28 Apr	29 Apr
Day:	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday
Number of Lifts:	18	26	20	5	12	13	8	12
Time of First Lift:	12:00	11:00	11:45	13:00	11:20	12:20	12:55	11:25
Time of Last lift:	17:40	18:10	18:30	15:00	16:30	17:05	16:00	15:30
Operating time (hours):	5:40	7:10	6:45	2:00	5:10	4:45	3:05	4:05
Average Water Temperature (°F):	67.4	64.7	63.6	61.9	60.3	59.5	59.5	60.6
American shad	147	99	289	149	129	341	676	346
Blueback herring	0	0	0	0	0	0	33	0
Alewife	3	12	2	3	33	26	0	0
Gizzard shad	22,250	52,300	18,400	2,825	11,750	8,250	3,425	14,350
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	68	63	24	28	15	4	3	17
Carp	25	7	5	0	0	0	0	1
Other species	2,603	4,761	484	102	185	165	632	9,173
Total	**25,096**	**57,242**	**19,204**	**3,107**	**12,112**	**8,786**	**4,769**	**23,887**

Date:	30 Apr	01 May	02 May	03 May	04 May	05 May	06 May	07 May
Day:	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
Number of Lifts:	12	18	14	18	18	23	25	17
Time of First Lift:	12:10	11:15	11:00	11:25	11:00	12:45	11:15	11:35
Time of Last lift:	17:15	17:15	15:30	16:45	18:10	17:50	17:30	17:15
Operating time (hours):	5:05	6:00	4:30	5:20	7:10	5:05	6:15	5:40
Average Water Temperature (°F):	59.2	60.9	60.2	60.8	59.5	60.5	59.6	61.6
American shad	174	114	135	30	142	10	233	217
Blueback herring	0	88	139	86	8	15	37	8
Alewife	2	18	1	22	0	3	15	0
Gizzard shad	3,800	9,600	11,100	30,000	16,950	32,100	44,600	13,000
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	7	33	9	6	8	0	17	13
Carp	0	1	2	1	0	2	5	5
Other species	6,217	14,235	899	2,299	827	1,449	1,480	3,806
Total	**10,200**	**24,089**	**12,285**	**32,444**	**17,935**	**33,579**	**46,387**	**17,049**

Table 2

Continued.

Date:	08 May	09 May	10 May	11 May	12 May	13 May	28 May	29 May
Day:	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday
Number of Lifts:	11	7	11	12	7	12	10	13
Time of First Lift:	11:00	11:10	11:50	10:50	12:00	10:40	11:25	11:00
Time of Last lift:	15:35	13:30	15:55	15:05	13:50	14:45	15:35	18:00
Operating time (hours):	4:35	2:20	4:05	4:15	1:50	4:05	4:10	7:00
Average Water Temperature (°F):	61.9	61.8	64.8	64.6	64.7	65.9	64.2	65.8
American shad	302	214	25	601	248	349	494	343
Blueback herring	4	2	5	0	1	0	1	0
Alewife	1	0	0	0	0	0	0	0
Gizzard shad	6,380	1,485	11,580	7,080	1,275	7,880	1,285	1,550
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	3	0	1	1	7	2	7	6
Carp	0	1	3	1	2	51	2	6
Other species	2,835	3,964	1,111	1,408	1,441	1,097	130	3,846
Total	**9,525**	**5,666**	**12,725**	**9,091**	**2,974**	**9,379**	**1,919**	**5,751**

Date:	30 May	31 May	03 Jun	04 Jun	05 Jun	06 Jun	07 Jun	**TOTAL**
Day:	Thursday	Friday	Monday	Tuesday	Wednesday	Thursday	Friday	
Number of Lifts:	10	6	18	2	20	12	7	**417**
Time of First Lift:	10:55	13:00	11:20	16:50	8:10	8:55	8:20	
Time of Last lift:	15:35	15:15	18:30	17:25	15:20	15:00	11:25	
Operating time (hours):	4:40	2:15	7:10	0:35	7:10	6:05	3:05	**147:05:00**
Average Water Temperature (°F):	66.7	69.8	76.9	76.1	75.6	78.5	76.5	
American shad	437	370	431	9	1,754	396	143	**9,347**
Blueback herring	0	0	0	0	0	1	0	**428**
Alewife	0	0	0	0	0	0	0	**141**
Gizzard shad	1,950	1,490	874	40	584	484	655	**339,292**
Hickory shad	0	0	0	0	0	0	0	**0**
Striped bass	47	83	496	115	108	704	191	**2,086**
Carp	0	11	41	2	0	48	3	**225**
Other species	1,128	686	340	65	44	97	75	**67,584**
Total	**3,562**	**2,640**	**2,182**	**231**	**2,490**	**1,730**	**1,067**	**419,103**

Table 3

Summary of American shad transported from the Conowingo Dam West Fish Lift, 2002.

Date	Number of Shad Transported	Location	Observed Mortality	Percent Survival
23 Apr	103	USFWS Lamar Hatchery	5	95.1
25 Apr	103	USFWS Lamar Hatchery	1	99.0
30 Apr	102	USFWS Lamar Hatchery	2	98.0
02 May	104	USFWS Lamar Hatchery	2	98.1
07 May	105	USFWS Lamar Hatchery	1	99.0
09 May	105	USFWS Lamar Hatchery	3	97.1
13 May	102	USFWS Lamar Hatchery	1	99.0
14 May	103	USFWS Lamar Hatchery	1	99.0
29 May	105	USFWS Lamar Hatchery	2	98.1
30 May	105	USFWS Lamar Hatchery	0	100.0
04 Jun	109	USFWS Lamar Hatchery	3	97.2
06 Jun	110	USFWS Lamar Hatchery	2	98.2
07 Jun	94	USFWS Lamar Hatchery	1	98.9
Total	**1350**		**24**	**98.2**

Table 4

Summary of American shad transported by Maryland DNR or processed on site from the Conowingo West Fish Lift, 2002.

Date	Water Temperature (°F)	Number of Shad Transported		Number of Shad Processed on Site	
		Female	Male	Female	Male
26 Apr	60.3			10	20
29 Apr	60.6	79	120		
07 May	61.6	20	31		
14 May	64.3*	10	45		
29 May	65.8				
07 Jun	76.5			8	
Sub Total		**109**	**196**	**18**	**20**
			Total transported or processed		**343**

* Holtwood Dam data

Table 5

Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods* in 1985-2002.

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**

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

Table 6

Operations and fish catch at Conowingo West Fish Lift, 1985 - 2002.

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**

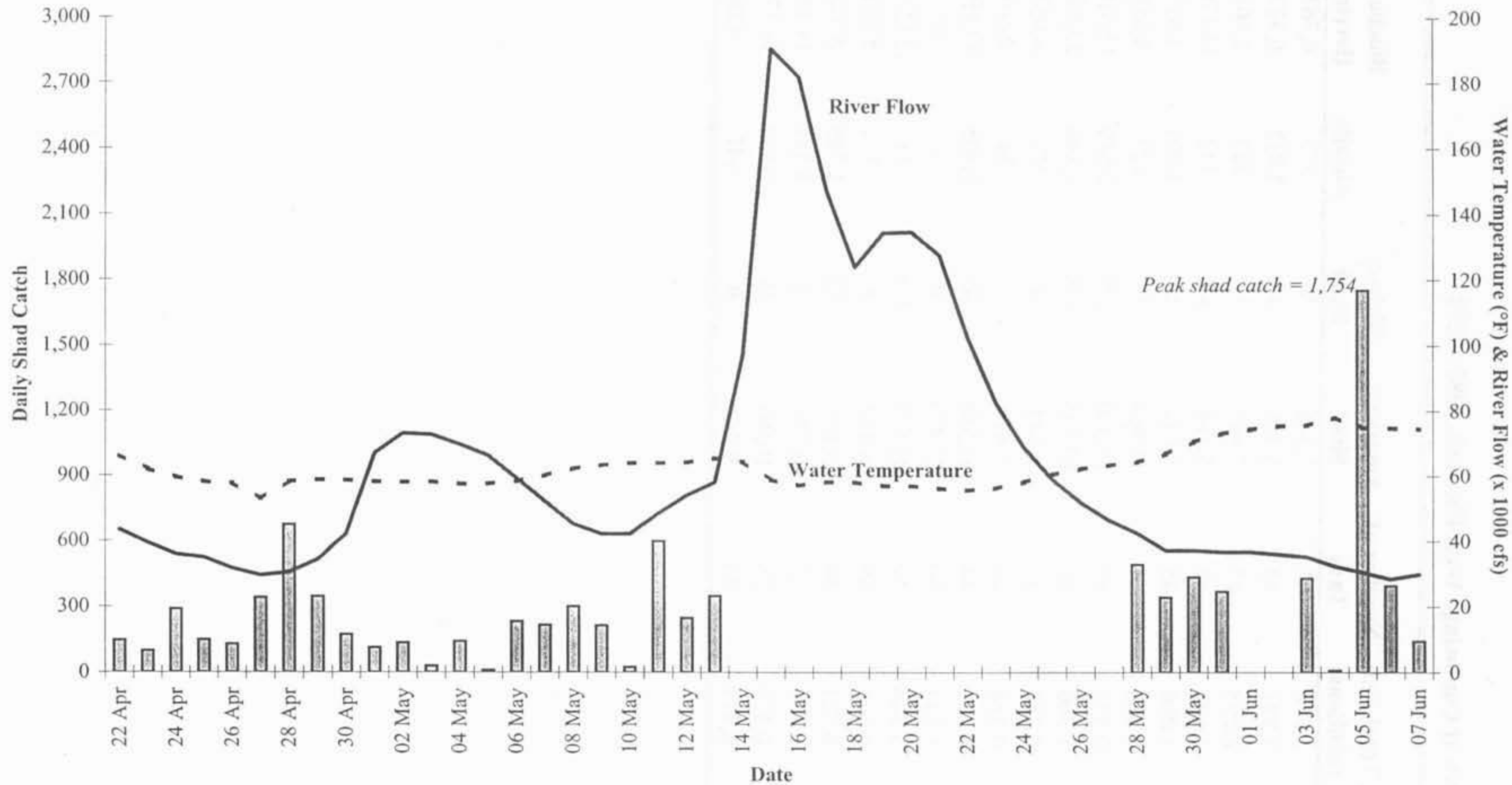

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 2002. No operation on May 14-27 and June 1-2.

JOB I - PART 3
SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY, SPRING 2002

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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 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 facility consisting of a tailrace and spillway lift successfully operated during spring 1997, 1998, 1999, 2000, and 2001. This year marked the sixth fish passage effort.

A meeting of the Holtwood Fish Passage Technical Advisory Committee (HFPTAC) comprised of PPL, United States Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives were held at Holtwood during February 2002. The meetings included discussions of, and a consensus on operation of the fishway during the 2002 spring migration season.

Objectives of 2002 upstream fishway operation were (1) monitor passage of migratory and resident fishes through the fishway; (2) continue to assess fishway operation; (3) observe and assess the effectiveness/ineffectiveness of shade screen installation over tailrace entrance channels and the tailrace "corner" area; and (4) manipulate valve 4 to improve/increase water flow through the tailrace crowder area.

HOLTWOOD OPERATION

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units having a combined generating capacity of 107 MW, and a reservoir (Lake Aldred) of 2,400 acres surface area. Each unit is capable of passing approximately 3,000 cfs. Spills occur at the project when river flow or project inflow exceeds the station 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 three rubber dams installed as part of the fishway project, and operation of the Safe Harbor Hydroelectric Station. Fishway operations at Holtwood began on 15 April 2002. In Spring 2002, spill events occurred frequently. The three rubber dams were usually inflated during fishway operations in 2002 to reduce the discharge of water into the east channel of the spillway.

Fishway Design

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

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough through which the fish swim into Lake Aldred. Attraction flows, in, through, and from the lifts are supplied 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 hopper(s) (6,700 gal capacity). Fish are then lifted in the hopper(s) and sluiced into the trough. Fish swim upstream through the trough past a counting facility and into the forebay through a 14 ft wide fish lift exit gate. Three inflatable rubber dams, operated from the hydro control room, are an integral component of effective spillway lift operation. During fish lift operations in 2002, all three rubber crest dams were usually kept inflated.

Design guidelines for fishway operation included three entrance combinations. These were: (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 were flexible and utilized experience gained in the first year of fish lift operation. Following these updated protocols/guidelines, entrances A and B, A, B, and C, or a combination of A and C were used in 2002.

Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch, and managed to maximize that catch. Constant oversight by PPL and Normandeau staff ensured that maintenance activities and mechanical or electrical problems were dealt with immediately to minimize fish lift operational interruptions. The tailrace and spillway lifts were functional 95% of the time throughout the 2002 season. A maintenance program that included periodic cleaning of the exit channel, nightly inspections, and cleaning of picket screens contributed to this excellent operating performance. Pre-season equipment preparations began in March, and lifts were fully operational on April 1. The catch of shad early in the season at Conowingo Dam triggered the start of Holtwood operations on 15 April. The tailrace lift operated for 35 days during the season while the spillway lift operated on 27 days. High river flows during historic peak American shad passage periods limited fishway operation in May 2002. Operational hours varied throughout the season to maximize the catch of American shad.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. A three person staff consisting of a lift supervisor, supervising biologist, and biological technician manned the lifts daily. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 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 and 12 ft long channel on the west side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are identified and counted. Passage from the fishway is controlled by two different gates. During the day, fish passage rates are controlled by the technician who opens/closes a set of gates downstream of the viewing window. At night fish are denied passage from the fishway by closing this gate. When necessary, flow is maintained through the exit channel to insure that adequate water quality exists for fish held overnight.

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

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

RESULTS

Relative Abundance

The diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2002 operational period are shown in Table 1. A total of 135,285 fish of 26 taxa and one hybrid passed upstream into Lake Aldred. Gizzard shad (107,600) comprised nearly 80% of the fishes passed. American shad numbered 17,522 (13% of the total) and represented the second largest portion of the catch. The 2002 American shad passage total was the second lowest observed and the lowest percentage of shad passed (based on Conowingo results) in the six years of fish lift operations (Tables 1 and 5). Other abundant fishes passed included shorthead redhorse (3,055), smallmouth bass (2,658), quillback (1,088), and channel catfish (1,006). The peak one-day passage of all species occurred on 13 May when 9,281 fish were passed, 94% of which were gizzard shad. Other migratory species collected by the fishway included 13 blueback herring, 7 striped bass, and 71 white perch (Table 1).

American Shad Passage

During five days of operation (May 9, 10, 29, 30, and 31) the lifts passed 9,164 American shad representing 52% of the season total. High river flows in May severely limited fishway operation during the historic peak passage period, and the fishway collected and passed more than 1,000 shad/day only on the five days mentioned previously. River flows averaged 39,100 cfs during those five days whereas the average river flow for the entire month of May was approximately 79,000 cfs. The highest single day catch occurred on 10 May when 2,978 American shad were captured and passed. American shad were collected and passed at water temperatures ranging from 57.5°F and 75.6°F, and river flows between 28,500 cfs to 66,900 cfs (Table 2 and Figure 1).

The capture of shad at the fishway occurred over a wide range of station operation and discharge conditions (Table 2). Shad were attracted to the tailrace lift at water elevations ranging from 114 ft. to 119 ft. Typically, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2002, most tailrace fishway operation coincided with constant ten turbine operation/generation due to high spring river flows. The spillway lift operated at spillway elevations of 116 ft to 130 ft. Spillage occurred on all but two days during fishway operation in Spring 2002.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 167 ft to 173 ft (Table 2). Visual observations indicated that shad readily passed through the fishway into Lake Aldred at this range of forebay elevations. High river flows prevented the installation of the slick bar and repair/replacement of flash boards during Spring, 2002.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Most shad (16,406) passed through the fishway between 0800 hrs and 1659 hrs. Generally, shad passage was strong from 0800 hrs to 1659 hrs, then declined sharply until operation was ended each evening.

The relative number of shad using the tailrace and spillway lifts were qualitatively assessed by viewing each hopper of fish and estimating the number of shad in each lift as they were sluiced into the trough. This information was summarized by lift, and applied to the daily shad passage count. The number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift was determined. Based on this assessment, 9,618 and 7,904 shad (55 and 45%) were captured in the tailrace and spillway lifts over the total operating period, respectively (Table 4). The contribution of each lift's catch to daily passage varied throughout the season. Both lifts appeared to catch shad effectively based on visual observations of fish movement up to, and in the vicinity of the lift entrances.

In 2002, spill events were common due to high spring river flows. The spillway lift was operated a total of 27 days during the season. Nearly 73% (5,756 shad) of the total spillway catch was collected during six days of operation (Table 4).

Passage Evaluation

In 2002, fishway evaluation efforts at Holtwood focused on addressing American shad behavior in the vicinity of the tailrace lift entrances based on findings disclosed in the telemetry report conducted in Spring, 2001. In an attempt to reduce the number of American shad that nose into the entrance way and then exit, or spend time in the "corner" of the tailrace upstream of the tailrace lift entrances, some operational and physical modifications were implemented. Evaluation of these modifications was difficult due to persistent high river flow conditions and overall poor water clarity.

On 9 May, partial shade tarps were installed over the tailrace lift entrance channels as well as a complete shade tarp installed over the "corner area". The corner shade tarp was damaged by rain and high water levels on 13 May and was unable to be reinstalled prior to the end of fishway operations. Some American shad were observed in the corner area from 10 May to the end of the season when the area was naturally shaded or exposed to full sunlight. Based on limited observations, the corner shade tarp did not hinder or deter American shad from entering that area of the tailrace. An accurate assessment of the partial shade tarps installed over the tailrace lift entrance channels was not possible. Poor water clarity and the low numbers of American shad observed in the daily passage counts made it difficult to determine what effect (if any) the shade tarps had on shad passage.

Throughout the season, valve 4, which supplies water to the tailrace lift entrances, was manipulated to increase water flow through the tailrace crowder area. Flow through the tailrace crowder area was improved and this also allowed the use of both tailrace entrances (A & B) although improved shad passage results could not be verified due to the overall low passage of American shad in Spring, 2002.

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. However, this table also shows that fish passage at higher river flows (particularly flows between 40,000 and 60,000 cfs), has improved during the past three seasons (2000 to 2002). Prior to the year 2000, the daily average for American shad passage (river flows between 40,000 and 60,000 cfs) was 162 shad. Since 2000, the daily average for that river flow range is 538 shad. At least two factors are responsible for this improvement: 1) experience with and understanding of the fishway systems, and 2) communication between PPL and Normandeau staff concerning river flow conditions. On different occasions, the fish lift operation schedule was modified to optimize fishing effort, usually prior to or shortly after a spill event.

It is hoped that future fishway operations will be optimized by utilizing knowledge gained through these observations and modifications. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis. Fish survival in the fishways was excellent and no mortalities were observed.

SUMMARY

In 2002, the Holtwood tailrace fish lift was operated for 35 days while the spillway lift operated on 27 days. The tailrace and spillway lifts were functional 95% of the time. Fishway systems and equipment functioned as designed and only minor difficulties were encountered. Minor problems resulted from safeguards designed into the electrical and/or mechanical aspects of equipment operation.

A total of 17,522 American shad were passed into Lake Aldred, the second lowest total and the lowest percentage of shad passed (based on Conowingo passage results) since operations started in 1997 (Table 6). A total of 13 blueback herring also passed through the fishway.

The catch of shad early in the season at Conowingo Dam triggered the start of Holtwood operations on 15 April. A total of 9,618 American shad (55% of total catch) was passed in the tailrace lift while the spillway lift accounted for 7,904 American shad (45% of total catch). Collection and passage of shad varied daily with 52% of total shad (9,164) passed on five days (May 9, 10, 29, 30, and 31). The highest daily shad catch occurred on 10 May when 2,978 shad moved upstream in nearly 10 hours of operation. On a daily basis, most shad passed through the fishway between 0800 hrs and 1659 hrs. American shad were collected and passed at water temperatures ranging from 57.5°F to 75.6°F, and river flows between 28,500 and 66,900 cfs.

A low, stable, river flow appears to be critical for enhancing shad passage rates. The high flow conditions in spring 2002 made fish passage difficult, but did allow personnel to experiment with various lift component settings that may improve passage rates in upcoming years. Future operations of the fishway will build on the past six years of operation experience.

RECOMMENDATIONS

1. 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.

2. Continue, as a routine part of fishway operation, 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.

3. As river flow conditions permit install the "Slick Bar" in front of the fishway exit channel to deflect 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.

4. Continue to assess effectiveness of manipulating water flow through valve 4 and the use of partial shade tarps over the tailrace entrance channels for improving American shad passage. Discontinue the use of the shade tarp over the upstream corner area of the tailrace.

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 2002. No operation on April 19, 21, May 2-5, and 14-26.

Date:	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*20 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*
Hours of Operation - Tailrace:	*5.4*	*7.3*	*7.6*	*6.2*	*3.2*	*6.8*	*4.7*	*5.8*	*5.2*	*5.8*
Number of Lifts - Tailrace:	*8*	*9*	*7*	*9*	*5*	*12*	*5*	*6*	*9*	*5*
Hours of Operation - Spillway:	*5.5*	*6.0*	*1.8*	*0.0*	*0.0*	*5.6*	*5.0*	*6.2*	*5.3*	*3.3*
Number of Lifts - Spillway:	*7*	*4*	*2*	*0*	*0*	*6*	*3*	*5*	*5*	*3*
Water Temperature (°F):	*58.7*	*60.5*	*63.5*	*67.1*	*68.9*	*66.3*	*62.8*	*59.6*	*58.3*	*57.7*
American shad	466	408	588	126	6	166	15	36	12	8
Blueback herring	0	0	0	0	0	0	0	0	0	0
Gizzard shad	566	911	1,118	2,148	2,244	5,600	1,686	1,783	1,201	1,226
Striped bass	0	0	0	0	0	0	0	0	0	1
Sea lamprey	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	1	0	0	1	1	0	1	0	0
Brown trout	4	1	0	0	3	1	4	2	0	0
Carp	0	0	0	6	23	537	60	3	0	0
Quillback	29	13	38	530	3	31	1	0	0	0
White sucker	11	2	2	9	0	45	0	0	0	0
Shorthead redhorse	143	79	193	635	61	61	23	2	1	6
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	2	1	11	13	41	51	19	5	1	2
White perch	0	0	0	0	0	0	0	0	0	0
Rock bass	0	3	3	1	6	4	1	1	2	1
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	0	0	5	0	0	20	0	4	0	0
Smallmouth bass	51	263	192	509	48	132	24	10	4	6
Largemouth bass	1	4	0	0	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	1	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	1	2	2	2	2	2
Walleye	6	17	13	14	8	19	4	4	6	3
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	0
Comely shiner	1	0	0	0	0	0	0	0	0	0
Total	***1,280***	***1,703***	***2,163***	***3,991***	***2,445***	***6,670***	***1,839***	***1,853***	***1,230***	***1,255***

Table 1

Continued.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*
Hours of Operation - Tailrace:	*5.2*	*10.7*	*7.5*	*6.6*	*5.6*	*1.3*	*6.9*	*8.2*	*8.2*	*10.3*
Number of Lifts - Tailrace:	*6*	*11*	*6*	*9*	*6*	*3*	*9*	*11*	*11*	*16*
Hours of Operation - Spillway:	*0.0*	*10.9*	*6.8*	*0.0*	*0.0*	*0.0*	*7.1*	*6.8*	*7.6*	*7.5*
Number of Lifts - Spillway:	*0*	*21*	*11*	*0*	*0*	*0*	*9*	*11*	*13*	*12*
Water Temperature (°F):	*57.5*	*57.8*	*58.7*	*58.5*	*57.6*	*59.2*	*59.5*	*61.4*	*63.1*	*63.7*
American shad	2	996	535	131	45	20	80	638	1,186	2,978
Blueback herring	0	0	0	0	0	0	0	0	0	0
Gizzard shad	853	4,747	1,210	1,210	610	2,167	3,150	4,820	7,323	4,686
Striped bass	0	0	0	0	0	0	0	0	0	0
Sea lamprey	1	0	0	0	0	0	0	0	1	2
Rainbow trout	0	5	2	5	2	2	0	1	1	0
Brown trout	0	0	1	1	0	0	0	0	3	1
Carp	0	4	6	16	2	3	0	1	3	1
Quillback	0	9	1	0	1	1	4	39	115	11
White sucker	0	0	0	0	0	0	0	0	2	0
Shorthead redhorse	2	182	159	58	53	22	33	266	269	68
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	0	6	43	25	10	56	20	24	45	25
White perch	0	0	1	0	0	2	0	2	12	3
Rock bass	0	0	1	0	0	2	1	0	2	8
Redbreast sunfish	0	0	0	0	0	0	0	0	2	1
Green sunfish	0	0	0	0	0	2	0	0	0	1
Pumpkinseed	0	0	0	0	0	0	0	0	1	0
Bluegill	1	1	1	0	0	2	0	0	0	0
Smallmouth bass	3	78	275	37	56	36	78	155	125	28
Largemouth bass	0	0	0	0	0	0	0	0	0	3
White crappie	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	2	3	0	0	0	0	0
Walleye	3	60	72	19	12	18	29	30	54	42
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	0
Comely shiner	0	0	0	0	0	0	0	0	0	0
Total	***865***	***6,088***	***2,307***	***1,504***	***794***	***2,333***	***3,395***	***5,976***	***9,144***	***7,858***

Table 1

Continued.

Date:	*11 May*	*12 May*	*13 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*
Hours of Operation - Tailrace:	*5.9*	*8.0*	*7.9*	*7.4*	*6.4*	*9.3*	*10.7*	*10.4*	*8.7*	*8.8*
Number of Lifts - Tailrace:	*13*	*13*	*13*	*11*	*8*	*12*	*16*	*13*	*11*	*13*
Hours of Operation - Spillway:	*0.0*	*0.9*	*0.0*	*7.4*	*6.3*	*7.5*	*7.3*	*10.3*	*8.8*	*8.4*
Number of Lifts - Spillway:	*0*	*1*	*0*	*6*	*6*	*17*	*13*	*16*	*8*	*9*
Water Temperature (°F):	*63.4*	*63.6*	*64.9*	*63.1*	*64.0*	*66.2*	*69.7*	*72.9*	*74.3*	*75.5*
American shad	542	310	280	56	48	1,551	1,895	1,554	391	589
Blueback herring	0	0	0	0	0	0	0	0	0	1
Gizzard shad	5,715	8,168	8,701	7,098	2,530	3,514	2,196	3,511	5,614	5,823
Striped bass	0	1	0	0	0	0	0	0	0	1
Sea lamprey	1	0	1	0	0	0	0	0	1	0
Rainbow trout	0	0	0	3	0	0	4	0	3	2
Brown trout	0	3	0	0	0	2	0	0	0	2
Carp	3	0	4	4	8	5	12	53	39	29
Quillback	0	0	17	1	13	18	41	87	28	7
White sucker	2	0	0	0	0	0	0	0	0	0
Shorthead redhorse	62	32	53	11	31	82	60	153	47	79
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	28	52	159	38	12	110	22	13	57	53
White perch	6	14	14	1	0	0	0	0	0	2
Rock bass	1	2	0	0	0	1	0	1	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Green sunfish	4	0	0	0	0	0	1	4	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	2	2	0	4	0	2	2	0	38	21
Smallmouth bass	30	45	27	88	40	104	84	50	15	20
Largemouth bass	0	1	0	0	0	3	0	2	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	1	0	0
Yellow perch	0	0	0	0	1	0	5	1	5	3
Walleye	26	33	25	16	23	39	48	69	30	40
Splake (brook x lake trout)	1	0	0	0	0	0	0	0	0	0
Comely shiner	0	0	0	0	0	0	0	0	0	0
Total	***6,423***	***8,663***	***9,281***	***7,320***	***2,706***	***5,431***	***4,370***	***5,499***	***6,268***	***6,672***

Table 1

Continued.

Date:	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*TOTAL*
Hours of Operation - Tailrace:	*7.4*	*7.3*	*9.1*	*8.5*	*5.8*	***207.2***
Number of Lifts - Tailrace:	*12*	*10*	*13*	*13*	*8*	***275***
Hours of Operation - Spillway:	*3.0*	*7.0*	*8.8*	*8.5*	*3.9*	***153.8***
Number of Lifts - Spillway:	*3*	*7*	*9*	*9*	*4*	***200***
Water Temperature (°F):	*75.6*	*75.1*	*74.3*	*74.5*	*74.6*	
American shad	375	237	654	416	182	***17,522***
Blueback herring	0	8	3	1	0	***13***
Gizzard shad	3,065	1,141	569	489	207	***107,600***
Striped bass	1	2	1	0	0	***7***
Sea lamprey	0	0	0	0	0	***7***
Rainbow trout	0	0	0	0	3	***37***
Brown trout	1	1	1	0	0	***31***
Carp	20	31	10	28	40	***951***
Quillback	3	15	8	12	12	***1,088***
White sucker	0	0	0	0	0	***73***
Shorthead redhorse	45	43	9	11	21	***3,055***
Brown bullhead	0	1	0	0	0	***1***
Channel catfish	0	8	14	10	30	***1,006***
White perch	0	8	4	1	1	***71***
Rock bass	0	2	0	2	1	***46***
Redbreast sunfish	0	7	0	6	6	***22***
Green sunfish	0	0	0	0	2	***14***
Pumpkinseed	0	2	0	0	0	***3***
Bluegill	0	15	0	13	6	***139***
Smallmouth bass	8	21	6	4	6	***2,658***
Largemouth bass	2	5	1	0	1	***23***
White crappie	0	0	0	0	0	***1***
Black crappie	0	0	0	0	0	***1***
Yellow perch	0	1	0	0	1	***33***
Walleye	33	16	17	9	24	***881***
Splake (brook x lake trout)	0	0	0	0	0	***1***
Comely shiner	0	0	0	0	0	***1***
Total	***3,553***	***1,564***	***1,297***	***1,002***	***543***	***135,285***

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 2002. No operation on April 19, 21, May 2-5, and 14-26.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
15 Apr	34,000	58.7	25	10	150		220	114-116	119-126	170-171
16 Apr	38,400	60.5	25	10	150		220	114-117	123-129	169-172
17 Apr	51,600	64.1	18	10	150		220	116	129	172-173
18 Apr	66,200	68.1	18	10	150			118-119	129	172
20 Apr	53,300	68.9	18	10	150			118	127	171-172
22 Apr	43,400	66.0	30	10	150		220	116-118	119-123	170-171
23 Apr	39,400	61.8	27	10	150		220	118	121-123	171
24 Apr	35,900	59.4	27	10	150		220	116-118	120-123	170-171
25 Apr	34,900	58.0	30	10	150		220/0	115-117	122-123	171
26 Apr	31,600	57.6	30	10	150		220	115-116	120-122	170-171
27 Apr	29,500	57.5	30	10	150			116	121-122	169
28 Apr	30,400	58.2	30	10	150		220	114-116	116-117	170
29 Apr	34,400	58.7	30	10	150		220	115-118	115-120	169-170
30 Apr	42,300	58.6	30	10	150			115-116	126	171-172
1 May	66,900	58.1	22	10	150			116-119	130	172-173
6 May	59,200	58.3	20	10	150			119	128	172
7 May	52,200	60.1	20	10	150		220	118-119	126-131	172-173
8 May	45,200	62.1	30	10	150		220	118	122-129	171-172
9 May	42,200	63.2	22	10	150		220	118	119-126	170-172
10 May	42,200	63.9	22	10	150		220	115-117	115-127	170-172
11 May	48,500	63.9	22	10	150	150		116-117	126-130	172
12 May	54,000	64.1	20	10	150	150	220	116-117	126	172-173
13 May	58,000	65.4	18	10	150	150		118-119	128	171-172
27 May	46,400	63.3	30	10	150	150	220	116-118	121-125	171
28 May	42,400	64.2	30	10	150	150	220	116-118	125	171

Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
29 May	37,200	66.8	30	10	150	150	220	115-118	115-123	169-171
30 May	37,200	70.4	30	10	150		220	114-119	116-122	169-171
31 May	36,700	73.1	30	10	150		220	118	116	168-170
1 Jun	36,700	74.3	30	10		150	220	114-118	115-123	167-171
2 Jun	36,000	75.4	30	10		150	220	115-118	115-124	169-171
3 Jun	35,200	75.5	30	10	150	150	220/0	114-118	115-118	169-171
4 Jun	32,400	75.0	30	10	150	150	220	114-118	115-121	169-171
5 Jun	30,500	74.8	30	10	150	150	220	114-118	115-121	168-171
6 Jun	28,500	74.7	30	10	150		220	114-118	115-119	168-170
7 Jun	29,900	74.4	26	10	150		220	114-118	115-118	169-170

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 2002. No operation on April 19, 21, May 2-5, and 14-26.

Date:	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*20 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Observation Time (Start):	*12:25*	*10:52*	*10:50*	*9:00*	*15:02*	*11:00*	*11:30*	*10:30*	*11:10*	*10:15*	*10:25*
Observation Time (End):	*18:15*	*18:20*	*18:45*	*15:30*	*17:50*	*18:15*	*16:00*	*16:50*	*16:30*	*16:20*	*15:45*
Military Time (hrs)											
0600 to 0659											
0700 to 0759											
0800 to 0859											
0900 to 0959				41							
1000 to 1059			8	37				3		2	2
1100 to 1159		31	22	19				3	4	2	0
1200 to 1259		43	2	4		13	4		3	1	0
1300 to 1359	43	42	148	14		29	1		0	0	0
1400 to 1459	152	51	105	9		66	5	6	4	0	0
1500 to 1559	110	37	81	2	3	26	5	15	1	2	0
1600 to 1659	86	96	121		2	20		9		1	
1700 to 1759	60	75	68		1	12					
1800 to 1859	15	33	33								
1900 to 1959											
2000 to 2059											
Total	**466**	**408**	**588**	**126**	**6**	**166**	**15**	**36**	**12**	**8**	**2**

Table 3

Continued.

Date:	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*
Observation Time (Start):	*8:25*	*10:30*	*10:00*	*10:30*	*15:00*	*10:20*	*10:20*	*8:15*	*8:20*	*8:50*	*9:00*
Observation Time (End):	*18:50*	*18:00*	*16:00*	*16:30*	*16:00*	*17:40*	*18:40*	*16:45*	*18:45*	*17:30*	*16:45*
Military Time (hrs)											
0600 to 0659											
0700 to 0759											
0800 to 0859	3							19	176	61	
0900 to 0959	45							141	1,147	58	37
1000 to 1059	97		56	6		4	12	232	342	48	8
1100 to 1159	94	87	16	17		15	25	200	138	49	9
1200 to 1259	101	57	11	6		10	73	156	346	30	15
1300 to 1359	123	137	7	5			100	252	169	88	43
1400 to 1459	134	94	7	3		4	163	115	176	94	68
1500 to 1559	152	60	34	2	20	14	102	51	234	86	74
1600 to 1659	120	71		6		17	100	20	182	20	56
1700 to 1759	87	29				16	18		68	8	
1800 to 1859	40						45				
1900 to 1959											
2000 to 2059											
Total	**996**	**535**	**131**	**45**	**20**	**80**	**638**	**1,186**	**2,978**	**542**	**310**

Table 3

Continued.

Date:	*13 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*
Observation Time (Start):	*8:20*	*9:00*	*9:30*	*6:30*	*7:15*	*7:30*	*8:10*	*7:53*	*7:30*	*8:00*	*9:00*
Observation Time (End):	*16:30*	*16:30*	*16:45*	*16:00*	*18:15*	*17:45*	*16:25*	*16:40*	*15:30*	*15:15*	*16:30*
Military Time (hrs)											
0600 to 0659				18							
0700 to 0759				140	39	60			2		
0800 to 0859	34			322	119	234	94	128	79	43	62
0900 to 0959	52	28	4	330	184	199	23	107	68	45	80
1000 to 1059	21	2	6	297	214	156	22	63	37	50	68
1100 to 1159	20	3	2	179	311	152	63	61	52	39	105
1200 to 1259	35	2	5	76	322	144		38	16	18	55
1300 to 1359	27	2	3	33	207	120	79	43	55	29	89
1400 to 1459	35	1	10	56	143	162	61	62	34	12	77
1500 to 1559	34	10	18	100	65	129	34	56	32	1	64
1600 to 1659	22	8			166	99	15	31			54
1700 to 1759					93	99					
1800 to 1859					32						
1900 to 1959											
2000 to 2059											
Total	**280**	**56**	**48**	**1,551**	**1,895**	**1,554**	**391**	**589**	**375**	**237**	**654**

Table 3

Continued.

Date:	*6 Jun*	*7 Jun*	
Observation Time (Start):	*7:20*	*7:30*	
Observation Time (End):	*16:15*	*14:35*	*Total*
Military Time (hrs)			
0600 to 0659			**18**
0700 to 0759	20	5	**266**
0800 to 0859	17	39	**1,430**
0900 to 0959	40	34	**2,663**
1000 to 1059	41	41	**1,875**
1100 to 1159	59	34	**1,811**
1200 to 1259	80	24	**1,690**
1300 to 1359	49	4	**1,941**
1400 to 1459	49	1	**1,959**
1500 to 1559	56		**1,710**
1600 to 1659	5		**1,327**
1700 to 1759			**634**
1800 to 1859			**198**
1900 to 1959			**0**
2000 to 2059			**0**
Total	**416**	**182**	**17,522**

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2002. No operation on April 19, 21, May 2-5, and 14-26.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
15 Apr	466	233	233	50%	50%
16 Apr	408	282	126	69%	31%
17 Apr	588	588	0	100%	0%
18 Apr	126	126		100%	0%
20 Apr	6	6		100%	0%
22 Apr	166	50	116	30%	70%
23 Apr	15	5	10	34%	66%
24 Apr	36	4	32	10%	90%
25 Apr	12	12	0	100%	0%
26 Apr	8	8	0	100%	0%
27 Apr	2	2		100%	0%
28 Apr	996	100	896	10%	90%
29 Apr	535	134	401	25%	75%
30 Apr	131	131		100%	0%
1 May	45	45		100%	0%
6 May	20	20		100%	0%
7 May	80	76	4	95%	5%
8 May	638	319	319	50%	50%
9 May	1,186	237	949	20%	80%
10 May	2,978	1,489	1,489	50%	50%
11 May	542	542		100%	0%
12 May	310	310	0	100%	0%
13 May	280	280		100%	0%
27 May	56	6	50	10%	90%
28 May	48	48	0	100%	0%
29 May	1,551	451	1,100	29%	71%
30 May	1,895	1,195	700	63%	37%
31 May	1,554	932	622	60%	40%
1 Jun	391	274	117	70%	30%
2 Jun	589	442	147	75%	25%
3 Jun	375	319	56	85%	15%
4 Jun	237	71	166	30%	70%
5 Jun	654	425	229	65%	35%
6 Jun	416	292	124	70%	30%
7 Jun	182	164	18	90%	10%
Total	*17,522*	*9,618*	*7,904*	*54.9%*	*45.1%*

Table 5

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

	1997	1998*	1999	2000*	2001	2002*
Migration season start date	18-Apr	27-Apr	25-Apr	6-May	27-Apr	15-Apr
Migration season end date	14-Jun	12-Jun	3-Jun	14-Jun	8-Jun	7-Jun
Season Duration (days)	58	47	40	40	43	55
Number of days of operation	55	41	40	36	42	35
American shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001
American shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522
River flow ≤40,000 cfs						
Number of days	48	22	34	19	40	19
Percent of season	87%	54%	85%	53%	95%	54%
Number of American shad passed	26,201	7,512	34,069	19,712	109,342	10,322
Daily average of American shad passed	546	341	1,002	1,037	2,733	543
Percent of Total Passage	93%	91%	98%	67%	99%	59%
River flow 40,001 to 60,000 cfs						
Number of days	7	2	6	12	2	14
Percent of season	13%	5%	15%	33%	5%	40%
Number of American shad passed	1,862	230	633	9,536	634	7,029
Daily average of American shad passed	266	115	106	795	317	502
Percent of Total Passage	7%	3%	2%	32%	1%	40%
River flow >60,000 cfs						
Number of days	0	17	0	5	0	2
Percent of season	0%	41%	0%	14%	0%	6%
Number of American shad passed	0	493	0	173	0	171
Daily average of American shad passed	0	29	0	35	0	86
Percent of Total Passage	0%	6%	0%	1%	0%	1%

* Denotes seasons of high river flow.

Table 6

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2002.

	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%

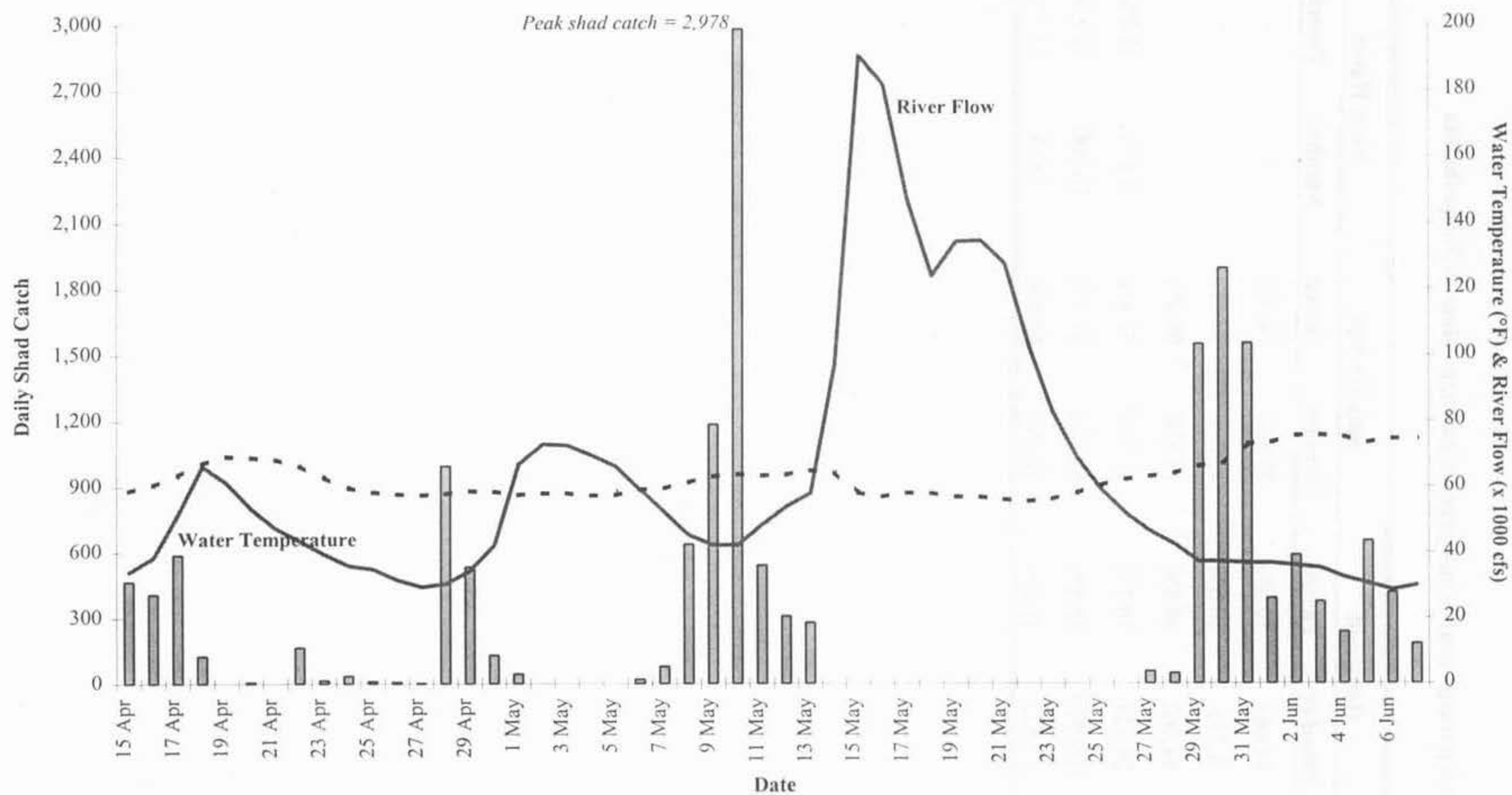

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2002. No operation on April 19, 21, May 2-5, and 14-26.

JOB I – PART 4
SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY IN SPRING 2002

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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 2002 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, the third upstream dam on the Susquehanna River is located at 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.

The station was built in 1931 and originally consisted of seven generating units. Five units were added and operational in 1986, which increased the hydraulic capacity to 110,000 cfs. Each unit is capable of passing approximately 8,500 cfs. Natural river flows in excess of

110,000 cfs are spilled over three regulating and 28 crest gates. The five new mixed-flow turbines have seven fixed-runner blades, a diameter of 240 in, and runner speed of 76.6 rpm. The runner blades are somewhat spiraled and do not have bands at the top or bottom. Two of these new turbines are equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The seven old units are five-blade Kaplan type turbines. These units have horizontal, adjustable, propeller-shaped blades.

Fishway Design and Operation

Fishway Design

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

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

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; (3) entrance A and C, and (4) entrance A, B, and C individually. Operation during most of the 2002 season utilized a combination of entrances A and C (Table 2).

Fishway Operation

Fishway operation was scheduled to commence two days after passage of 500 American shad via the Holtwood Fishway, which occurred on 16 April. The Safe Harbor fishway began operation on 17 April and continued until 13 June. Operation ceased on 13 June, at which time the fish catch was dwindling and the water temperature was rising; indications that the migration run was ending. Throughout the 2002 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

Daily operation of the Safe Harbor fishway was dependent on the American shad catch and managed in a flexible fashion. To minimize interruptions to fishway operation, SHWPC performed maintenance activities that included periodic cleaning of the exit channel, daily inspections, cleaning of picket screens, and other routine maintenance activities. Mechanical and/or electrical problems were addressed as needed. During the 2002 season, no loss of fishing time occurred due to mechanical problems with fish lift equipment.

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. Passage from the fishway was controlled by one gate located downstream of the window. Generally, fish passage was controlled by the technician, who opened/closed a set of gates downstream of the viewing window from a controller located in the counting room. Once shad passage increased, fish were denied passage from the fishway by closing the gates downstream of the window each night.

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 most of the season, the adjustable screen was set at 18 in.

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

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed in 2002 by the Safe Harbor fishway is presented in Table 1. A total of 135,720 fish of 28 species and 3 hybrids passed upstream into Lake Clarke. Gizzard shad (98,138) was the dominant species passed and comprised 72% of the catch. Some 11,705 American shad were passed upstream through the fishway. Other predominant fishes passed included quillback (10,034), smallmouth bass (5,968), shorthead redhorse (5,350), and walleye (2,685). Peak passage occurred on 13 May, when 14,823 fish were passed.

Passage of American Shad and other alosids

The Safe Harbor fishway passed 11,705 American shad in 2002 during 35 days of operation (Table 1). Though collection and passage of shad varied daily, numbers were generally lower than in recent years due to high spring river flows and fewer American shad passed by the downstream fish passage facilities. Peak shad passage occurred on 13 May when 2,021 shad were captured and passed in approximately eight hours of operation.

American shad were passed at water temperatures of 56.0°F to 75.0°F and river flows of 28,500 to 97,200 cfs (Table 2 and Figure 1). Water temperature and river flow on those days when more than 500 American shad were passed, averaged 68.4°F (62°F to 75.0°F) and 39,662 cfs (28,500 cfs to 58,000 cfs), respectively.

The number of American shad observed passing through the trough by hour is shown in Table 3. With the season's shad catch broken down based on hour of observation, passage rates were generally similar from 0900 to 1559 hr, with a sharp, then steady decrease in catch from 1600 to 1759 hr. A total of 9,483 American shad (81% of total shad passage) passed during the six-hour period between 1000 and 1559 hr. The highest hourly passage (1,871) occurred between 1300 and 1359 hr. During the 2002 season, no American shad tagged downstream of Conowingo dam by the MDDNR were observed at the Safe Harbor fishway.

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2002. High river flows may have hindered migration efforts of herring since only a total of 13 blueback herring were observed passing through the Holtwood fish passage facility.

SUMMARY

The 2002 Safe Harbor fishway operating season was successful. Although high river flows impacted American shad passage, no operational time was lost due to mechanical problems. In 35 days, 11,705 American shad were passed into Lake Clarke, or nearly 67% 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 six years of experience.

RECOMMENDATIONS

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

LITERATURE CITED

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

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

Table 1

Number and disposition of fish passed by the Safe Harbor fishway in 2002. No operation on April 20-21, 27-28, May 4-5, 11-12, 15-27, and June 9-10.

Date:	*17 Apr*	*18 Apr*	*19 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*
Hours of Operation:	*5.3*	*6.0*	*5.7*	*5.0*	*5.3*	*9.4*	*7.8*	*4.2*
Start Time:	*10:30*	*9:47*	*9:52*	*10:30*	*10:10*	*8:00*	*9:13*	*10:10*
End Time:	*15:50*	*15:45*	*15:33*	*15:30*	*15:30*	*17:23*	*17:00*	*14:20*
Numbers of Lifts:	*6*	*6*	*6*	*5*	*6*	*19*	*15*	*5*
Water Temperature (F):	*64.0*	*68.0*	*68.0*	*64.0*	*60.0*	*68.5*	*70.2*	*56.0*
American shad	342	268	119	88	44	41	41	20
Gizzard shad	739	1,634	2,302	787	2,818	351	247	321
Rainbow trout	0	0	0	0	1	0	0	0
Brown trout	1	3	4	0	1	1	0	0
Brook trout	0	0	0	0	0	0	0	0
Splake	0	0	0	0	0	1	0	0
Tiger muskie	0	0	0	0	0	0	0	0
Carp	0	0	2	1	0	0	0	1
Sea lamprey	0	0	1	0	0	0	0	0
Quillback	1,376	1,977	916	168	0	1	4	0
White sucker	20	9	11	3	0	0	1	0
Northern hogsucker	0	0	2	0	0	0	0	0
Shorthead redhorse	354	1,629	1,009	192	13	8	8	1
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	6	40	18	3	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	2	4	2	1	0	2
Green sunfish	0	1	0	0	0	1	0	0
Pumpkinseed	0	2	1	2	0	0	0	0
Bluegill	21	2	0	5	0	0	0	0
Hybrid Striped bass	1	0	0	0	0	0	0	0
Rock bass	9	8	7	5	0	1	0	0
Smallmouth bass	1,332	1,276	963	80	7	16	12	10
Largemouth bass	0	0	1	0	0	0	0	0
White crappie	0	1	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0
Tessellated darter	0	0	1	0	0	0	0	0
Greenside darter	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	26	42	58	17	0	0	1	0
Total	***4,227***	***6,892***	***5,417***	***1,355***	***2,886***	***422***	***314***	***355***

Table 1

Continued.

Date:	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*6 May*	*7 May*	*8 May*
Hours of Operation:	*5.6*	*3.8*	*6.1*	*4.5*	*6.3*	*4.2*	*7.8*	*6.3*
Start Time:	*10:00*	*11:50*	*9:45*	*11:30*	*8:30*	*11:10*	*8:55*	*9:30*
End Time:	*15:37*	*15:40*	*15:50*	*16:00*	*14:45*	*15:20*	*16:40*	*15:45*
Numbers of Lifts:	*6*	*5*	*6*	*5*	*5*	*7*	*10*	*11*
Water Temperature (F):	*57.0*	*57.0*	*57.0*	*57.2*	*57.0*	*58.0*	*60.0*	*61.0*
American shad	149	218	242	75	50	239	384	173
Gizzard shad	1,800	738	1,790	2,215	569	809	1,672	3,317
Rainbow trout	0	0	0	0	0	1	1	1
Brown trout	0	0	0	1	1	1	3	4
Brook trout	0	0	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0
Carp	0	3	4	0	0	1	1	3
Sea lamprey	0	1	1	0	0	1	0	1
Quillback	821	69	13	0	1	101	847	334
White sucker	1	0	0	1	0	1	1	1
Northern hogsucker	0	0	0	0	0	0	0	0
Shorthead redhorse	103	44	22	9	5	96	773	372
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	1	0	3	5	0	2	1
Yellow bullhead	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
Redbreast sunfish	2	0	0	0	0	1	0	0
Green sunfish	0	0	0	0	0	0	0	10
Pumpkinseed	1	1	0	1	0	0	1	5
Bluegill	0	1	9	0	0	0	4	24
Hybrid Striped bass	1	0	0	0	0	0	0	0
Rock bass	1	0	0	6	1	4	10	14
Smallmouth bass	242	88	85	46	28	65	449	200
Largemouth bass	2	0	1	0	0	1	4	4
White crappie	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0
Tessellated darter	0	0	0	0	0	0	0	0
Greenside darter	0	0	0	0	1	0	0	0
Yellow perch	0	0	2	0	0	0	0	0
Walleye	6	4	8	4	4	4	80	169
Total	***3,129***	***1,168***	***2,177***	***2,361***	***665***	***1,325***	***4,232***	***4,633***

Table 1

Continued.

Date:	*9 May*	*10 May*	*13 May*	*14 May*	*28 May*	*29 May*	*30 May*	*31 May*
Hours of Operation:	*8.3*	*6.3*	*7.7*	*5.5*	*6.3*	*6.5*	*8.6*	*7.5*
Start Time:	*8:20*	*9:45*	*8:55*	*8:30*	*8:00*	*8:30*	*9:00*	*8:00*
End Time:	*16:40*	*16:00*	*16:35*	*14:00*	*14:20*	*15:00*	*17:33*	*15:30*
Numbers of Lifts:	*9*	*9*	*12*	*9*	*8*	*9*	*15*	*11*
Water Temperature (F):	*63.0*	*62.0*	*64.0*	*63.0*	*63.0*	*66.0*	*70.0*	*71.0*
American shad	528	646	2,021	153	134	221	1,073	683
Gizzard shad	4,050	2,142	12,424	14,335	5,235	6,677	4,782	2,875
Rainbow trout	0	0	0	0	0	0	5	0
Brown trout	1	0	1	0	0	1	2	1
Brook trout	0	0	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	1	0	0
Carp	1	0	3	5	6	14	98	66
Sea lamprey	1	1	0	3	1	2	0	1
Quillback	38	1	47	40	361	412	360	462
White sucker	0	0	0	0	1	0	2	0
Northern hogsucker	0	0	0	0	0	0	0	0
Shorthead redhorse	44	8	30	9	57	147	98	145
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	11	0	7	12	10	20	73	62
Yellow bullhead	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	2	0	4	5	13	3
Green sunfish	0	3	9	4	0	2	0	0
Pumpkinseed	1	4	3	2	2	6	0	1
Bluegill	5	8	18	5	17	2	15	9
Hybrid Striped bass	0	0	0	0	0	0	0	0
Rock bass	24	2	13	9	2	10	13	5
Smallmouth bass	217	19	122	73	75	170	121	80
Largemouth bass	0	1	1	1	1	9	9	6
White crappie	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	2	0	0
Tessellated darter	0	0	0	0	0	0	0	0
Greenside darter	0	0	0	0	0	0	0	0
Yellow perch	1	0	0	0	0	1	0	0
Walleye	83	7	122	59	71	99	147	185
Total	***5,005***	***2,842***	***14,823***	***14,710***	***5,977***	***7,801***	***6,811***	***4,584***

Table 1

Continued.

Date:	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*
Hours of Operation:	*7.8*	*8.5*	*6.3*	*6.5*	*6.3*	*8.3*	*7.5*	*4.6*
Start Time:	*8:45*	*8:30*	*8:45*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*
End Time:	*16:30*	*17:00*	*15:00*	*14:30*	*14:15*	*16:20*	*15:30*	*12:36*
Numbers of Lifts:	*16*	*16*	*9*	*8*	*7*	*12*	*11*	*8*
Water Temperature (F):	*70.0*	*72.0*	*73.0*	*73.0*	*73.0*	*75.0*	*73.0*	*73.0*
American shad	943	699	329	252	110	520	413	211
Gizzard shad	2,687	3,735	1,629	1,313	694	1,537	4,507	1,554
Rainbow trout	5	3	1	0	0	0	0	0
Brown trout	0	2	0	0	0	0	0	0
Brook trout	1	0	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0
Carp	9	9	29	79	19	27	13	0
Sea lamprey	0	1	0	0	0	0	2	0
Quillback	444	684	70	102	11	17	9	90
White sucker	1	0	1	0	0	0	0	0
Northern hogsucker	0	0	0	0	0	0	0	0
Shorthead redhorse	48	44	11	5	4	1	1	7
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	45	92	28	17	4	25	24	63
Yellow bullhead	0	1	0	0	0	1	0	0
Striped bass	0	0	0	0	0	1	0	0
Redbreast sunfish	5	11	2	2	1	6	1	4
Green sunfish	2	3	1	2	0	0	1	1
Pumpkinseed	3	4	3	0	2	2	2	2
Bluegill	10	9	2	0	2	3	0	8
Hybrid Striped bass	0	0	0	0	0	0	0	0
Rock bass	3	7	0	0	1	0	3	0
Smallmouth bass	43	38	28	11	11	22	10	7
Largemouth bass	5	3	5	2	8	11	5	2
White crappie	0	0	0	0	0	1	0	0
Black crappie	0	0	0	0	0	0	0	0
Tessellated darter	0	0	0	0	0	0	0	0
Greenside darter	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	1	0	0
Walleye	189	336	108	71	40	41	107	218
Total	***4,443***	***5,681***	***2,247***	***1,856***	***907***	***2,216***	***5,098***	***2,167***

Table 1

Continued.

Date:	*11 Jun*	*12 Jun*	*13 Jun*	***Totals***
Hours of Operation:	*5.7*	*6.3*	*3.7*	***221.5***
Start Time:	*8:20*	*7:50*	*8:05*	*--*
End Time:	*14:00*	*14:10*	*11:45*	*--*
Numbers of Lifts:	*8*	*10*	*5*	***315.0***
Water Temperature (F):	*70.0*	*70.0*	*74.0*	*--*
American shad	212	58	6	***11,705***
Gizzard shad	3,257	1,769	827	***98,138***
Rainbow trout	3	1	1	***23***
Brown trout	0	0	0	***28***
Brook trout	0	0	0	***1***
Splake	0	0	0	***1***
Tiger muskie	0	0	0	***1***
Carp	3	0	2	***399***
Sea lamprey	0	0	0	***17***
Quillback	92	115	51	***10,034***
White sucker	0	0	0	***54***
Northern hogsucker	0	0	0	***2***
Shorthead redhorse	32	14	7	***5,350***
Brown bullhead	0	1	0	***1***
Channel catfish	29	38	17	***656***
Yellow bullhead	0	0	1	***3***
Striped bass	0	0	0	***1***
Redbreast sunfish	6	7	5	***91***
Green sunfish	3	0	1	***44***
Pumpkinseed	3	1	0	***55***
Bluegill	3	6	7	***195***
Hybrid Striped bass	0	0	0	***2***
Rock bass	9	2	1	***170***
Smallmouth bass	6	13	3	***5,968***
Largemouth bass	1	2	0	***85***
White crappie	0	0	0	***2***
Black crappie	0	0	0	***2***
Tessellated darter	0	0	0	***1***
Greenside darter	0	0	0	***1***
Yellow perch	0	0	0	***5***
Walleye	187	170	22	***2,685***
Total	***3,846***	***2,197***	***951***	***135,720***

Table 2

Summary of daily average river flow, water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Safe Harbor fish passage facility in 2002. No operation on April 20-21, 27-28, May 4-5, 11-12, 15-27, and June 9-10.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
17 Apr	51,600	64.0	18	10	1,3 to 10,12	A & C	500	173.3-174.03	225.8-226.6
18 Apr	66,200	68.0	18	10	1,3 to 10,12	A & C	500	173.5-175.0	225.6-225.8
19 Apr	61,100	68.0	20	10	1,3 to 10,12	A & C	500	173.9-174.0	226.4-226.5
22 Apr	43,400	64.0	30	7	1,3 to 7,9	A & C	500	171.5-172.0	225.97-226.0
23 Apr	39,400	64.0	30	7	1,3 to7,9	A & C	500	172.2-173.1	225.5-225.6
24 Apr	35,900	57.0	30	6	1, 3 to 7	A & C	500	172.05-172.5	225.76-225.91
25 Apr	34,900	57.0	23	6	1, 3 to 7	A & C	500	171.58-173.3	225.77-225.79
26 Apr	31,600	56.0	28	6	2 to 7	A & C	500	171.50-171.68	225.8-225.9
29 Apr	34,400	57.0	22	7	1, 3 to 8	A, B &C	500	170.2-172.1	226.3-226.5
30 Apr	42,300	57.0	24	8	1, 3 to 7, 9,10	A & C	500	172.3-172.9	225.2-225.5
1 May	66,900	57.0	30	10	1, 3 to 11	A & C	500	174.6-175.3	225.6-225.8
2 May	73,000	57.2	22	11	1, 3 to 12	A & C	500	174.6-175.3	224.6-224.8
03 May	72,600	57.0	22	11	1, 3 to 12	A & C	500	175.5-175.7	224.9-225.6
06 May	59,200	58.0	32	9	1,3 to 7,9 to 11	A & C	500	173.96-174.99	224.65-225.25
07 May	52,200	60.0	30	9	1,3 to 7,9,10,12	A & C	500	173.6-175.0	224.8-226.43
08 May	45,200	61.0	36	8	1, 3 to 7, 9,10	A & C	500	172.42-175.5	225.6-226.31
09 May	42,200	63.0	22	7	1,3 to 7,9	A & C	500	171.3-173.3	225.9-226.7
10 May	42,200	62.0	32	7	1, 3 to 7,9	A & C	500	172.4-173.9	225.3-226.1
13 May	58,000	64.0	20	10	1, 4 to 12	A & C	500	173.25-174.20	224.77-225.46
14 May	97,200	63.0	19	12	1 to 12	A & C	500	175.0-175.7	225.0
28 May	42,400	63.0	32	9	1 to 7,9,10	A & C	500	172.4-173.8	225.40-226.5
29 May	37,200	66.0	26	6	1, 3 to 7	A & C	500	170.69-172.05	225.95-226.43
30 May	37,200	70.0	20	6	1, 3 to 7	A & C	500	170.4-173.6	225.4-226.5

Table 2

Continued.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
31 May	36,700	71.0	26	6	1, 3 to 7	A & C	500	170.6-172.17	226.0-226.14
01 Jun	36,700	70.0	18	7	3 to 7,9,10	A & C	500	170.8-173.6	225.5-226.8
02 Jun	36,000	72.0	20	8	3 to 6,9 to12	A & C	500	170.4-172.1	225.2-226.8
03 Jun	35,200	73.0	25	11	1 to 7,9 to 12	A & C	500	171.49-173.35	225.45-226.67
04 Jun	32,400	73.0	24	10	1 to 7,9 to 11	A & C	500	169.72-172.60	225.92-226.84
05 Jun	30,500	73.0	24	9	1,3 to 7,9 to11	A & C	500	170.1-172.75	26.15-226.7
06 Jun	28,500	75.0	25	9	1,4 to 7,9 to 12	A & C	500	170.1-174.95	224.95-226.7
07 Jun	29,900	73	24	9	1 to 7,9,10	A & C	500	171.30-172.46	225.53-225.92
08 Jun	77,900	73	22	12.0	1 to 12	A & C	500	173.5-175.33	225.9-226.3
11 Jun	71,400	70	16	12	1 to 12	A & C	500	175.1-176.30	225.95-226.60
12 Jun	53,400	70	19	11	1, 3 to 12	A & C	500	173.03-173.88	225.38-226.60
13 Jun	44,500	74	25	8	1, 3 to 9	A & C	500	172.2-172.9	226.60-226.80

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2002. No operation on April 20-21, 27-28, May 4-5, 11-12, 15-27, and June 9-10.

Date:	*17 Apr*	*18 Apr*	*19 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*
Observation Time (Start):	*10:30*	*10:35*	*10:30*	*10:00*	*10:10*	*10:00*	*10:30*	*10:00*	*12:30*	*11:30*	*9:30*	*12:25*
Observation Time (End):	*16:15*	*16:00*	*15:45*	*16:00*	*16:00*	*14:30*	*14:45*	*14:40*	*16:00*	*16:00*	*16:15*	*15:40*
Military time (hrs)												
0800 to 0859												
0900 to 0959											20	
1000 to 1059	1	15	28	8	8	6	10	7			45	
1100 to 1159	7	57	22	29	5	6	15	1		12	22	
1200 to 1259	20	43	23	23	7	13	6	0	54	22	43	30
1300 to 1359	64	86	27	8	7	4	3	5	36	51	54	12
1400 to 1459	91	44	13	11	10	12	7	7	31	77	22	13
1500 to 1559	96	23	6	9	7				28	56	33	20
1600 to 1659	63										3	
1700 to 1759												
Total	***342***	***268***	***119***	***88***	***44***	***41***	***41***	***20***	***149***	***218***	***242***	***75***

Date:	*3 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*13 May*	*14 May*	*28 May*	*29 May*	*30 May*	*31 May*
Observation Time (Start):	*10:00*	*10;00*	*10:00*	*9:30*	*9:30*	*11:00*	*8:50*	*8:30*	*9:20*	*8:15*	*9:00*	*8:30*
Observation Time (End):	*15:00*	*16:00*	*17:00*	*16:05*	*17:05*	*16:15*	*16:50*	*14:05*	*14:40*	*15:05*	*17:45*	*16:00*
Military time (hrs)												
0800 to 0859							9	58		2		93
0900 to 0959				11	56		41	24	4	26	142	153
1000 to 1059	21	1	49	23	50		329	27	29	16	55	123
1100 to 1159	9	13	42	38	42	87	210	5	21	31	133	104
1200 to 1259	7	66	85	26	97	96	266	7	28	10	128	54
1300 to 1359	5	67	70	19	73	189	386	24	24	27	138	51
1400 to 1459	8	60	74	23	51	145	263	8	28	64	178	80
1500 to 1559		32	38	33	63	83	331			45	112	25
1600 to 1659			26		76	46	186				83	
1700 to 1759					20						104	
Total	***50***	***239***	***384***	***173***	***528***	***646***	***2,021***	***153***	***134***	***221***	***1,073***	***683***

Table 3

Continued.

Date:	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	***TOTAL***
Observation Time (Start):	*9:10*	*8:30*	*9:15*	*8:30*	*8:30*	*9:00*	*9:00*	*8:00*	*8:45*	*9:00*	*9:00*	
Observation Time (End):	*16:45*	*17:30*	*15:15*	*15:30*	*15:00*	*16:45*	*16:00*	*12:55*	*14:15*	*14:15*	*12:20*	
Military time (hrs)												
0800 to 0859		154		0	17			47	11	34		***425***
0900 to 0959	143	53	119	36	24	24	116	23	56	2	2	***1,075***
1000 to 1059	204	58	68	33	18	64	40	77	39	16	1	***1,469***
1100 to 1159	150	63	41	42	4	88	46	32	45	2	3	***1,427***
1200 to 1259	118	64	19	55	6	36	84	32	24	4	0	***1,596***
1300 to 1359	105	74	41	47	23	79	49		23	0		***1,871***
1400 to 1459	91	109	28	29	18	173	42		14			***1,824***
1500 to 1559	67	74	13	10		56	36					***1,296***
1600 to 1659	65	35				0						***583***
1700 to 1759		15										***139***
Total	***943***	***699***	***329***	***252***	***110***	***520***	***413***	***211***	***212***	***58***	***6***	***11,705***

Table 4

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2002.

	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%

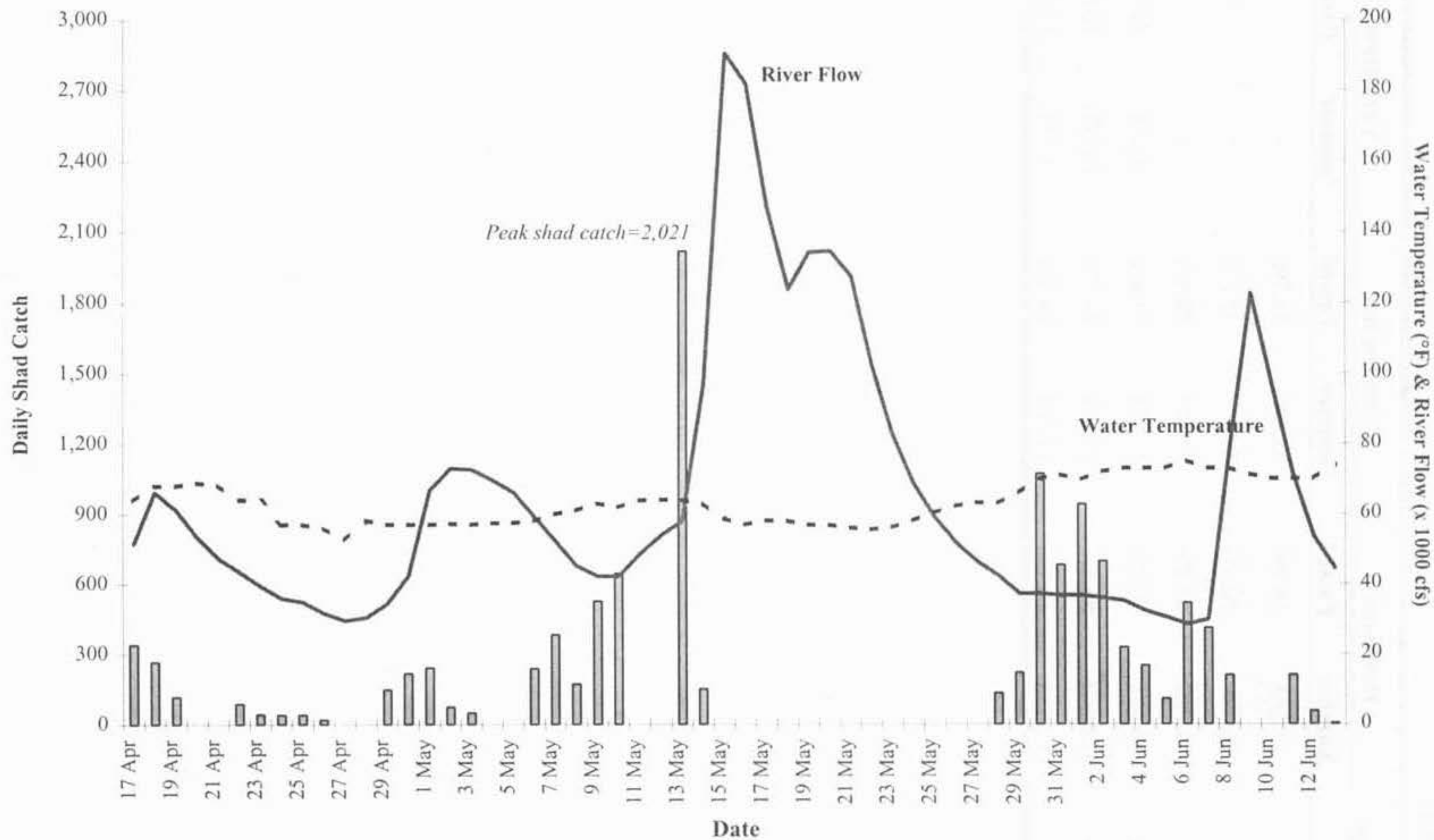

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Safe Harbor fish passage facility, spring 2002. No operation on April 20-21, 27-28, May 4-5, 11-12, 15-27, and June 9-10.

JOB I - Part 5
SUMMARY OF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT IN 2002

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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.

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 York Haven Fishway (Fishway) is located in Dauphin County, PA at the Three Mile Island end of the East Channel Dam at the York Haven Hydroelectric Project (FERC No. 1888). The Fishway was placed in service by YHPC in April 2000.

Fishway operation coincides with a springtime minimum flow release. As part of the 1997 agreement, YHPC agreed to maintain a spill of up to 4,000 cfs over the Main Dam and a minimum release of approximately 2,000 cfs in the East Channel through the Fishway during spring operation. In 2001, on a trial basis as approved by the FPTAC, Main Dam spill was reduced to 1,000 cfs on alternate nights. Since the number of fish passing the Fishway was greater on the days following reduced night-time spill in 2001 the FPTAC consequently approved reduction of spill to 1,000 cfs each night and, on a trial basis, reduction of spill to 1,000 cfs on alternate days in 2002. Specific recommendations concerning minimum flows included in the 2002 Fishway Operation Procedure included:

1. Reducing the night-time controlled spill of 4,000 cfs over the Main dam if/when flows were less than 23,000 cfs. Spilling a minimum of 1,000 cfs nightly between the end of daily Fishway operation (1900 hrs) and 0600 hrs the following morning.

2. On a trial basis, if/when River flows were less than 23,000 cfs, reduce the 4,000 cfs spill over the Main Dam on an alternate day basis to a nominal minimum spill of 1,000 cfs during daily Fishway operation (0600 to 1900 hrs).

Objectives of 2002 operation were to monitor passage of migratory and resident fishes through the Fishway and continue to assess operation, including improvements to the Fishway and modifications to springtime minimum flow releases.

Project Operation

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

Fishway Design and Operation

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 found in 2000 and 2001 summary reports. (Kleinschmidt 2000 and 2002).

All preseason preparations to the Fishway were completed prior to 1 April. The Fishway was opened on 29 April, 13 days after the Safe Harbor Fish Lift was placed into service. Although the Fishway was open through 11 June, fish were only allowed to pass through the ladder on 31 days. Unlike the previous two seasons, river flows were varied and high in 2002, which disrupted the passage schedule. High flows and limited shad passage resulted in the Fishway being manned on alternate days between 2 and 6 May and 17 and 31 May. High flows on 15 and 16 May and 9 June resulted in the cancellation of Fishway operation. Generally, the Fishway was manned between 0800 hrs and 1500 hrs throughout the spring migration season. The USFWS Susquehanna River Anadromous Fish Coordinator was apprized and agreed with this modified Fishway operation schedule. The decision to shut the Fishway down for the season was mutually decided by members of the FPTAC based on several factors, including a noticeable reduction in daily shad passage, a late season high flow event coupled with rising water temperatures in excess of 70°F.

Two people opened the Fishway. First, the attraction flow through the "weir cut" was released by opening both 20-ft wide fixed wheel gates. Next, the downstream entrance gate and the upstream "exit gate" of the ladder were opened. Then the "diffuser gate" was opened. These five gates remained opened the entire season. 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 operation, which involved opening and closing the Fishway, the Fishway was typically manned 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.

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. The counting area is located approximately 25-ft upstream of the upper most pool (Figure 2). As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 2-ft wide and 5-ft long channel that is located on the west side of the exit flume. This channel is adjacent to a 4-ft by 8-ft 6-in window located in the counting room through which fish are enumerated. The area in front of the window is illuminated by two 500 watt underwater pool lights that are mounted in the grating that forms the bottom of this channel. Intensity of these lights is rheostat-controlled from inside the counting room enabling the fish counter to set the lights to enhance viewing conditions as needed.

In 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. Normally, this gate was closed each night at 1500 hrs and opened each morning the Fishway was manned between 0800 hrs and 0900 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 an effort to improve viewing, the adjustable crowder screen, modified prior to the start of operation, was adjusted as needed to allow all fish that past to be observed. Gate settings varied from 6 in to 20 in depending on river conditions.

As in the previous two 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 personnel on a daily basis. In addition, weekly passage information was supplied electronically to YHPC and other appropriate personnel along with 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. Several selected segments of tape were reviewed by a biologist using the video cassette recorder/player, which was equipped with a search dial control. This feature allowed selected segments of a day's tape to be quickly located and reviewed at different speeds during playback, including slow motion and frame by frame.

Results

Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 145,935 fish of 24 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (100,779) was the dominant fish species passed and comprised nearly 70% of the fish passed. Some 1,555 American shad were counted as they passed through the ladder. Other predominant fishes passed included walleye (14,415), quillback (11,935), shorthead redhorse (7,218), smallmouth bass (4,403), and channel catfish (3,859). Peak passage occurred on 11 June when some 33,159 fish, or 22.7% of the season total, were passed.

American Shad Passage

A total of 1,555 American shad passed upstream through the ladder in 2002 (Table 1). Shad passage varied daily with approximately 95% (1,473) passing during two periods interrupted by a high flow period. Some 618 (39.7%) and 855 (55.0%) shad passed between 6 and 14 May and 31 May and 8 June, respectively. Peak shad passage occurred on 2 June when 208 shad were passed. Some 0.5%, 44.3% and 54.7% of the shad passed in April, May and June, respectively.

American shad were collected and passed at water temperatures of 54.3°F to 73.2°F, river flows of 28,850 cfs to 140,167 cfs and East Channel flows of 3,200 cfs to 20,600 cfs (Tables 2 and 3, Figures 3 and 4). As previously indicated most shad passed through the ladder during two distinct time periods. Peak passage occurred between 31 May and 8 June at water temperatures that varied from 70.0°F to 73.2°F. During this period river flows generally declined from 34,441 cfs to 23,633 cfs between 31 May and 6 June before increasing to 93,133 cfs on 8 June. East channel flows during this period varied from 3,200 cfs to 13,000 cfs. Passage between 6 and 14 May or the other period, occurred at water temperatures that varied from 59.1°F to 63.7°F. River flows during this period flows varied from 37,350 cfs to 52,717 cfs before rising to 109,500 cfs on 18 May. East channel flows varied from 4,800 cfs to 18,200 cfs.

The hourly passage of American shad through the fish ladder is given in Table 3. Generally, daily shad passage was highest during the first three hours, it declined and leveled off between late morning and early afternoon and then continued to decline during the last three hours of viewing. Peak hourly passage of shad (97) occurred on 2 June between 0800 hrs and 0859 hrs. Over 66% of the shad passed during the first three hours, some 259 shad passed during the first hour, 460 shad passed during the second hour, and 321 shad passed during the third hour. Total passage hourly from 1100 hrs to 1259 hrs, although similar, declined from that during the first three hours and declined from 192 shad to 157 shad per hour. Total hourly passage between 1300 hrs and 1500 hrs declined slightly from mid-day levels and varied from 92 to 68 shad per hour. One alewife was passed on 8 May (Table 1). No blueback herring or hickory shad were observed passing through the ladder.

Video Record

A review of the video record showed that fish passage was adequately captured on the tape record. Data in Table 5 lists by date and time the shad count, the tape count, and the difference between the two counts. Differences between counts were negligible with most counts being identical or differing by 1 shad indicating that at this level of passage visual counts accurately reflect shad passage.

Although high flows in the spring 2002 reduced visibility during most of the season the crowder screen, modified prior to the start of the season, was easily adjusted by the individual viewing fish to water clarity conditions each day allowing all fish that past the viewing window to be identified. Although high river flows resulted in poor water clarity condition, tape quality was not affected. Visibility varied from 1.7-in to 24.0-in but was 12-in or less on 23 days during the spring season (Table 2).

Making a video record of fish passage should be continued as it provides a back-up, and the means to verify the accuracy of visual counts as the hourly passage of shad increases. Taping fish passage could also provide fishway operators flexibility to respond to other aspects of Fishway operation for limited periods of time. In the future, when hourly passage of shad exceeds 1,000 fish per hour, a limited review of the passage record should be conducted to determine the accuracy f visual counts.

Observations

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

Although it was not anticipated that American shad would be able to pass though the "weir cut" due to high velocities, observations were made several times each day in an attempt to see if American shad or other fishes passed upstream through this portion of the Fishway. No fish were observed passing through this portion of the Fishway.

Summary

The spring 2002 York Haven Fishway operating season was considered a success. Survival of fish that utilized the Fishway was considered excellent as no mortalities were observed. Some 1,555 American shad used the Fishway to pass upstream. This was 13.3% of the number of shad that passed Safe Harbor.

Although the impact high river flows had on upstream movement of shad in the river in 2002 is unknown, it is likely this factor resulted in lower passage rates at York Haven and the other three downstream dam fishways. Shad passage this season at York Haven was the lowest recorded since the Fishway was placed into service in 2000. YHPC will incorporate operating experience gained during the first three seasons which will enable all those involved with the restoration of American shad to the river to gain a better understanding of fish passage at York Haven.

Recommendations for 2003 Operation

1. Continue to work with the FPTAC to determine the minimum spill at the Main Dam and the attraction flow in the East Channel necessary to optimize fish passage and generation at the Project.

2. Continue the video tape record of fish passage since it provides back-up documentation. Review tape if hourly passage exceeds 1,000 shad.

DOWNSTREAM FISH PASSAGE

At the February 2002 FPTAC meeting plans were developed to finalize the "Downstream Passage Report" that was being prepared for submittal to FERC. The report had the concurrence of all FPTAC members and concluded that continued implementation of YHPC's "Downstream Operations Protocol" would provide effective juvenile downstream passage at the Project. Members also concluded that it would be prudent to re-examine downstream passage of post-spawn adult American shad and other anadromous species later in the restoration program and that it be tied to upstream passage at the York Haven Fishway. Although no formal post-spawned adult downstream passage monitoring program is presently required, YHPC agreed to make periodic observations for adults in the forebay and that they would open the trash gate if/when large numbers of adults were observed.

Adult Passage

Station personnel made periodic observations of the forebay area from June 11, 2002 through August 29, 2002. No observations of post-spawned adult shad were noted. During this period the Station sluice gate was opened 21 times. The period between each opening was less than 1 week. This observation process will continue through 2003.

Juvenile Passage

YHPC in concert with the FPTAC developed a plan ("Juvenile Downstream Passage Protocol") combining preferential unit operation with use of the project trash sluice. 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 continues until about 11:30 p.m. Downstream Operation includes:

  (1) Turning on temporary lighting at the trash sluiceway and opening the sluiceway;

  (2) Operating only Units 1-6 when river flow is insufficient for operation of any of the remaining units;

  (3) 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.;

  (4) 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;

  (5) 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 24 September when river water temperature was 72° F and river flow at Harrisburg was 6,833 cfs. Downstream Operation began on 15 October and continued until 22 October (8 days), in accordance with the protocol. On 22 October, river water temperature was 53°F and river flow was 27,500 cfs.

During the 2002 Downstream Operation period, the York Haven units were operated according to the protocol. River flow exceeded station hydraulic capacity (17,000 cfs) during the eight day period. Daily average river flow peaked on 18 October at 50,533 cfs and declined to 17,500 cfs on 22 October.

Although the trash sluice was closed on 22 October, station personnel continued making observations nightly in the forebay through the remainder of October. As no juveniles were observed and water temperatures had fallen to 48.0°F it was determined that the juveniles had passed on the high flow event during mid-October and there was no need to continue making nightly observations in the forebay.

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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 2002.

Date	29-Apr	30-Apr	2-May	4-May	6-May	7-May	8-May	9-May	10-May	11-May
Observation Time	5.0	7.6	7.2	7.5	6.0	6.4	7.1	5.8	6.5	6.3
Water Temperature (°F)	57.7	54.7	55.4	54.3	59.1	59.9	61.6	61.3	61.4	62.3
AMERICAN SHAD	7	0	2	1	47	57	70	59	59	45
ALEWIFE	0	0	0	0	0	0	1	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	1348	1380	2,886	4,937	3,390	1,608	1,153	807	1,205	1,392
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	1	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	1	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	2
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	1
CARP	34	25	9	1	4	23	23	23	6	41
QUILLBACK	84	174	625	336	945	1,407	982	729	247	1,503
WHITE SUCKER	70	44	40	9	23	7	16	8	2	5
SHORTHEAD REDHORSE	30	105	332	247	723	1,119	775	440	431	780
YELLOW BULLHEAD	0	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	1	5	88	47	220	162	169	69	19	174
ROCK BASS	0	0	0	0	0	0	3	0	0	0
GREEN SUNFISH	0	0	0	0	0	2	0	14	0	0
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
BLUEGILL	0	0	0	0	0	0	2	1	0	6
SMALLMOUTH BASS	6	47	43	87	777	848	617	449	118	153
LARGEMOUTH BASS	0	0	0	0	0	0	1	0	0	0
YeLLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	12	243	88	52	409	832	1,080	976	458	599
FALLFISH	0	0	0	0	1	2	1	5	0	4
GOLD FISH	0	0	0	0	0	0	0	0	0	1
Total	1,592	2,023	4,113	5,717	6,541	6,067	4,893	3,580	2,545	4,706

Table 1. Continued

Date	12-May	13-May	14-May	17-May	19-May	21-May	23-May	25-May	27-May	29-May
Observation Time	6.0	6.3	6.1	7.0	6.5	5.8	7.0	6.5	6.3	7.0
Water Temperature (°F)	63.7	62.8	59.6	57.0	55.2	54.3	55.9	60.7	63.1	68.9
AMERICAN SHAD	118	139	24	1	4	0	13	17	4	3
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	771	1,115	975	4,431	3,275	1,048	496	2,172	1,178	1,112
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	2	0	1	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	3	1	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	1
CARP	7	13	10	23	8	1	7	1	2	18
QUILLBACK	1,831	602	182	38	13	5	4	12	36	585
WHITE SUCKER	7	0	3	1	0	0	0	19	0	0
SHORTHEAD REDHORSE	739	609	190	91	9	13	25	64	46	226
YELLOW BULLHEAD	0	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	0	0	0	0	0	0	0
CHANNEL CATFISH	170	99	545	66	13	1	0	4	3	34
ROCK BASS	0	0	0	0	0	0	0	15	0	0
GREEN SUNFISH	2	0	0	0	1	0	1	3	0	0
PUMKINSEED	0	0	0	0	0	0	0	0	0	0
BLUEGILL	36	8	0	0	0	0	0	1	12	28
SMALLMOUTH BASS	76	48	19	8	16	11	80	426	189	116
LARGEMOUTH BASS	0	0	0	0	0	0	0	2	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	809	645	147	16	27	10	8	670	792	930
FALLFISH	0	0	0	0	0	0	0	60	0	0
GOLD FISH	0	0	0	0	0	0	0	0	0	0
Total	4,568	3,278	2,096	4,675	3,366	1,089	637	3,467	2,262	3,053

Table 1. Continued

Date	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	10-Jun
Observation Time	7.0	6.1	7.0	6.3	7.0	6.2	7.0	7.0	6.4	7.0
Water Temperature (°F)	72.5	72.7	73.0	71.6	71.0	71.9	73.2	70.0	70.1	68.5
AMERICAN SHAD	35	66	208	102	89	64	162	60	69	0
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	1,556	1,483	1,678	2,803	3,868	3,276	2,749	1,607	4,548	7,835
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	2	3	1	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	1	3	0	0	0
BROWN TROUT	0	0	0	10	17	0	9	12	2	2
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	51	47	39	23	69	102	149	102	5	11
QUILLBACK	106	216	310	70	89	51	374	218	107	4
WHITE SUCKER	0	7	7	2	2	1	15	15	10	2
SHORTHEAD REDHORSE	52	21	52	15	8	4	6	9	49	1
YELLOW BULLHEAD	0	0	0	0	0	2	0	0	0	0
BROWN BULLHEAD	0	1	0	0	0	0	0	0	3	0
CHANNEL CATFISH	75	199	187	100	55	67	113	74	838	117
ROCK BASS	0	3	2	6	1	3	0	2	2	0
GREEN SUNFISH	0	0	2	0	0	0	0	0	0	0
PUMKINSEED	0	0	0	7	8	0	4	2	0	0
BLUEGILL	15	5	38	29	6	11	5	4	4	0
SMALLMOUTH BASS	22	18	47	55	44	36	31	13	0	1
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	3	0	0
WALLEYE	713	179	757	977	972	686	655	363	167	11
FALLFISH	0	21	0	0	0	5	0	0	1	0
GOLD FISH	0	0	0	0	0	0	0	0	0	0
Total	2,625	2,266	3,327	4,199	5,230	4,312	4,276	2,484	5,805	7,984

Table 1. Continued

Date	11-Jun	Total
Observation Time	6.3	203.4
Water Temperature (°F)	70.7	
AMERICAN SHAD	30	1,555
ALEWIFE	0	1
BLUEBACK HERRING	0	0
GIZZARD SHAD	32,697	100,779
HICKORY SHAD	0	0
STRIPED BASS	1	11
AMERICAN EEL	0	0
RAINBOW TROUT	0	9
BROWN TROUT	0	54
MUSKELLUNGE	0	2
CARP	87	964
QUILLBACK	50	11,935
WHITE SUCKER	2	317
SHORTHEAD REDHORSE	7	7,218
YELLOW BULLHEAD	0	2
BROWN BULLHEAD	6	10
CHANNEL CATFISH	145	3,859
ROCK BASS	0	37
GREEN SUNFISH	0	25
PUMKINSEED	0	21
BLUEGILL	0	211
SMALLMOUTH BASS	2	4,403
LARGEMOUTH BASS	0	3
YELLOW PERCH	0	3
WALLEYE	132	14,415
FALLFISH	0	100
GOLD FISH	0	1
Total	33,159	145,935

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East channel, sum of average flow from power station and main dam, water temperature, secchi, stop log gate position, and East channel and fishway water elevations during operation of the York Haven fishway complex in 2002.

	River	East	Main Dam	Water				Stop	Elevation (ft)					
	Flow	Channel	Flow	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	(cfs)	(°F)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
29-Apr	28,850	3,400	25,450	57.7	10.3	10.0	12.0	closed	279.5	279.4	279.5	274.6	274.5	275.6
30-Apr	43,817	5,700	38,117	54.7	12.0	12.0	12.0	closed	280.1	279.9	280.1	275.4	275.2	275.5
2-May	66,000	10,200	55,800	55.4	11.1	10.0	12.0	closed	280.8	280.8	280.8	276.9	276.9	277.0
4-May	64,850	10,200	54,650	54.3	12.0	12.0	12.0	closed	280.8	280.8	280.8	276.9	276.8	276.9
6-May	52,717	7,700	45,017	59.1	14.0	14.0	14.0	closed	280.4	280.4	280.4	276.3	276.2	276.3
7-May	46,300	5,700	40,600	59.9	18.0	18.0	18.0	closed	280.1	280.0	280.2	275.6	275.5	275.7
8-May	40,950	6,750	34,200	61.6	15.0	15.0	15.0	closed	280.0	279.9	280.0	275.4	275.3	275.5
9-May	37,350	4,800	32,550	61.3	18.0	18.0	18.0	closed	279.8	279.8	279.8	275.4	275.3	275.4
10-May	39,433	4,800	34,633	61.4	24.0	24.0	24.0	closed	279.8	279.8	279.9	275.1	2275.1	275.2
11-May	46,667	12,900	33,767	62.3	14.0	14.0	14.0	closed	281.1	281.0	281.1	275.6	275.6	275.6
12-May	49,033	6,750	42,283	63.7	9.0	7.0	10.0	closed	280.3	280.2	280.3	276.0	275.9	276.0
13-May	51,200	6,400	44,800	62.8	6.4	5.0	7.0	closed	280.2	280.2	280.2	275.8	275.8	275.9
14-May	109,500	18,200	91,300	59.6	7.4	6.0	8.0	closed	281.6	281.1	282.0	278.5	277.4	279.4
17-May	140,167	20,600	119,567	57.0	6.0	6.0	6.0	closed	282.4	282.4	282.5	280.1	280.0	280.3
19-May	126,333	19,350	106,983	55.2	6.0	6.0	6.0	closed	282.1	282.1	282.1	279.7	279.7	279.7
21-May	121,183	19,350	101,833	54.3	5.6	5.0	6.0	closed	282.1	282.1	282.1	279.6	279.4	279.7
23-May	76,517	11,400	65,117	55.9	12.0	12.0	12.0	closed	281.0	281.0	281.0	277.5	277.5	277.6
25-May	52,517	7,700	44,817	60.7	12.0	12.0	12.0	closed	280.4	280.4	280.4	276.9	276.9	276.9
27-May	41,383	5,700	35,683	63.1	24.0	24.0	24.0	closed	280.1	280.0	280.2	276.0	276.0	276.0
29-May	33,233	5,200	28,033	68.9	10.0	10.0	10.0	closed	280.9	280.9	280.9	275.7	275.7	275.7
31-May	33,687	4,900	28,787	72.5	5.4	5.0	6.0	closed	-	-	-	275.5	275.5	275.5
1-Jun	34,417	3,950	30,467	72.7	12.0	12.0	12.0	closed	279.6	279.6	279.6	274.7	274.6	275.0
2-Jun	33,100	3,950	29,150	73.0	7.5	7.0	8.0	closed	279.6	279.6	279.6	275.2	275.2	275.2
3-Jun	32,400	3,950	28,450	71.6	12.0	12.0	12.0	closed	279.6	279.6	279.6	275.2	275.2	275.2
4-Jun	29,567	3,400	26,167	71.0	12.0	12.0	12.0	closed	279.5	279.5	279.5	274.8	274.8	274.8
5-Jun	26,317	3,300	23,017	71.9	15.0	15.0	15.0	closed	279.3	279.3	279.4	274.3	274.2	274.3
6-Jun	23,633	3,200	20,433	73.2	10.0	10.0	10.0	closed	279.2	279.2	279.2	274.2	274.2	274.2
7-Jun	30,700	3,400	27,300	70.0	12.0	12.0	12.0	closed	279.3	279.3	279.3	274.5	274.5	274.5
8-Jun	93,133	13,000	80,133	70.1	7.0	7.0	7.0	closed	281.4	281.0	281.5	278.1	277.1	278.8
10-Jun	92,517	12,400	80,117	68.5	1.7	1.0	3.0	closed	281.3	281.2	281.4	278.1	277.9	278.3
11-Jun	64,383	9,600	54,783	70.7	7.0	7.0	7.0	closed	280.7	280.6	280.7	276.8	276.6	277.0

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2002.

	River	Elevation (ft)																				
	Flow	Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
Date	(cfs)	Avg.	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.
29-Apr	28,850	279.5	279.4	279.5	274.6	274.5	275.6	275.5	275.3	276.2	277.7	277.0	277.7	279.2	279.2	279.3	277.4	277.4	277.4	279.2	279.2	279.2
30-Apr	43,817	280.1	279.9	280.1	275.4	275.2	275.5	275.9	275.7	276.0	278.0	278.0	278.0	279.9	279.7	279.9	277.8	277.6	277.8	279.8	279.7	279.8
2-May	66,000	280.8	280.8	280.8	276.9	276.9	277.0	277.3	277.2	277.4	278.7	278.6	278.7	280.6	280.6	280.6	278.4	278.3	278.4	280.6	280.6	280.6
4-May	64,850	280.8	280.8	280.8	276.9	276.8	276.9	277.4	277.4	277.4	278.7	278.6	278.7	280.6	280.6	280.6	278.3	278.3	278.4	280.6	280.6	280.6
6-May	52,717	280.4	280.4	280.4	276.3	276.2	276.3	276.7	276.7	276.7	278.4	278.4	278.4	280.2	280.2	280.3	278.1	278.1	278.1	280.1	280.1	280.1
7-May	46,300	280.1	280.0	280.2	275.6	275.5	275.7	276.3	276.2	276.4	278.2	278.2	278.2	280.0	279.9	280.0	278.0	278.0	278.0	279.9	279.8	279.9
8-May	40,950	280.0	279.9	280.0	275.4	275.3	275.5	276.0	275.9	276.0	278.0	277.9	278.0	279.8	279.7	278.9	277.8	277.7	277.9	279.7	279.7	279.7
9-May	37,350	279.8	279.8	279.8	275.4	275.3	275.4	275.9	275.9	275.9	278.0	277.8	278.0	279.7	279.6	279.8	277.9	277.9	277.9	279.5	279.4	279.5
10-May	39,433	279.8	279.8	279.9	275.1	2275.1	275.2	275.6	275.6	275.7	277.9	277.9	277.9	279.6	279.6	279.7	278.6	278.6	278.7	279.5	279.5	279.6
11-May	46,667	281.1	281.0	281.1	275.6	275.6	275.6	276.1	276.1	276.1	278.1	278.1	278.1	280.0	280.0	280.0	278.0	278.0	278.0	279.9	279.9	279.9
12-May	49,033	280.3	280.2	280.3	276.0	275.9	276.0	276.4	276.3	276.4	278.4	278.3	278.4	280.1	280.1	280.1	278.0	278.0	278.0	280.0	280.0	280.0
13-May	51,200	280.2	280.2	280.2	275.8	275.8	275.9	276.2	276.2	276.3	278.2	278.2	278.2	280.0	280.0	280.0	278.0	278.0	278.1	280.0	280.0	280.0
14-May	109,500	281.6	281.1	282.0	278.5	277.4	279.4	278.7	277.7	279.6	279.6	278.9	280.2	281.4	280.9	281.9	279.2	278.5	279.7	281.3	280.9	281.7
17-May	140,167	282.4	282.4	282.5	280.1	280.0	280.3	280.5	280.4	280.6	280.7	280.5	280.7	282.3	282.2	282.4	280.4	280.2	280.5	282.3	282.2	282.4
19-May	126,333	282.1	282.1	282.1	279.7	279.7	279.7	280.2	280.2	280.2	280.4	280.4	280.4	283.0	283.0	283.0	280.1	280.1	280.1	282.0	282.0	282.0
21-May	121,183	282.1	282.1	282.1	279.6	279.4	279.7	280.1	279.9	280.2	280.3	280.2	280.4	281.9	281.8	282.0	280.2	280.1	280.3	281.9	281.8	282.0
23-May	76,517	281.0	281.0	281.0	277.5	277.5	277.6	278.0	278.0	278.1	278.8	278.8	278.9	280.8	280.8	280.9	278.5	278.5	278.6	280.8	280.8	280.9
25-May	52,517	280.4	280.4	280.4	276.9	276.9	276.9	277.4	277.4	277.4	278.4	278.4	278.4	280.1	280.1	280.1	278.0	278.0	278.0	280.1	280.1	280.1
27-May	41,383	280.1	280.0	280.2	276.0	276.0	276.0	276.5	276.5	276.5	277.8	277.8	277.8	279.8	279.8	279.8	277.7	277.7	277.7	279.8	279.7	279.8
29-May	33,233	280.9	280.9	280.9	275.7	275.7	275.7	276.3	276.3	276.3	277.7	277.7	277.7	279.4	279.4	279.4	277.5	277.5	277.5	279.3	279.3	279.4
31-May	33,687	-	-	-	275.5	275.5	275.5	276.3	276.3	276.3	277.6	277.6	277.6	279.3	279.3	279.3	277.5	277.5	277.5	279.3	279.3	279.3
1-Jun	34,417	279.6	279.6	279.6	274.7	274.6	275.0	275.9	275.9	275.9	277.7	277.6	277.7	279.4	279.4	279.4	277.5	277.4	277.5	279.3	279.3	272.4
2-Jun	33,100	279.6	279.6	279.6	275.2	275.2	275.2	275.7	275.7	275.7	277.9	277.9	277.9	279.3	279.3	279.3	277.5	277.5	277.5	279.3	279.3	279.3
3-Jun	32,400	279.6	279.6	279.6	275.2	275.2	275.2	275.7	275.7	275.7	277.7	277.7	277.7	279.3	279.3	279.3	277.5	277.5	277.5	279.2	279.2	279.2
4-Jun	29,567	279.5	279.5	279.5	274.8	274.8	274.8	275.3	275.3	275.3	277.5	277.5	277.5	279.2	279.2	279.2	277.5	277.5	277.5	279.1	279.0	279.2
5-Jun	26,317	279.3	279.3	279.4	274.3	274.2	274.3	275.1	275.1	275.1	277.5	277.5	277.6	279.1	279.1	279.2	277.3	277.3	277.3	279.0	279.0	279.0
6-Jun	23,633	279.2	279.2	279.2	274.2	274.2	274.2	275.0	275.0	275.0	277.5	277.5	277.5	279.0	279.0	279.0	277.5	277.5	277.5	278.9	278.8	278.9
7-Jun	30,700	279.3	279.3	279.3	274.5	274.5	274.5	275.0	275.0	275.0	277.6	277.6	277.6	279.0	279.0	279.0	277.6	277.6	277.6	279.0	279.0	279.0
8-Jun	93,133	281.4	281.0	281.5	278.1	277.1	278.8	278.4	277.3	279.2	279.5	278.9	279.9	281.2	280.7	281.6	279.1	278.5	279.4	281.1	280.7	281.5
10-Jun	92,517	281.3	281.2	281.4	278.1	277.9	278.3	278.6	278.4	278.8	279.1	278.4	279.5	281.1	281.0	281.2	279.9	279.3	281.0	281.1	281.0	281.2
11-Jun	64,383	280.7	280.6	280.7	276.8	276.6	277.0	277.3	277.1	277.7	278.6	278.6	278.7	280.4	280.4	280.5	278.3	278.3	278.4	280.3	280.3	280.4

Table 4. Hourly summary of American shad passage through the sepentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2002.

Date	29-Apr	30-Apr	2-May	4-May	6-May	7-May	8-May	9-May	10-May	11-May
Observation Time (Start)	901	822	849	830	901	838	853	910	830	840
Observation Time (End)	1500	1500	1500	1500	1600	1500	1500	1500	1500	1500
Military Time (HRS)										
0800 - 0859	-	0	0	0	-	7	11	-	16	3
0900 - 0959	0	0	0	0	21	12	22	18	15	18
1000 - 1059	0	0	0	0	7	6	19	17	8	8
1100 - 1159	0	0	0	1	7	10	6	9	10	5
1200 - 1259	0	0	0	0	6	9	9	9	2	7
1300 - 1359	4	0	1	0	0	7	1	6	5	4
1400 - 1459	3	0	1	0	6	6	2	0	3	0
1500 - 1559	-	-	-	-	-	-	-	-	-	-
Total Catch	7	0	2	1	47	57	70	59	59	45

Date	12-May	13-May	14-May	17-May	19-May	21-May	23-May	25-May	27-May	29-May
Observation Time (Start)	901	840	854	801	832	840	801	830	840	801
Observation Time (End)	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Military Time (HRS)										
0800 - 0859	-	32	0	0	0	0	0	0	1	2
0900 - 0959	42	36	13	0	2	0	0	11	2	0
1000 - 1059	16	34	5	0	1	0	0	4	0	0
1100 - 1159	21	16	1	0	1	0	0	2	0	1
1200 - 1259	25	10	0	1	0	0	13	0	1	0
1300 - 1359	9	7	4	0	0	0	0	0	0	0
1400 - 1459	5	4	1	0	0	0	0	0	0	0
1500 - 1559	-	-	-	-	-	-	-	-	-	-
Total Catch	118	139	24	1	4	0	13	17	4	3

Table 4. Continued

Date	31-May	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	10-Jun
Observation Time (Start)	801	853	801	801	901	847	801	801	835	901
Observation Time (End)	1500	1500	1500	1520	1500	1500	1500	1500	1500	1500
Military Time (HRS)										
0800 - 0859	4	3	97	6	-	5	36	21	13	-
0900 - 0959	9	37	44	49	34	16	13	14	20	0
1000 - 1059	4	7	23	23	32	17	67	6	10	0
1100 - 1159	2	5	20	8	10	16	26	11	4	0
1200 - 1259	4	2	15	7	6	6	9	1	9	0
1300 - 1359	0	8	4	3	3	3	7	2	12	0
1400 - 1459	12	4	5	0	4	1	4	5	1	0
1500 - 1559	-	-	-	6	-	-	-	-	-	-
Total Catch	**35**	**66**	**208**	**102**	**89**	**64**	**162**	**60**	**69**	**0**

Date	11-Jun	Total
Observation Time (Start)	840	
Observation Time (End)	1500	
Military Time (HRS)		
0800 - 0859	2	259
0900 - 0959	12	460
1000 - 1059	7	321
1100 - 1159	0	192
1200 - 1259	6	157
1300 - 1359	2	92
1400 - 1459	1	68
1500 - 1559	-	6
Total Catch	**30**	**1555**

Table 5. Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 2002 York Haven fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
13-May	6.4	0800 to 0859	32	32	0 (0%)
1-Jun	12.0	0900 to 0959	37	37	0 (0%)
2-Jun	7.5	1000 to 1059	97	96	1 (1%)
4-Jun	12.0	0900 to 0959	34	34	0 (0%)
6-Jun	10.0	1000 to 1059	67	68	-1 -(1%)

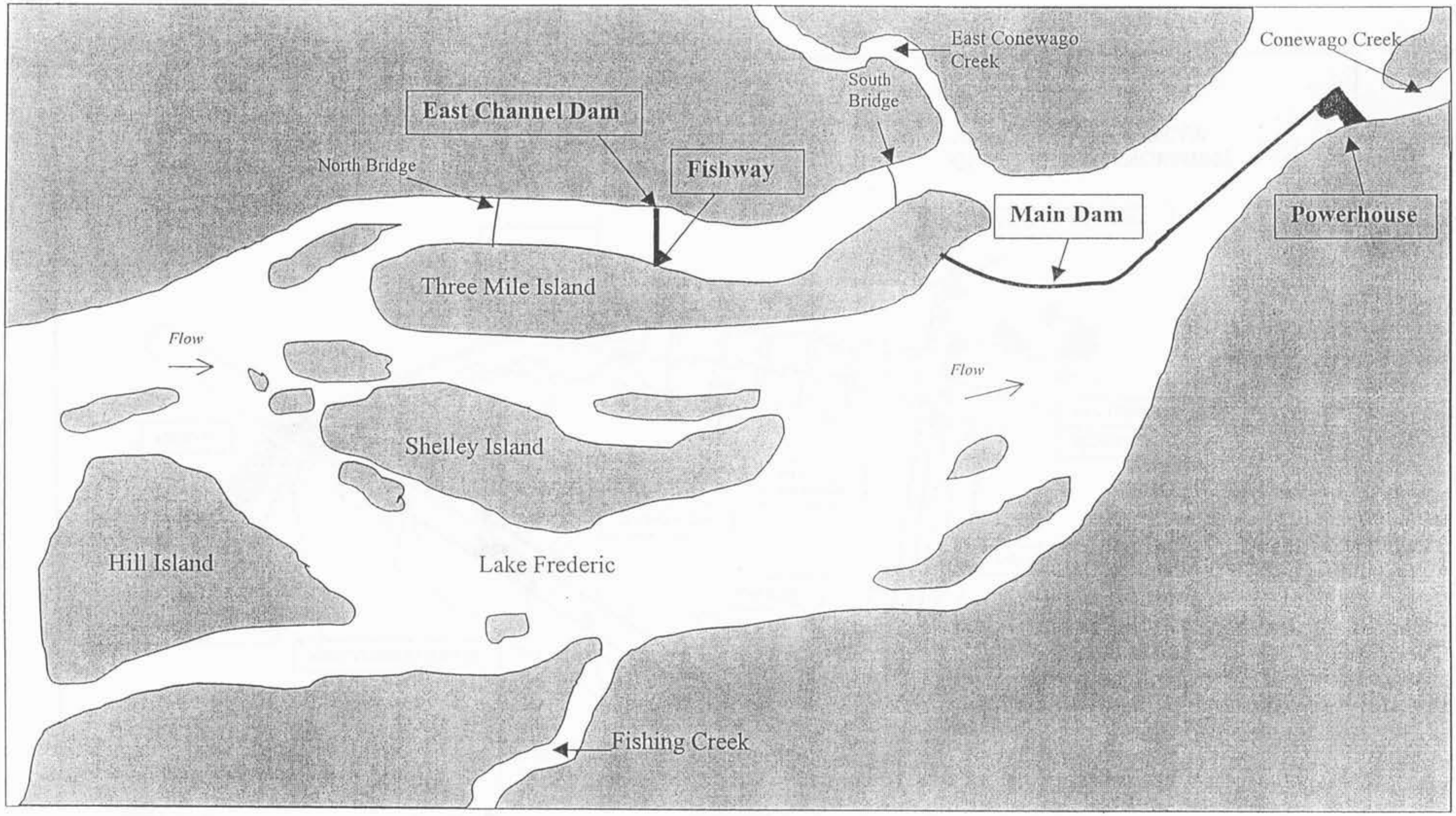
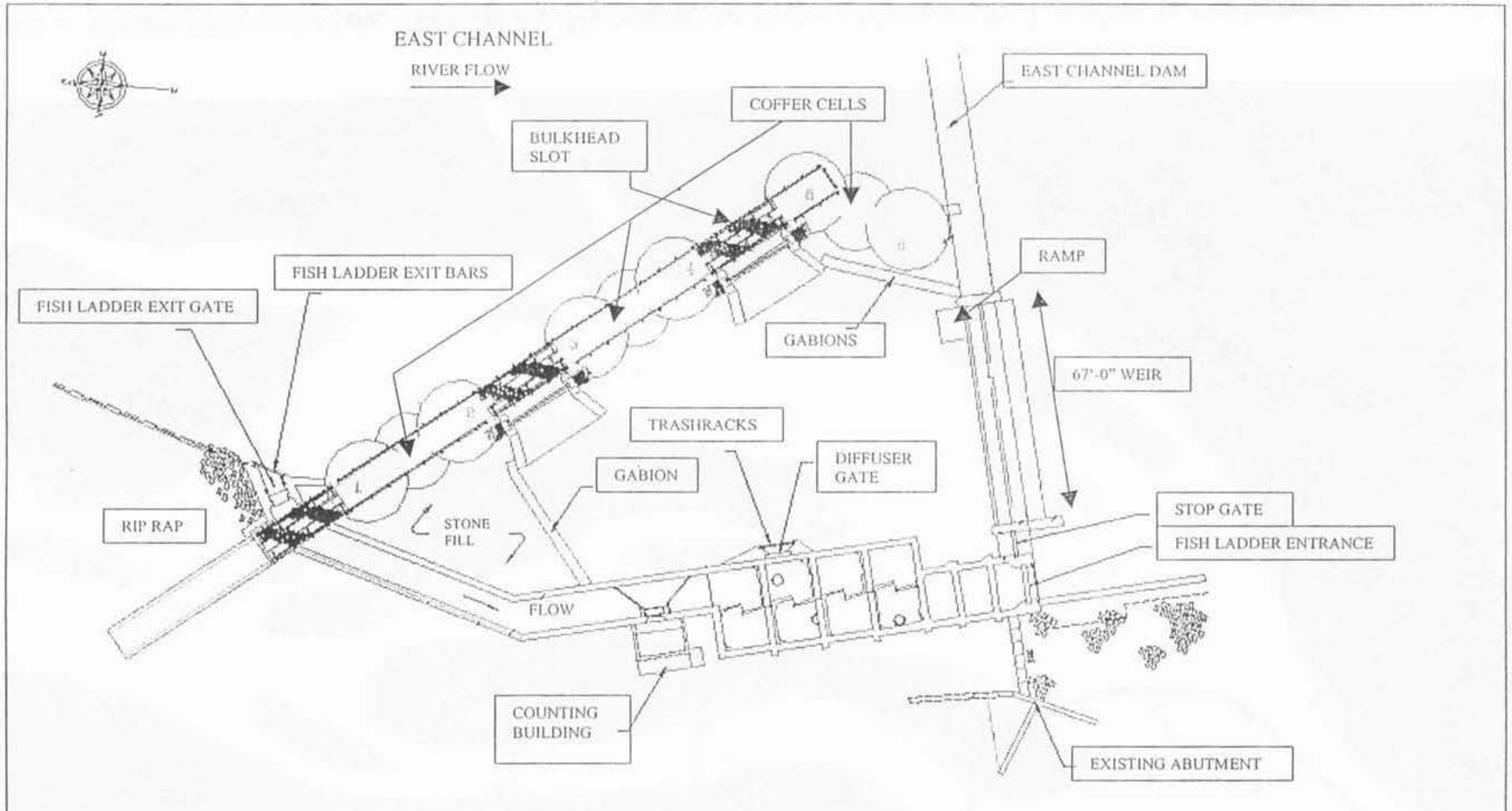


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



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 2002

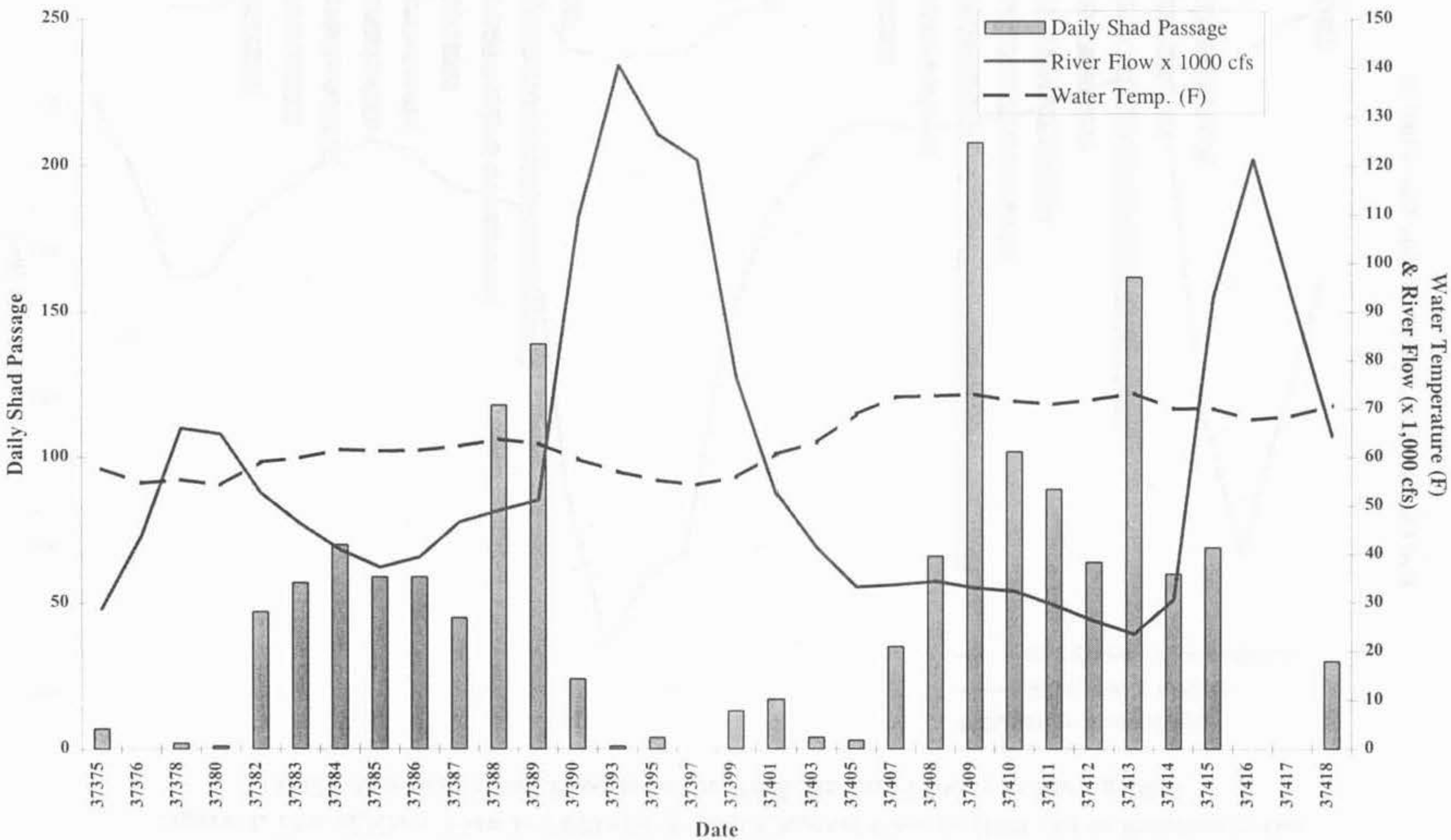
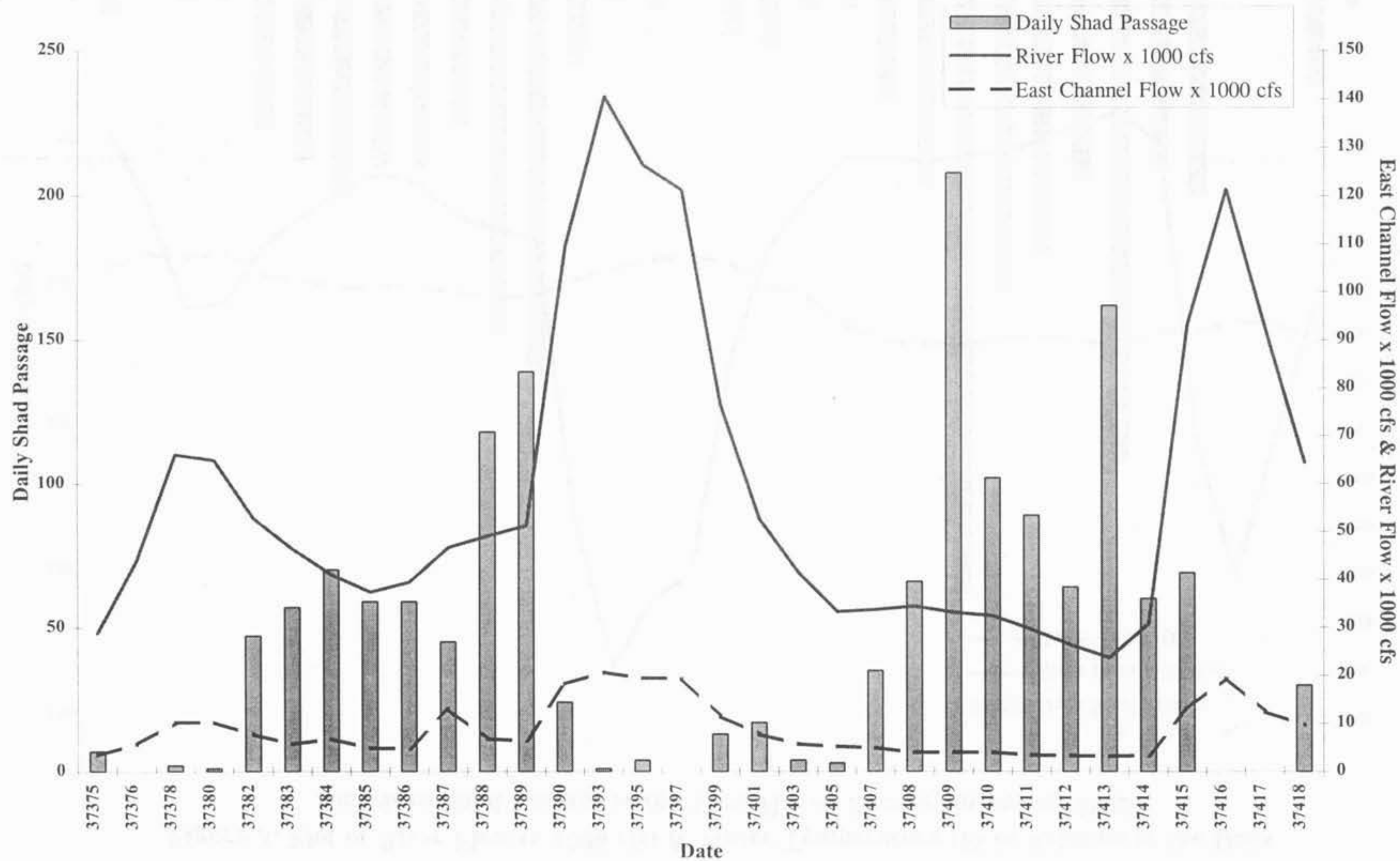


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2002



Job II – Part 1

AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2002

THE WYATT GROUP, INC.
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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. is 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 2002 was to deliver 10 to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Since the early 1970s 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 SCHEDULES

Each collecting crew was assigned to a boat equipped with gill nets and the gear required for artificial fertilization and packing of shad eggs. When warranted, they fished simultaneously. Monofilament gill nets were of 4.0 to 5.5 inch meshes, up to 600 feet long and 8 feet deep. Nets with larger mesh size were used primarily to capture female shad while the smaller mesh nets were used to capture male shad. Each crew set some 900 to 1200 feet of net. Gill nets were mainly anchored at a site and tended regularly after being set, or occasionally drifted and tended after an approximately 30-45 minute drift. Fishing commenced just before dusk and continued until ripe shad were no longer caught. Generally, this was from about 7:00 PM to 1:00 AM.

During collection efforts in 1988-1995, The Wyatt Group fished for ripe adult American shad between Kingston (RM 95) and the Troy Dam at Albany, NY (RM 151). Within this reach ripe shad were concentrated and could be consistently captured in large numbers between Barrytown (RM 99) and Castleton-on-Hudson (RM 123). The only collection site in 2002 was Coxsackie.

The sampling schedule was organized in an order of priority that reflected probability of success based on past experience. It was governed by water temperature, tidal conditions, time of day, and weather. Each variable has an influence on the success of capturing ripe shad. Water temperature was important in deciding the time to commence and end efforts to collect ripe shad. Experience has shown that ripe shad are usually available when waters reach 51°F with larger numbers of eggs being collected at water temperatures of 54-64°F. Some spawning activity may occur up to a temperature of 68°F.

All netting is done in tidal areas. The impact of tidal conditions, although mostly affecting netting efficiency at certain sites, influences the availability of ripe shad. On the Hudson River spawning shad are especially vulnerable to gill netting on the flats and along the shore during the period when the tide changes from ebb to flood. Tide tables were used to decide when gill netting would be most effective at selected sites. At Cheviot and Glasco the depth at the shoreline prevents the setting of gill nets at ebb tide. 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 the boat and only running ripe females were used. Eggs from 4-6 ripe shad were gently 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 2 liters of pure oxygen was injected into the bag, 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. Eggs from each night of collection from both crews were brought to Catskill, NY and loaded for delivery. The goal was to have the eggs arrive at the hatchery between 10:00 and 11:30 AM with all shipments arriving before 3:00 PM the next day. The Field Supervisor (or a designate) notified the hatchery regarding the number of liters of eggs shipped and the estimated arrival time.

RESULTS AND DISCUSSION

The first crew began sampling on May 7. Once the second boat began operations on May 11, it was used regularly until egg collection efforts ceased. Egg collection was ended on June 5 when water temperature reached 63°F. Sampling occurred on 23 dates during this period including 43 boat-days of gill netting. Haul seining was not used during the 2002 shad-fishing season.

A total of 18.51 million eggs were shipped to the Van Dyke Hatchery (Table 2). Hudson River Egg collection in 2002 did not exceed that of 1999 when 21.1 million eggs was taken. All of the eggs came from the Coxsackie site. The Castleton and Cheviot sites were not fished during the 2002 season. The goal of 60-70% viability was met with an overall average of 62% and a range from 23% to 87% in individual shipments.

Eggs were collected over a period of 28 days from May 7 to June 3. Eggs were available on a consistent basis at Coxsackie. Boat 1 began collection efforts on May 7 and ended on June 5. Boat 2 joined the collection efforts on May 11 and also ended on June 5. Weather conditions did not significantly hamper egg collection in 2002. Collection was temporarily halted on May 27 due to hatchery furnace repairs. Water temperature increased gradually contributing, in part, to consistent collection of eggs.

SUMMARY

A total of 18.51 million American shad eggs were collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 2002. The number of eggs collected was greater than that of 2000 when 16.4 million eggs were taken. This success is attributed in part to favorable weather and water temperature conditions over an extended period of time. The use of two independent boat crews increased the probability of capturing sufficient bucks to fertilize the eggs obtained by the combined effort. Egg viability averaged 61.9%, meeting the goal of 60-70% established by the PFBC.

Table 1. American shad eggs (millions) collected from the Delaware and Hudson Rivers and delivered to the Van Dyke Hatchery, 1983-2002.

Year	Delaware	Hudson	Totals
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
Totals	142.87	159.78	303.82

Table 2. Collection data for American shad eggs from the Hudson River in 2002.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability
5/7/02	Coxsackie	16.3	486,498	18	53	54.8%
5/8/02	Coxsackie	29.8	831,228	19	54	59.3%
5/11/02	Coxsackie	103.8	2,774,104	27	55	61.4%
5/12/02	Coxsackie	70.5	2,034,560	31	56	62.6%
5/13/02	Coxsackie	14.6	384,458	32	55	57.0%
5/14/02	Coxsackie	24.7	720,887	35	53	51.7%
5/22/02	Coxsackie	60.6	1,748,856	44	52	22.7%
5/23/02	Coxsackie	86.3	2,547,134	45	55	63.1%
5/24/02	Coxsackie	3.2	90,281	46	52	39.2%
5/25/02	Coxsackie	59.6	1,860,366	47	57	62.8%
5/26/02	Coxsackie	67.2	1,939,326	48	59	73.7%
5/28/02	Coxsackie	38.3	1,168,808	49	61	84.5%
5/29/02	Coxsackie	23.5	670,567	50	62	75.4%
5/30/02	Coxsackie	7.8	246,027	51	63	86.9%
6/1/02	Coxsackie	9.4	293,260	54	65	80.5%
6/2/02	Coxsackie	12.1	398,617	57	65	77.6%
6/3/02	Coxsackie	8.9	312,595	60	64	74.4%
Totals		636.6	18,507,572	17	58	61.9%

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER IN 2002

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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 from 1983 to 2002, 139 million American shad eggs have been collected from the Delaware River. From those eggs, some 32 million larvae have been stocked in the Susquehanna River, 13.4 million in the Lehigh River and 2.8 million in the Schuylkill River. The goal of this activity in 2002, 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 218.0), within the Delaware Water Gap National Recreation Area near Bushkill, PA. In past years, Ecology III of Berwick, PA provided a boat, equipment and labor support to assist the PFBC Area Fisheries Manager and his staff stationed at Bushkill, PA. In 2000 through 2002, 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. Twelve to sixteen 200-foot gill nets were set per night with mesh sizes ranging 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 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 Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

After spawning the shad, catch data was recorded for all shad including gillnet mesh size, sex, length (total and fork) and weight. Representative samples of each night's catch of both sexes were collected for scale and otolith analysis. Ovaries from females in various stages of development (immature to spawned-out) 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 and June 2002. American shad spawning operations commenced on May 8, when river flow was 5,240 cfs (USGS gauge at Montague, NJ), and river temperature was 17.0 C (62.6 F). Egg take ended on June 5, when river flow was 4,980 cfs and temperature was 20.0 C (68 F). The 2002 egg-take operation was conducted during highly fluctuating flow and temperature conditions (Figure 1, Table 1). Sustained high water, turbidity and debris adversely impacted egg collection operations. Throughout most of the netting period, nets were operating at flow conditions which threatened to dislodge their anchors. Most of the successful egg collections occurred when flow was near or below 62 year mean flows (Figure 1).

Nets were set on ten nights with 12 nets set on 9 nights and 11 nets set on one night. The usual number of nets set per mesh size (stretch, inch) each night was: 4.50- 1 each; 4.75- 2 each; 5.00- 4 each; 5.25- 1 each; 5.50- 1 each; 5.75- 1 each; and 6.00- 2 each. On May 8, only one 6.00 inch net was set.

A total of 400 adult American shad were caught (Table 1). Nightly catches ranged from 0 to 86 shad. Sex ratio (male to female) was 0.39:1. The egg-take was terminated on June 5, 2002 due to poor survival of fry at the hatchery.

Summary

Shad eggs were collected and shipped on 6 of the 10 nights that were fished from 8 May through 5 June 2002. During this time, 400 adult shad were captured and 62 liters of eggs were shipped for a hatchery count of 2.0 million eggs. Overall, the percent viability of eggs was 41%.

References

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

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

Table 1. Delaware River American shad egg collection data, 2002.

Date	No. of nets	Water Temp ©	No. of shad captured	No. of eggs shipped (liters)	No. of eggs shipped	No. of viable eggs shipped	Percent Viability
05/08/02	11	17.0	81	12.1	337,512	141,193	42%
05/09/02	12	15.5	28	0.0	No shipment		
05/12/02	12	15.2	37	8.9	262,682	95,788	36%
05/13/02	12	14.6	0	0.0	No shipment		
05/28/02	0	19.0	0	0.0	No fishing		
05/29/02	12	18.5	1	0.0	No shipment		
05/30/02	12	18.0	8	0.0	No shipment		
06/02/02	12	20.0	59	11.3	409,601	236,741	58%
06/03/02	12	19.3	40	5.7	185,759	86,368	46%
06/04/02	12	19.3	86	10.5	400,843	42,161	11%
06/05/02	12	20.0	60	13.6	443,215	228,183	51%
Totals	119		400	62.1	2,039,613	830,435	41%

Figure 1. American shad egg collections and flow, Delaware River, 2002.

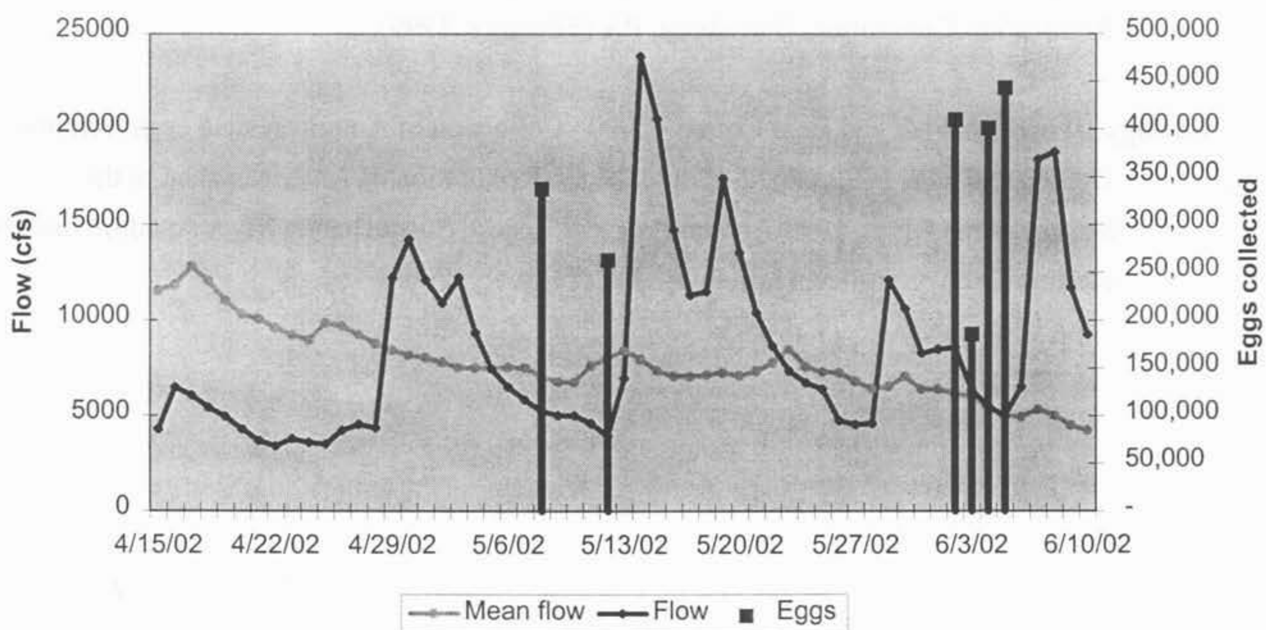
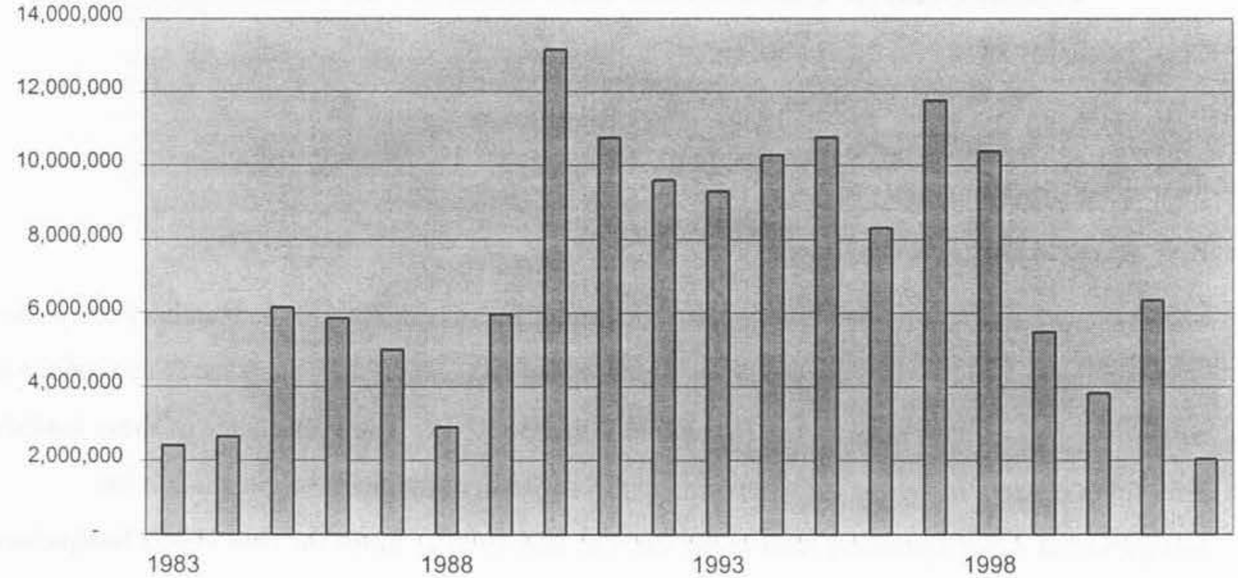


Figure 2. American shad eggs collected from the Delaware River.



JOB II – PART 3
HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN SHAD CONDUCTED AT CONOWINGO DAM DURING THE SPRING OF 2002

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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 to 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 declined to 40 to 50%.

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, Normandeau was contracted by SRAFRC in 2001-2002 to conduct experimental tank spawning of Susquehanna River source American shad at Conowingo Dam using hormone implants.

INTRODUCTION

The Conowingo Dam West Fish Lift was built in 1972 and has been operated annually during the months of April, May and early June. Initially it was an integral part of the anadromous fish restoration effort, which combined the operation of the West Fish Lift, hand sorting of target species, and a fleet of transport trucks to carry American shad and other alosids to upriver release sites. Since completion of permanent fish lifts at Conowingo Dam (1991), Holtwood and Safe Harbor dams (1997), plus a fish ladder at York Haven Dam (2000), the Conowingo West Fish Lift is now operated under contract as (1) a source of shad broodfish for hormone induced spawning trials at the USFWS Northeast Fishery Center at Lamar and at Maryland Department of Natural Resources' Manning Hatchery; (2) collection of biological information from American shad; and, (3) to provide up to 10,000 adult herring annually for the Pennsylvania Fish and Boat Commission's tributary stocking program. Herring transports were not included in the 2002 work plan.

The West Fish Lift is operated daily from 11AM to 7 PM from late April through early June and 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 2 to 3 days with 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.

METHODS AND MATERIALS

American shad tank-spawning trials conducted on site at the Conowingo West Fish Lift in 2002 were patterned after similar trials conducted by USFWS at Lamar in previous years and on the trials conducted at Conowingo Dam in 2001. Most equipment, supplies and hormones needed to conduct the spawning trials was provided by the Lamar Hatchery using SRAFRC funds.

Two fiberglass tanks were utilized for spawning trials in 2002. In addition to the 12 ft diameter tank used in 2001, a 10 ft diameter tank was plumbed in a similar configuration (Figure 1). Both tanks were supplied with 25 to 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 large (S-1) and small (S-2) tanks were 9,200 and 6,400 liters respectively. An egg sock fastened to the discharge from the standpipe prevented the shad eggs from entering the internal standpipe drain that maintained the water level in the egg tank.

Each trial included 50 shad with a sex ratio of 2:1 favoring males. Thus, all trials were conducted with 33 males and 17 females. Each shad was injected with a Salmonid Gonadotropin Releasing Hormone analog (SGnRHa) implant in the thick muscles of the shoulder area. Both males and females received a 150 µg implant.

The egg sock was examined daily during each spawning trial. If eggs were present, they were transferred into a framed nylon net, sieved to remove scales and measured for volume in a graduated 2 liter measuring cup. The packaging of eggs for shipment followed well-established techniques. Up to 5 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. The bags were placed into marked insulated shipping containers and driven to the PFBC Van Dyke facility by PFBC or Normandeau personnel. Eggs collected from an overnight or morning pulse were driven to Van Dyke on the same day. Eggs collected during afternoon hours were packaged for shipment, held overnight in an air conditioned room and transported the next day. When less than 5 liters of eggs were collected in a two-day period, they were measured for volume and released in the river. After the initial egg pulse, which occurred 24 to 48 hours following injection with SGnRHa, the tanks were drained, mortalities, if any, were 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 American shad at Conowingo Dam began on 24 April and concluded on 6 June 2002. During this interval, 20 spawning trials (10 trials in each tank) were conducted with 1,000 adult American shad. The start dates for trials 1 and 2 were staggered between the two tanks but from trial 3 through 10 the start and end date were synchronized for both tanks. High river flows and associated spill at Conowingo Dam halted West Fish Lift operation and shad spawning trials between 15 and 28 May. Each trial ran from 1 to 3 days with the longer trials at the beginning of the season and the shortest trials at the end of the season. A total of 146.8 liters of eggs (72 liters from the 12 ft tank and 74.8 liters from the 10 ft tank) was collected from all trials (Table 1). Of this total, 138.4 liters were shipped to the Van Dyke

Hatchery and 5.3 liters were shipped to the University of Memphis for research purposes. The remaining 3.1 liters were released into the river below Conowingo Dam. The overall viability of the shad eggs sent to the Van Dyke Hatchery was 10.1% (see Job III).

River temperature and dissolved oxygen levels were generally recorded at the beginning and end of each day's operation of the West Fish Lift and averaged to obtain a single value for that day. River temperatures ranged from 15.1 to 25.8°C during the spawning trials (Table 2). Water temperatures in the spawning tanks fluctuated from 0.6°C less than river temperature to 1.2°C above river temperature. Dissolved oxygen levels in the spawning tanks generally ranged from 6-10 ppm (Table 2) and were always lower than river levels, as was expected. Oxygen levels in the 12 ft tank averaged 1.96 ppm lower than the river (range 0.5 to 4.4 ppm) and in the 10 ft tank oxygen levels averaged 2.61 ppm (range 0.9 to 4.6 ppm) lower than the river value. Supplemental aeration was not supplied to the 12 ft tank during the spawning trials but when dissolved oxygen levels dropped to 4.4 ppm in the10 ft tank during trial 10, a fine-pore oxygen diffuser was placed in the tank and maintained until the end of the trial. Appendix tables A-1 and A-2 show specific results from all 20 spawning trials conducted in 2002. Figure 2 compares egg production per female shad between 2001 and 2002.

Dead shad were removed from spawning tanks when they floated to the surface or at the end of each trial. A total of 37 shad (12 males and 25 females) died during the spawning trials. The mortality count for the10 ft tank (20) was only slightly higher than the count in the 12 ft tank (17).

SUMMARY

The results of the hormone-induced spawning trials conducted at Conowingo Dam in 2002 show that American shad stocked at densities of one shad per 128 liters of water (10 ft tank) and at one shad per 184 liters of water (12 ft tank) produced similar quantities (74.8 versus 72.0 liters) of fertilized eggs. American shad stocked at the higher density may require aeration or supplemental oxygen when water temperature approaches 24°C. For unknown reasons, the

estimated 10.1% viability of American shad eggs collected from tank spawned fish at Conowingo Dam in 2002 was much lower than the 33% viability estimate for 2001 eggs.

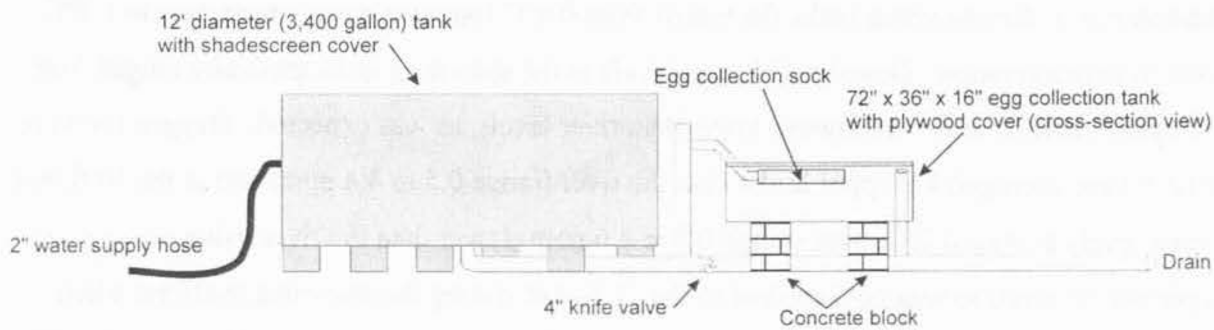

Figure 1

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

Fig. 2. Comparison of American Shad Egg Production per Female by Trial Number and Year at Conowingo Dam

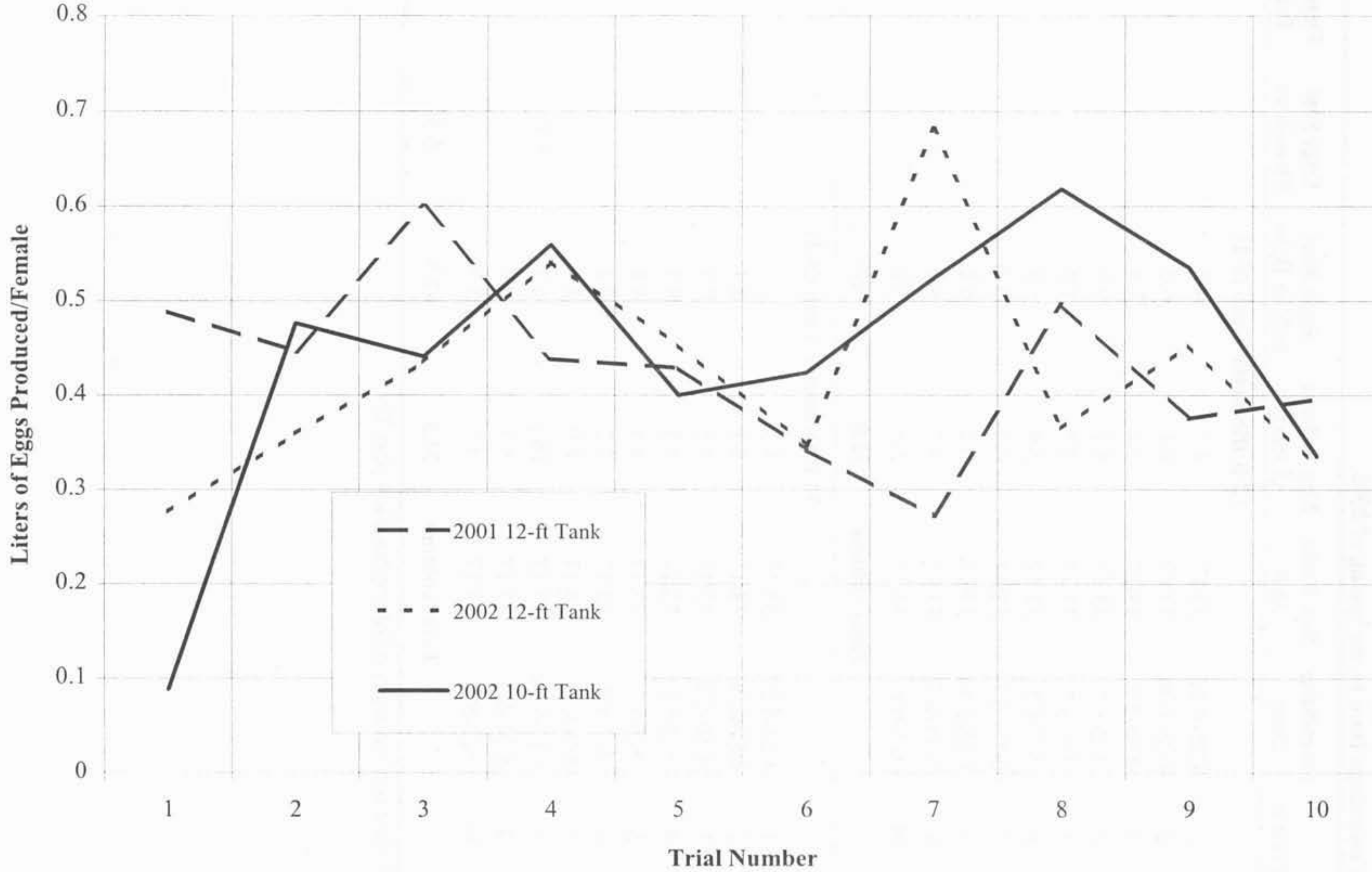

Table 1

Summary of egg production data for hormone-induced spawning trials conducted at Conowingo Dam in the spring of 2002.

Trial #	Start/Stop Date	Sex Ratio M/F	Egg Volume (Liters)	Eggs Sent to Van Dyke	Eggs Sent Elsewhere	Eggs Released Below Dam
			12 ft Diameter Tank (S-1)			
1	4/25-4/28	33/17	4.7	4.7		
2	4/28-4/30	33/17	6.1	6.0		0.1
3	4/30-5/2	33/17	7.4	7.4		
4	5/2-5/5	33/17	9.2	9.2		
5	5/5-5/7	33/17	7.7	7.7		
6	5/7-5/9	33/17	5.9	5.9		
7	5/9-5/11	33/17	11.6	11.6		
8	5/12-5/14	33/17	6.2	6.2		
9	5/31-6/3	33/17	7.7	6.7		1.0
10	6/5-6/6	33/17	5.5	5.5		
		Total volume	**72.0**	**70.9**		**1.1**
			10 ft Diameter Tank (S-2)			
1	4/24-4/27	33/17	1.5			1.5
2	4/27-4/30	33/17	8.1	8.1		
3	4/30-5/2	33/17	7.5	7.5		
4	5/2-5/5	33/17	9.5	9.5		
5	5/5-5/7	33/17	6.8	6.8		
6	5/7-5/9	33/17	7.2	7.2		
7	5/9-5/11	33/17	8.9	8.9		
8	5/12-5/14	33/17	10.5	5.2	5.3*	
9	5/31-6/3	33/17	9.1	8.6		0.5
10	6/5-6/6	33/17	5.7	5.7		
		Total volume	**74.8**	**67.5**	**5.3**	**2.0**

* Sent to University of Memphis, Memphis TN.

Table 2

Temperature and dissolved oxygen data collected during hormone induced spawning trials with American shad at Conowingo Dam, spring 2002.

Date	River Temp. (°C)	River D.O. (ppm)	S-1 Temp. (°C)	S-1 D.O. (ppm)	S-1 Dev. (ppm*)	S-2 Temp. (°C)	S-2 D.O. (ppm)	S-2 Dev. (ppm*)
24 Apr	17.6	9.7				18.0	7.1	-2.6
25 Apr	16.6	10	16.8	7.9	-2.1	17.8	7.3	-2.7
26 Apr	15.7	11.8	16.4	7.4	-4.4	16.4	7.2	-4.6
27 Apr	15.3	10.6	15.9	8.2	-2.4	15.8	9.0	-1.6
28 Apr	15.3	10.3	15.9	8.2	-2.1	15.8	9.0	-1.3
29 Apr	15.9	11.6	16.3	10.2	-1.4	16.3	9.6	-2.0
30 Apr	15.1	11.3	15.5	8.7	-2.6	15.3	10.0	-1.3
01 May	16.1	12.4	15.9	10.4	-2.0	16.0	10.5	-1.9
02 May	15.7	12.5	15.6	10.9	-1.6	15.6	10.8	-1.7
03 May	16.0	10.6	16.2	9.3	-1.3	16.3	8.2	-2.4
04 May	15.3	10.4	15.5	9.2	-1.2	15.5	8.5	-1.9
05 May	15.8	12.2	17.0	10.3	-1.9	16.9	8.8	-3.4
06 May	15.3	11.4	15.7	9.6	-1.8	15.8	8.6	-2.8
07 May	16.4	11.2	15.8	9.8	-1.4	15.6-17.1	7.5-9.2	-3.7
08 May	16.6	11.4	17.2	9.3	-2.1	17.2	7.6	-3.8
09 May	16.6	10.7	16.5	9.0	-1.7	16.5	7.3	-3.4
10 May	18.2	10.8	18.0	8.0	-2.8	18.0	6.7	-4.1
11 May	18.1	10.4	18.0	8.7	-1.7	18.0	8.0	-2.4
12 May	18.2	10.3	18.8	9.8	-0.5	18.8	9.4	-0.9
13 May	18.8	10.8	18.8	8.9	-1.9	18.8	6.5	-4.3
14 May			18.2	8.4		18.3	7.4	
31 May	21.0	12.3	21.2	10.7	-1.6	21.1-21.7	8.4-10.0	-3.9
01 Jun			22.4	8.0		22.4	7.3	
02 Jun			22.5	6.6		22.5	6.2	
05 Jun	24.2	7.6	24.9	5.3-6.2	-2.3	24.9-25.0	4.4-8.0	-3.2
06 Jun	25.8	7.8	24.5-26.0	5.5-6.2	-2.3	24.5-26.0	7.6	-0.2

*Deviation between river D.O. and tank D.O.

Appendix Table A-1

Hormone Induced American Shad Spawning Trials Conducted at Conowingo Dam West Fish Lift in a 12 Ft Diam. Tank (S-1) with a 33/17 (M/F) Sex Ratio, Spring 2002.

Trial No. 1
Start Date 4/25/2002
End Date 4/28/2002

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/2002	1130	16.8	7.9				
4/26/2002	1050	16.4	7.4				1m
4/27/2002	1730	15.9	8.2				
4/27/2002	1800			3.9L			
4/28/2002	1000			0.8L	4.7L		1m,1f

Trial No. 2
Start Date 4/28/2002
End Date 4/30/2002

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/28/2002	1730	15.9	8.2				
4/29/2002	1050	16.3	10.2				
4/30/2002	1030	15.4	10.0	6.1	6	0.1	1f

Trial No. 3
Start Date 4/30/2002 1625
End Date 5/2/2002 1645

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/30/2002	1630	15.5	8.7				
5/1/2002	1053	15.9	10.4				
5/2/2002	1040	15.6	10.9				
5/2/2002	1300			7.4	7.4		
5/2/2002	1700						2m,2f

Trial No. 4
Start Date 5/2/2002 1700
End Date 5/5/2002 1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/3/2002	1606	16.2	9.3				
5/4/2002	1127	15.5	9.2				
5/4/2002	1330			9.2	9.2		
5/5/2002	1030			<0.1		<0.1	

Appendix Table A-1 cont.

Trial No. **5**
Start Date 5/5/2002 1200
End Date 5/7/2002 1115

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/5/2002	1740	17.0	10.3				
5/6/2002	1057	15.7	9.6				
5/7/2002	1040	15.8	9.8	7.7	7.7		

Trial No. **6**
Start Date 5/7/2002 1630
End Date 5/9/2002 1430

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/7/2002	1730	17.0	9.4				
5/8/2002	1555	17.2	9.3				
5/9/2002	0940	16.5	9.0				
5/9/2002	1430			5.9	5.9		5f

Trial No. **7**
Start Date 5/9/2002 1600
End Date 5/11/2002 1600

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2002	1109	18.0	8.0				
5/11/2002	1042	18.0	8.7				
5/11/2002	1600			11.6	11.6		

Trial No. **8**
Start Date 5/12/2002 1145
End Date 5/14/2002 1130

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/12/2002	1535	18.8	9.8				
5/13/2002	0950	18.8	8.9				
5/14/2002	1130	18.2	8.4	6.2	6.2		

Appendix Table A-1 cont.

Trial No.	**9**	
Start Date	5/31/2002	1200
End Date	6/3/2002	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/31/2002	1210	21.2	10.7				
5/31/2002	1540	21.7	10.6				
6/1/2002	1240	22.4	8.0	6.7			
6/2/2002	0715	22.5	6.6	1.0	6.7	1.0	
6/3/2002	1030						3f

Trial No.	**10**	
Start Date	6/5/2002	1040
End Date	6/6/2002	1140

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/5/2002	1245	24.9	5.3				
6/5/2002	1553	25.0	6.1				
6/5/2002	1700		5.8				
6/5/2002	2145		6.2				
6/6/2002	0717	24.5	6.2				
6/6/2002	1100	26.0	5.5	5.5	5.5		1m

Appendix Table A-2

Hormone Induced American Shad Spawning Trials Conducted at Conowingo Dam West Fish Lift in a 10 Ft Diam. Tank (S-2) with a 33/17 (M/F) Sex Ratio, Spring 2002.

Trial No. **1**
Start Date 4/24/2002
End Date 4/27/2002

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/24/2002	1130	18.0	7.1				
4/25/2002	1145	17.8	7.3				
4/26/2002	1045	16.4	7.2				1m 2f
	1730			1.5L			
4/27/2002	1130					1.5L	3m,4f

Trial No. **2**
Start Date 4/27/2002
End Date 4/30/2002

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/27/2002	1730	15.8	9.0				
4/28/2002	1730	15.8	9.0				
4/29/2002	1040	16.3	9.6				1m 1f
4/29/2002	1600			8.1	8.1		

Trial No. **3**
Start Date 4/30/2002 1130
End Date 5/2/2002 1600

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/30/2002	1730	15.3	10.0				
5/1/2002	1050	16.0	10.5				
5/2/2002	1040	15.6	10.8				
5/2/2002	1300			7.5	7.5		
5/2/2002	1600						1m

Trial No. **4**
Start Date 5/2/2002 1630
End Date 5/5/2002 1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/3/2002	1605	16.3	8.2				
5/4/2002	1124	15.5	8.5				
5/4/2002	1415			9.5	9.5		
5/5/2002	1030			<0.1		<0.1	

Appendix Table A-2 cont.

Trial No.	**5**	
Start Date	5/5/2002	1130
End Date	5/7/2002	1040

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/5/2002	1740	16.9	8.8				
5/6/2002	1055	15.8	8.6				
5/7/2002	1000	15.6	9.2	6.8	6.8		

Trial No.	**6**	
Start Date	5/7/2002	1600
End Date	5/9/2002	1400

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/7/2002	1730	17.1	7.5				
5/8/2002	1552	17.2	7.6				
5/9/2002	0940	16.5	7.3				
5/9/2002	1400			7.2	7.2		

Trial No.	**7**	
Start Date	5/9/2002	1530
End Date	5/11/2002	1530

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/10/2002	1105	18.0	6.7				
5/11/2002	1040	18.0	8.0				
5/11/2002	1530			8.9	8.9		1 f

Trial No.	**8**	
Start Date	5/12/2002	1115
End Date	5/14/2002	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/12/2002	1535	18.8	9.4				
5/13/2002	0949	18.8	6.5				
5/14/2002	1030	18.3	7.4	10.5	5.2 PA 5.3 TN		

Appendix Table A-2 cont.

Trial No.	**9**	
Start Date	5/31/2002	1130
End Date	6/3/2002	1030

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/31/2002	1210	21.1	8.4				
5/31/2002	1540	21.7	10				
6/1/2002	1240	22.4	7.3	8.6			
6/2/2002	0715	22.5	6.2	0.5	8.6	0.5	
6/3/2002	1030						3f

Trial No.	**10**	
Start Date	6/5/2002	1020
End Date	6/6/2002	1130

Date	Time	Temp. (°C)	Oxygen ((ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/5/2002	1245	24.9	4.4				
6/5/2002	1555	25.0	7.5				
6/5/2002	1700		7.4				
6/5/2002	2145	25.0	8.0				
6/6/2002	0713	24.5	7.6				
6/6/2002	1100	26.0		5.7	5.7		1m,2f

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2002

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INTRODUCTION

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

Production goals for 2002 were to stock 10-20 million American shad larvae. All Van Dyke hatchery-reared American shad larvae were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by natural spawning of transplanted adults. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

EGG SHIPMENTS

A total of 35.6 million eggs (944 L) were received in 69 shipments in 2002 (Table 1). This was the third most eggs since the program began in 1976 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 38.8%. Low egg viability was due to the large number of low viability eggs received from tank-spawning operations at Conowingo Dam and Lamar and strip-spawning operations on the Delaware River.

Hudson River egg shipments were received from May 8 to June 3, 2002. Hudson River eggs were collected only from the site at Coxsackie, where water depths permit gill netting at all stages of the tide. Seventeen shipments (18.5 million eggs) were delivered with an overall viability of 61.9%.

Delaware River shipments were received from May 9 to June 6. A total of 6 shipments of eggs were received from the Delaware River (2.0 million eggs) with a viability of 40.7%.

The U. S. Fish and Wildlife Service, Northeast Fishery Center, in Lamar, PA continued tank-spawning operations in 2002. Susquehanna River source, pre-spawn adult American shad were obtained from the West Lift at Conowingo Dam, injected with hormones and allowed to spawn naturally. Some 8.0 million eggs, in 25 shipments, were delivered to the Van Dyke Hatchery. Viability of Lamar tank-spawned eggs at Van Dyke was 10.3%.

Eggs were also obtained from a tank-spawning operation at Conowingo Dam, operated by Normandeau Associates with assistance from the USFWS, Northeast Fishery Center. Pre-spawn adult American shad were obtained from the West Lift at

Conowingo Dam, injected with hormones and allowed to spawn naturally. Some 7.0 million eggs, in 21 shipments, were delivered to the Van Dyke Hatchery. Viability of Conowingo tank-spawned eggs, delivered to Van Dyke for incubation was 10.1%.

An effort was made in 2002 to determine the feasibility of obtaining American shad eggs from Lewis Haul Seine Fishery on the Delaware River. That effort is discussed in Appendix 2.

SURVIVAL

Overall survival of larvae was 19% compared to a range of 41% to 94% for the period 1984 through 2001. The low survival is believed to be due to toxicity associated with fire retardants in the foam bottom screen used on Van Dyke incubation jars.

Survival of individual tanks followed two patterns (Figure 1). Four tanks, whose eggs were incubated in May-Sloan Jars, exhibited 13-day survival averaging 89.5%. This is typical of survival patterns experienced in the past. All remaining tanks suffered high mortality beginning on days 3 and 4. These tanks experienced problems with larvae laying on the bottom of the tank and the larvae fed very poorly, if at all. All larvae in this group came from eggs incubated in Van Dyke jars, with foam bottom screens. Fourteen-day survival for these tanks averaged 15%, with 15 tanks discarded due to complete mortality.

The mortality problems experienced in 2002 were difficult to diagnose. The eggs incubated and developed normally. The first evidence of problems was with larvae laying on the bottom after hatch. This has been a common problem in the past, attributed to hatching larvae too soon or lower than optimal water temperatures. Given the unusually cold, wet weather, and the furnace problems we experienced, we attributed the initial problems to water temperature effects. Rearing temperatures were as much as 5F below the optimal 65F. In addition, the first five tanks cultured utilized eggs from 17 tank-spawn egg shipments with low egg viability (14.7%). Our initial assessment was that these were bad eggs with little chance of survival. By the time the first Hudson River egg shipments showed signs of not feeding at 4d of age, it was May 20, and the first 43 egg shipments had already arrived, and were incubating, largely in Van Dyke jars.

A number of potential causes for the mortalities in 2002 were considered, including toxicity of leachate from treated lumber, gas super-saturation, low culture temperature, aluminum toxicity from drought followed by acid precipitation, and OTC tagging (some of the OTC used was brown in color instead of the typical yellow). In addition, gypsy moth spraying occurred in the Van Dyke drainage for the first time since 1992, filamentous algae grew in the warming pond for the first time ever, and we had a pre-season drought, followed by ample rainfall, much like the 1992 season when we also had mortality problems. We tested the hypothesis that OTC marking was involved by rearing two tanks (E41, F11) with no OTC marking. Both tanks were discarded after suffering complete mortality. In addition, none of these scenarios explain the good survival of all eggs incubated in May-Sloan jars and the poor survival of all eggs incubated in Van Dyke jars. Hudson River shipment 50 provided definitive proof that the mortalities were related to incubation in Van Dyke jars. The shipment was divided between one Van Dyke jar and four May-Sloan jars. Tank D22 received eggs from the Van Dyke jar and had only 2,000 larvae (1%) survive to 18 days. Tank D32 received eggs from the May-Sloan jars and had 198,000 larvae (83%) survive to 18 days.

Van Dyke jars were mounted in the tanks for hatch with steel holders, recently painted with aluminum paint. May-Sloan jars were mounted in the tanks with holders constructed of aluminum and PVC plastic. Since the holders were in the tank at the time of hatch for 6 to 48 hours, and the eggs appeared normal until hatch, we considered the possibility that aluminum was leaching out of the freshly painted holders and causing aluminum toxicity. We tested this at the end of the culture season by setting up two tanks, one without any holders and one with 3 aluminum-painted steel holders, mounted in the water as they would if they held hatching egg jars. After 24 hours, we sampled the water. Dissolved aluminum was 0.02 mg/L in both tanks, 10 times less than levels which should cause concern. Based on the above considerations, we have concluded that the mortality problems were related to the use of the open-cell foam bottom screens in Van Dyke jars.

Testing of our homemade Van Dyke jars began in 1987. Specifications of the Van Dyke jar are listed in Table 6. While use of the Van Dyke jar increased egg battery capacity from 250L to 450L, problems with dead spots (areas of reduced flow) in the jar were common. Upwelling flow in the May-Sloan jar, with its 6-inch (152mm) diameter, was generally sufficient to keep all the eggs rolling, unless the flow was reduced by improper adjustment, attempts to conserve water, or an obstruction which blocked the orifice. In contrast, the larger diameter (13.5 inches, 343mm) Van Dyke jar, when fitted with a window screen bottom, experienced routine problems with dead spots in the middle of the jar, as the flow was concentrated around the perimeter. These dead spots resulted in mortality of fully developed, eyed eggs, which appeared to be dead fry in the jar.

Open-cell foam was first used as a bottom screen at Van Dyke in 1990. In two trials, egg survival was slightly less (2-5%) than in window screen bottom controls (Hendricks et al. 1991). The advantage of the foam was the uniform flow through the eggs with no dead spots, and consequently no dead fry in the jar. Four additional replicates were conducted in 1991. Survival of eggs in jars with foam screens was higher than controls in two replicates (Hudson River eggs) and lower in the other two replicates (Delaware River eggs, Hendricks et al 1992). The lower survival in the two Delaware River shipments was attributed to enumeration problems due to numbers of small dead eggs, which did not layer out and could not be enumerated until after hatch, when enumeration is imprecise. Foam bottom screens were also used in 21 production jars in 1991. No dead fry were observed in any of the 25 foam bottom screen jars used in 1991. In contrast, Van Dyke jars with window screen bottoms were used 36 times in 1991, with dead fry observed in 30 of the 36 jars.

As a result of the experience in 1991, we used foam bottom screens exclusively, beginning in 1992. Some of the foam used in 1992 and 1993 was left over from 1991 and previous years, dried thoroughly and stored in garbage bags at Van Dyke. Serious mortality problems in some tanks in 1992 and 1993 were attributed to the use of used foam bottom screens (Hendricks and Bender 1994). Shipment 40 (1993) was particularly revealing. Shipment 40 was split between one Van Dyke jar and four May-Sloan jars. Tank J31 received eggs from the four May-Sloan jars and exhibited 18d survival of 68%. Tank J41 received eggs from the Van Dyke jar and suffered complete mortality by day 11. It was observed that the used foam was beginning to breakdown, giving off small particles of foam. Although no records were kept regarding which jars had used foam, we speculated that the larvae were eating these particles, plugging their digestive tract and causing mortality. Alternatively, the foam may have reacted with sunlight, ozone or iodophore disinfectant to produce toxic substances (Hendricks and Bender 1994). New foam was purchased each year from 1994 through 2001 and no further problems were noted until 2002.

After the source of the 2002 mortalities was confirmed to be the foam bottom screens, I began researching open-cell foam in an effort to determine the specific cause of the problem, in light of the lack of problems in 1994 through 2001. Open-cell polyurethane foam is used primarily in the automobile, construction and furniture industries. It is a versatile material with an unlimited variety of formulations and additives. "Combustion Modified Foam" is defined as "Flexible polyurethane foams manufactured by using additives based on chlorine, bromine, and phosphorus chemistry to reduce ease of ignition. Hydrated alumina or melamine is also used" (Polyurethane Foam Association, Flexible Polyurethane Foam Glossary, http://www.pfa.org/glossary.html). According to Aquatic Ecosystems, Inc., 1999 catalogue, their bio-filter foam "...contains no fire retardants or germicides. (Be careful with cheap air filter foam as it can be toxic.)"

The foam used for bottom screens in 2002 was purchased from O. W. Houts department store in April 2002. The foam was slightly yellowed, in contrast to previous years when the foam was bright white in color. Yellowing occurs gradually as the foam is exposed to air (personal communication, Kathy Fox, O.W. Houts). The foam used in 2002 was not breaking down, as in 1992. After rough kneading and abrasion by hand, there was no evidence of foam particles in a container of water, even when viewed under a microscope.

In 2002, O.W. Houts purchased their foam from Foamex in Williamsport, PA. Prior to 2002, the supplier was Keystone Foam in Loyalhanna, PA. The foam purchased from Foamex in 2002 contained fire retardants, which were added to the liquid, prior to polymerization (personal communication, Dave George, Foamex). The specific compound(s) used as a fire retardant was not specified. Foam made by Keystone Foam does not routinely contain fire retardants (personal communication, Brian Quinn, Keystone Foam). In light of the above discussion, it is likely that our 2002 mortalities were caused by fire retardants in the foam. In retrospect, the problems experienced in 1992 and 1993 may have also been due to fire retardants or some other chemical in the foam, not intestinal problems from eating foam, as was originally speculated. Open-cell polyurethane foam can be special-ordered with no additives or fire-retardants.

LARVAL PRODUCTION

Production and stocking of American shad larvae, summarized in Tables 2, 3 and 4, totaled 2.7 million. A total of 2.1 million was released in the Juniata River, 159 thousand in the North Branch Susquehanna River in New York, 200 thousand in the Chemung River in New York, 21 thousand in the North Branch Susquehanna River in Pennsylvania, and 50 thousand in the West Branch Susquehanna River. American shad larvae were also stocked in tributaries: 2 thousand in Conodoguinet Creek, 19 thousand in the Conestoga River, and 15 thousand in Swatara Creek. West Conewago Creek was not stocked in 2002. In addition, 85 thousand larvae were stocked in the Lehigh River and 2 thousand were stocked in the Schuylkill River to support restoration efforts there.

TETRACYCLINE MARKING

All American shad larvae produced at Van Dyke received marks produced by immersion in tetracycline (Table 5). Immersion marks were administered by bath treatments in 256-ppm oxytetracycline hydrochloride for 4h duration. All larvae were marked according to stocking site and/or egg source. Larvae from the Susquehanna River egg source, reared at Van Dyke, and stocked in the Juniata River were given a triple mark at 3,6, and 9 days of age. One tank of larvae from eggs collected by tank-spawning at Lamar was mistakenly given a single mark on day 3 and stocked at Millerstown. Larvae from the Susquehanna River egg source, reared at Lamar, and stocked in the Bald Eagle Cr, tributary to the West Branch Susquehanna River, were given a triple mark at 3,9, and 12 days of age.

Larvae from out-of-basin egg sources and stocked in the Juniata River were marked at 3 days of age. Larvae stocked in the Conodoguinet Creek were given a quadruple mark at 3, 6, 12 and 15 days of age. Larvae stocked in the Conestoga River were given a quadruple mark at 3, 9, 12, and 15 days of age. Larvae stocked in Swatara Creek were given a quintuple mark at 3, 6, 9, 15, and 18 days of age. Larvae stocked in the North Branch Susquehanna River (NY) were given a quintuple mark at 3,6,9, 12, and 18 days of age. Two batches of larvae were stocked in the Chemung River (NY). One batch of 2 thousand larvae were given a triple mark at 9, 12 and 15 days of age. A second batch of 198 thousand larvae was given a triple mark at 3,12 and 15 days of age.

Larvae stocked in the North Branch Susquehanna River (PA) were given a quintuple mark at 3, 6, 12, 15 and 18 days of age. Larvae stocked in the Lehigh River were given a triple mark at 3, 6, and 12 days of age. Larvae stocked in the Schuylkill River were given a quadruple mark at 3, 6, 9, and 12 days of age.

Verification of mark retention was accomplished by examining whole otoliths several days after the last mark was administered. Larvae were transported live to Benner Spring, the whole fish crushed between two microscope slides and the otoliths examined under an epi-fluorescent microscope with a UV light source. Mark retention was 100% for all groups examined (Table 5).

SUMMARY

A total of 69 shipments (35.6 million eggs) was received at Van Dyke in 2002. Total egg viability was 39% and survival of viable eggs to stocking was 19%, resulting in production of 2.6 million larvae. The majority of the larvae were stocked in the Juniata River (2,122,732). Larvae were also released in Conodoguinet Cr. (2,000), Conestoga River (18,924), Swatara Creek (15,000), the North Branch Susquehanna River (NY- 158,790), the Chemung River (NY- 200,351), the North Branch Susquehanna River (PA- 21,000), the West Branch Susquehanna River (50,000 from Van Dyke and 51,350 from Lamar), the Lehigh River (85,025), and the Schuylkill River (2,000).

Overall survival of larvae was 19%. The low survival was associated with incubation in Van Dyke Jars with open-cell foam bottom screens. The specific cause of the mortalities has not been proven, but toxicity due to fire retardants is suspected.

All American shad larvae cultured at Van Dyke were marked by 4-hour immersion in 256 ppm oxytetracycline. Marks were assigned based on release site and/or egg source river. Retention of tetracycline marks was 100% for all production marks.

RECOMMENDATIONS FOR 2003

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55F.
3. Routinely feed all larvae beginning at hatch.
4. Rear American shad larvae at 65 to 66F instead of 64F.
5. 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.
6. Continue to siphon eggshells from the rearing tank within hours of egg hatch.
7. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
8. Continue to hold Delaware River eggs until 8:00AM before processing.
9. Buy new foam bottom screens each year and specify "no-fire retardants" when ordering foam.
10. Modify ¼ of the egg battery to accept experimental 42" high X 6" diameter, triple May-Sloan jars and 60" high X 6" diameter Acrylic jars. Develop equipment and procedures to utilize these larger jars in larval production.
11. Modify two Van Dyke jars to accept aluminum bottom screens with Chapman diffusers to ensure no dead spots in the jar.

12. Conduct controlled experiments to test viability of eggs incubated in triple May-Sloan jars, Acrylic jars, and modified Van Dyke jars, vs. the standard May-Sloan and Van Dyke jars.

13. In the event that the experimental jars do not meet expectations, incubate a maximum number of eggs in May-Sloan jars to maximize production.

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Figure 1. Survival of American shad larvae at Van Dyke, 2002.

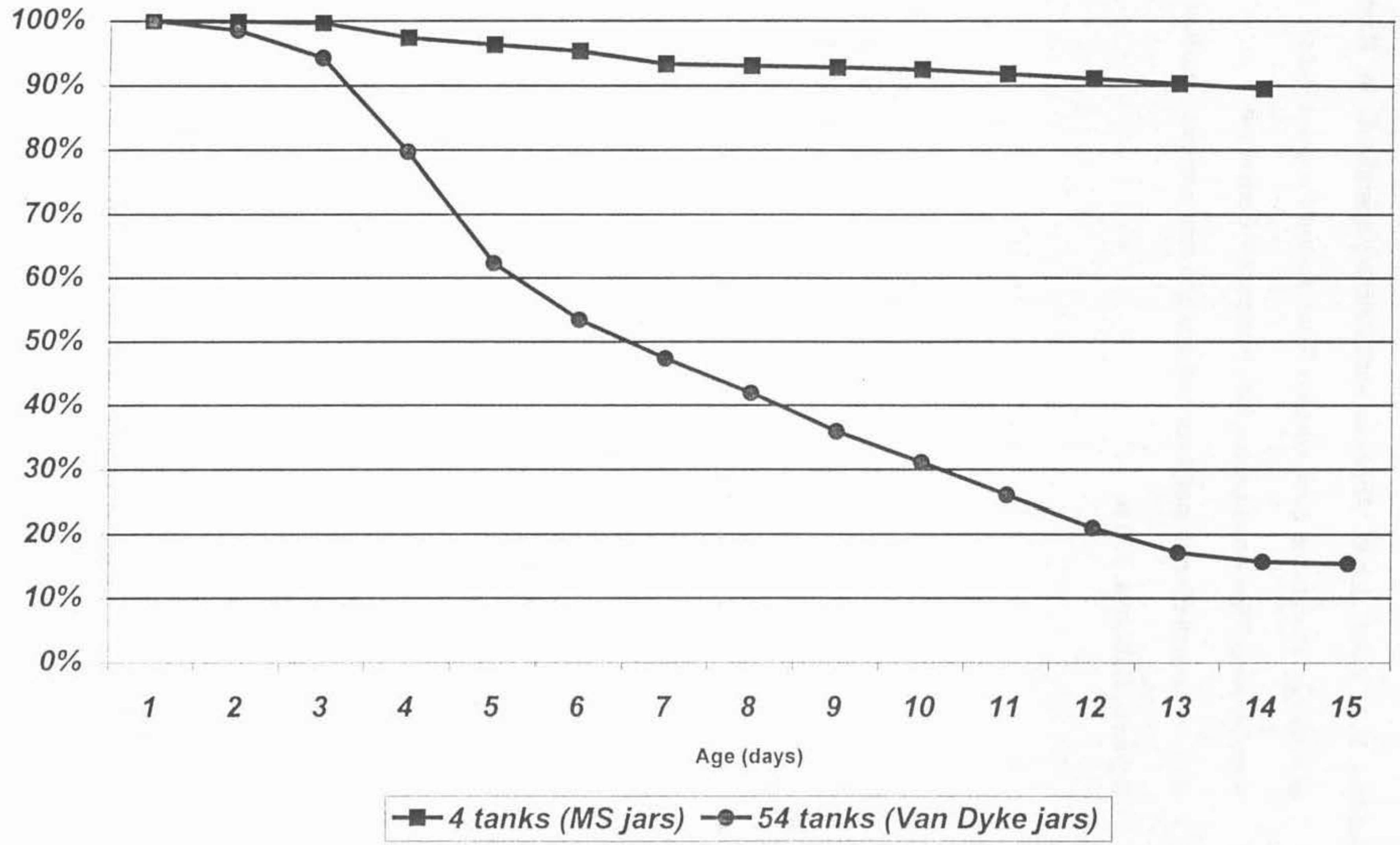

Table 1. American shad egg shipments received at Van Dyke, 2002.

No.	Egg Source	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	Susq.-Lamar	4/24/02	4/25/02	4.6	383,983	48,310	12.6%
2	Susq.-Lamar	4/26/02	4/27/02	5.7	401,015	105,500	26.3%
3	Susq.-Conowingo	4/27/02	4/28/02	4.7	231,748	56,320	24.3%
4	Susq.-Conowingo	4/29/02	4/29/02	8.1	414,657	88,835	21.4%
5	Susq.-Conowingo	4/30/02	4/30/02	6	307,153	36,819	12.0%
6	Susq.-Lamar	5/1/02	5/2/02	5.5	451,880	12,335	2.7%
7	Susq._Lamar	5/1/02	5/2/02	2.2	227,427	-	0.0%
8	Susq-Conowingo	5/02/02	5/02/02	7.4	341,310	79,958	23.4%
9	Susq-Conowingo	5/02/02	5/02/02	7.5	405,807	62,134	15.3%
10	Susq.-Lamar	5/3/02	5/4/02	8.4	611,001	47,207	7.7%
11	Susq.-Lamar	5/3/02	5/4/02	0.6	52,501	1,129	2.2%
12	Susq.-Conowingo	5/4/02	5/4/02	4.6	210,126	5,841	2.8%
13	Susq.-Conowingo	5/4/02	5/4/02	4.7	186,900	34,798	18.6%
14	Susq.-Conowingo	5/4/02	5/5/02	4.6	198,160	8,353	4.2%
15	Susq.-Conowingo	5/4/02	5/5/02	4.8	194,772	61,132	31.4%
16	Susq.-Conowingo	5/7/02	5/7/02	7.7	334,986	78,862	23.5%
17	Susq.-Conowingo	5/7/02	5/7/02	6.8	275,927	43,299	15.7%
18	Hudson	5/7/02	5/8/02	16.3	486,498	266,744	54.8%
19	Hudson	5/8/02	5/9/02	29.8	831,228	493,101	59.3%
20	Delaware	5/8/02	5/9/02	12.1	337,512	141,193	41.8%
21	Susq.-Lamar	5/8/02	5/9/02	6.4	399,477	1,835	0.5%
22	Susq.- Lamar	5/8/02	5/9/02	3.2	212,182	865	0.4%
23	Susq.-Conowingo	5/9/02	5/10/02	5.9	261,760	3,490	1.3%
24	Susq.-Conowingo	5/9/02	5/10/02	7.2	386,022	18,163	4.7%
25	Susq.-Lamar	5/10/02	5/11/02	2.4	208,373	-	0.0%
26	Susq.-Lamar	5/10/02	5/11/02	2.4	198,757	663	0.3%
27	Hudson	5/11/02	5/12/02	103.8	2,774,104	1,702,810	61.4%
28	Susq.-Conowingo	5/12/02	5/12/02	11.6	571,974	8,624	1.5%
29	Susq.-Conowingo	5/12/02	5/12/02	8.9	477,166	12,130	2.5%
30	Delaware	5/12/02	5/13/02	8.9	262,682	95,788	36.5%
31	Hudson	5/12/02	5/13/02	70.5	2,034,560	1,273,671	62.6%
32	Hudson	5/13/02	5/14/02	14.6	384,458	218,975	57.0%
33	Susq.-Conowingo	5/13/02	5/14/02	6.2	311,514	70,618	22.7%
34	Susq.-Conowingo	5/13/02	5/14/02	5.2	263,727	46,886	17.8%
35	Hudson	5/14/02	5/15/02	24.7	720,887	372,507	51.7%
36	Susq.-Lamar	5/14/02	5/15/02	5.9	313,431	303	0.1%
37	Susq.-Lamar	5/14/02	5/15/02	3.9	293,187	5,334	1.8%
38	Susq.-Lamar	5/15/02	5/16/02	1.1	109,574	3,007	2.7%
39	Susq.-Lamar	5/15/02	5/16/02	6.4	346,289	90,512	26.1%
40	Susq.-Lamar	5/15/02	5/16/02	2.2	170,869	12,429	7.3%
41	Susq.-Lamar	5/15/02	5/16/02	3.4	239,202	2,265	0.9%
42	Susq.-Lamar	5/16/02	5/17/02	2.8	272,718	11,799	4.3%
43	Susq.- Lamar	5/16/02	5/17/02	4.2	310,592	71,788	23.1%
44	Hudson	5/22/02	5/23/02	60.6	1,748,856	396,406	22.7%

Table 1. (Continued).

No.	Egg Source	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
45	Hudson	5/23/02	5/24/02	86.3	2,547,134	1,608,380	63.1%
46	Hudson	5/22/02	5/24/02	3.2	90,281	35,368	39.2%
47	Hudson	5/25/02	5/26/02	59.6	1,860,366	1,167,662	62.8%
48	Hudson	5/26/02	5/27/02	67.2	1,939,326	1,428,542	73.7%
49	Hudson	5/28/02	5/29/02	38.3	1,168,808	987,584	84.5%
50	Hudson	5/29/02	5/30/02	23.5	670,567	505,393	75.4%
51	Hudson	5/30/02	5/31/02	7.8	246,027	213,680	86.9%
52	Susq.-Lamar	5/31/02	6/1/02	6.2	466,092	233,956	50.2%
53	Susq.-Lamar	5/31/02	6/1/02	2.8	254,676	927	0.4%
54	Hudson	6/1/02	6/2/02	9.4	293,260	235,967	80.5%
55	Susq.-Conowingo	6/1/02	6/2/02	8.6	500,211	-	0.0%
56	Susq.-Conowingo	6/1/02	6/2/02	6.7	355,930	-	0.0%
57	Hudson	6/2/02	6/3/02	12.1	398,617	309,296	77.6%
58	Delaware	6/2/02	6/3/02	11.3	409,601	236,741	57.8%
59	Delaware	6/3/02	6/4/02	5.7	185,759	86,368	46.5%
60	Hudson	6/3/02	6/4/02	8.9	312,595	233,227	74.6%
61	Delaware	6/4/02	6/5/02	10.5	400,843	42,161	10.5%
62	Delaware	6/5/02	6/6/02	13.6	443,215	228,183	51.5%
63	Susq.-Lamar	6/5/02	6/6/02	7.1	491,185	7,639	1.6%
64	Susq.-Lamar	6/5/02	6/6/02	3.2	273,512	7,785	2.8%
65	Susq.-Conowingo	6/5/02	6/6/02	5.5	374,118	-	0.0%
66	Susq.-Conowingo	6/5/02	6/6/02	5.7	475,805	-	0.0%
67	Susq.-Lamar	6/7/02	6/8/02	4.4	385,009	116,024	30.1%
68	Susq.-Lamar	6/7/02	6/8/02	3.3	284,280	27,266	9.6%
69	Susq.-Lamar	6/8/02	6/9/02	8.4	636,670	12,193	1.9%
Totals		No. of shipments					
	Hudson	17		636.6	18,507,572	11,449,313	61.9%
	Delaware	6		62.1	2,039,613	830,435	40.7%
	Susq.Conowingo	21		138.4	7,079,774	716,261	10.1%
	Susq.-Lamar	25		106.7	7,993,882	821,072	10.3%
	Grand total	69		943.8	35,620,841	13,817,082	38.8%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976-2002.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of shad stocked (all rivers) Fry (exp.3)	Fing-erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969	35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629	34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526	5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048	98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996	30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876	61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274	81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267	60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034	253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963	233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870	79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720 *	140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930 *	-	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466 *	-	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757	2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412	-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535	-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524	7	6,531	0.31	0.88
2002	943	36	38.8	13.8	2,589	-	2,589	0.07	0.19
						Total	216,833		
					Total since 1985 (OTC marked)		185,436		

*Includes fry reared at Manning.

Table 3. American shad stocking and fish transfer activities, 2002.

Date	Tank	Number	OTC mark (days)	Location	Origin	Age	Size
5/29/02	A1 1	10,000	3,6,9,15,18	Swatara Creek	Susq.-Lamar	24	Fry
5/29/02	A2 1	5,000	3,6,9,15,18	Swatara Creek	Susq.-Conowingo	22	Fry
5/29/02	A3 1	18,924	3,9,12,15	Conestoga River	Susq.-Con/Lamar	19	Fry
5/30/02	A4 1	2,000	3,6,12,15	Conodoguinet Creek	Susq.-Con/Lamar	19	Fry
	B1 1	-	3,6,9,15	discarded	Susq.-Conowingo	16	Fry
5/30/02	B2 1	50,000	3,9,12	W. Br. Susq. River	Hudson	14	Fry
5/28/02	B3 1	100,000	3	Thompsontown	Hudson	12	Fry
	B4 1	-	3,6,9,12	discarded	Delaware		
5/29/02	C1 1	19,104	3,6,9	Mexico	Susq.-Con/Lamar	10	Fry
	C2 1	-	3,6,9,15,18	discarded	Hudson		
	C3 1	-	3,6,12,15	discarded	Hudson		
	C4 1	-	3,6,9,15	discarded	Hudson		
5/28/02	D1 1	115,543	3	Thompsontown	Hudson	8	Fry
5/28/02	D2 1	130,458	3	Thompsontown	Hudson	8	Fry
5/28/02	D3 1	122,949	3	Thompsontown	Hudson	8	Fry
5/28/02	D4 1	122,223	3	Thompsontown	Hudson	8	Fry
	E1 1	-	3,6,9,12	discarded	Delaware		
	E2 1	-	3,12,15	discarded	Hudson		
	E3 1	-	3,12,15	discarded	Hudson		
	E4 1	-	0	discarded	Hudson		
	F1 1	-	0	discarded	Hudson		
	F2 1	-	3,6,12,15,18	discarded	Hudson		
	F3 1	-	9,12,15	discarded	Hudson		
6/4/02	F4 1	39,613	3,6,9	Thompsontown	Susq.-Conowingo	12	Fry
	G1 1	-	9,12,15	discarded	Hudson		
6/13/02	G2 1	158,790	3,6,9,12,18	N. Br. Susq. R. (NY)	Susq.-Lamar	19	Fry
6/20/02	J1 1	1,000	3,6,12,15,18	N. Br. Susq. R. (Danville)	Hudson	20	Fry
6/20/02	J2 1	20,000	3,6,12,15,18	N. Br. Susq. R. (Danville)	Hudson	20	Fry
6/13/02	J3 1	50,000	3	Millerstown (Greenwood)	Hudson	12	Fry
6/13/02	J4 1	20,000	3	Millerstown (Greenwood)	Hudson	12	Fry
6/13/02	A1 2	30,000	3	Millerstown (Greenwood)	Hudson	11	Fry
6/13/02	A2 2	5,000	3	Millerstown (Greenwood)	Hudson	11	Fry
6/13/02	A3 2	125,000	3	Millerstown (Rt. 17 Bridge)	Hudson	9	Fry
6/13/02	A4 2	150,000	3	Millerstown (Rt. 17 Bridge)	Hudson	9	Fry
6/13/02	B1 2	5,000	3	Millerstown (Rt. 17 Bridge)	Hudson	8	Fry
6/13/02	B2 2	50,000	3	Millerstown (Rt. 17 Bridge)	Hudson	8	Fry
6/13/02	B3 2	50,000	3	Muskrat Springs	Hudson	8	Fry
6/13/02	B4 2	100,000	3	Muskrat Springs	Hudson	8	Fry
6/13/02	C1 2	5,000	3	Muskrat Springs	Hudson	8	Fry
6/13/02	C2 2	50,000	3	Muskrat Springs	Hudson	7	Fry
6/13/02	C3 2	50,000	3	Mexico	Hudson	7	Fry
6/13/02	C4 2	50,000	3	Mexico	Hudson	7	Fry
6/13/02	D1 2	10,000	3	Mexico	Hudson	7	Fry
6/25/02	D2 2	2,000	9,12,15	Chemung R.	Hudson	18	Fry
6/25/02	D3 2	198,351	3,12,15	Chemung R.	Hudson	18	Fry
6/14/02	D4 2	100,000	3	Millerstown (Rt. 17 Bridge)	Hudson	6	Fry
6/14/02	E1 2	200,000	3	Millerstown (Rt. 17 Bridge)	Susq.-Lamar	5	Fry

Table 3. (Continued).

Date	Tank	Number	OTC mark (days)	Location	Origin	Age	Size
6/14/02	E2 2	150,000	3	Millerstown (Rt. 17 Bridge)	Hudson	5	Fry
6/14/02	E3 2	50,000	3	Millerstown (Rt. 17 Bridge)	Hudson	4	Fry
6/14/02	E4 2	50,000	3	Millerstown (Rt. 17 Bridge)	Hudson	4	Fry
	F1 2	-	3,6,9,12	discarded	Delaware		
	F2 2	-	3,6,9,12	discarded	Delaware		
6/26/02	F3 2	2,000	3,6,9,12	Schuylkill R.	Delaware	17	Fry
6/28/02	F4 2	15,000	3	Millerstown (Rt. 17 Bridge)	Hudson	17	Fry
6/26/02	G1 2	7,571	3,6,12	Lehigh R.	Delaware	14	Fry
6/26/02	G3 2	74,454	3,6,12	Lehigh R.	Delaware	13	Fry
6/26/02	G4 2	3,000	3,6,12	Lehigh R.	Delaware	13	Fry
6/28/02	H1 2	157,843	3,6,9	Millerstown (Rt. 17 Bridge)	Susq.-Con/Lamar	13	Fry

Table 4. Production and utilization of juvenile American shad, Van Dyke, 2002.

	Site	Fry
Releases	Millerstown (Greenwood)	105,000
	Millerstown (Rt. 17 Bridge)	1,052,843
	Miller's Canoe Rental	
	Thompsontown	630,786
	Muskrat Springs	205,000
	Mexico	129,104
	Mifflin	
	Treaster's Exxon	
	Juniata River Subtotal	2,122,732
	Clemson Island	
	Montgomery Ferry	
	Millersburg Ferry	
	Liverpool	
	Mahantango	
	Conodoguinet Creek	2,000
	Conestoga River	18,924
	Swatara Creek	15,000
	West Conewago Creek	
	North Branch Susquehanna River (NY)	158,790
	Chemung River	200,351
	North Branch Susquehanna River (PA)	21,000
	West Banch Susquehanna River	50,000
	Susquehanna River Basin Subtotal	2,588,797
	Schuylkill River	2,000
	Lehigh River	85,025
	Nanticoke River	
	Raritan River	
	Total	2,675,822

Table 5. Summary of marked Alosids stocked in Pennsylvania, 2002.

Number	Size	Mark Immersion (days)	Mark Feed	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers.	Mark Retention (%) Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source
American shad											
1,706,173	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata R.	Hudson
200,000	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata R.	Susq.
216,560	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata R.	Susq.
50,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	W. Br. Susq. R.	Hudson
51,350	Fry	3,9,12	-	200ppm OTC	-	?	-	Lamar	-	W. Br. Susq. R.	Susq.
2,000	Fry	3,6,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Susq.
2,000	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Schuylkill R.*	Delaware
18,924	Fry	3,9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Susq.
85,025	Fry	3,6,12	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.*	Delaware
15,000	Fry	3,6,9,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	Swatara Cr.	Susq.
21,000	Fry	3,6,12,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.(PA)	Hudson
158,790	Fry	3,6,9,12,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.(NY)	Susq.
2,000	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Chemung R. (NY)	Hudson
198,351	Fry	3,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Chemung R. (NY)	Hudson
2,727,173	Fry	Subtotal									
Hickory shad											
100,000	Fry	3		200ppm OTC				Manning (MD)		Ridley Cr.*	Susq.

* Tributaries to the Delaware River.

Appendix 1

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2002.

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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 256ppm oxytetracycline hydrochloride. Detectable fluorophore from these marks is visible in the one otolith increment produced on the day of marking. Multiple marks, 3 or 4d apart, have been used to evaluate the relative survival of groups uniquely marked according to release site, egg source river, release time of day, or release habitat (Hendricks et al., 1992, Hendricks et al., 1993).

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

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

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

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

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

In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2002 and summarizes results from 1995 to 2002.

Materials and Methods

Production larvae, stocked in 2002, included 1.90 million Hudson River source (strip-spawn) larvae marked at three days of age; and 217 thousand 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. Sites were generally stocked in succession, moving upriver. Repeated stockings at one site, within a short time interval, were avoided. Smaller numbers of uniquely marked larvae were stocked at other sites, including the Conestoga, Conodoguinet, and Swatara Creeks, the West Branch Susquehanna River, the North Branch of the Susquehanna River in both Pennsylvania and New York, and the Chemung River in New York. West Conewago Creek was not stocked in 2002.

Juvenile American shad were recaptured 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 2001 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. Relative survival was calculated by dividing the recovery rate for each group by the highest recovery rate.

Results and Discussion

In 2002, Hudson River source larvae stocked in the Chemung River exhibited the best survival (relative survival set to 1.00, Table A1-1). Hudson River egg source larvae stocked in the North Branch Susquehanna River in New York exhibited relative survival of

0.62. Susquehanna River source larvae stocked in the Juniata River exhibited a relative survival of 0.37 and Hudson River egg source larvae stocked in the Juniata River exhibited a relative survival of 0.15. Larvae stocked in the West Branch Susquehanna River had a relative survival of 0.10. No larvae stocked in the Conestoga River, Swatara Cr., Conodoguinet Cr., or the North Branch Susquehanna River (PA) were recovered.

A summary of the results of seven years of uniquely marking larvae according to stocking site is provided in Table A1-2. Recovery rates for 2002 varied from 0.00 to 1.01. The overall recovery rate for 2002 (0.27) was the third lowest for the period, indicating poor survival of larvae. The poor survival was probably due to the fact that many of the larvae were not feeding, and were stocked early before they would have died in the hatchery. Coupled with the low numbers of larvae stocked, this poor survival made for a very poor year for the hatchery.

Larvae stocked in the North Branch in Pennsylvania did extremely well in previous years, but none were recovered in 2002. Larvae stocked in the West Branch have not done well, exhibiting relative survival of 0.00 to 0.41 during the period 1996 to 2002. Only one fish from these plantings was recovered in 2002.

No recoveries were made from American shad larvae stocked in smaller tributaries, in 2002. This was due to the fact that small tributaries were stocked with few larvae, and the larvae that were stocked, were not in good condition. In the past, larvae stocked in smaller tributaries did well in some years and poorly in others (Hendricks, 2002).

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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, 2002.

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	7-17	5/28-6/28	1,906,172	75%	29.0	43	0.15	0.15
Juniata R./ middle Susq. R. near Mont. Ferry	Susq.-Con./Lamar	10-13	5/29-6/28	216,560	8%	8.0	12	0.37	0.37
Conodoguinet Cr.	Susq.-Con./Lamar	19	5/30	2,000	0%	0.0	0	0.00	0.00
Conestoga R.	Susq.-Con./Lamar	19	5/29	18,924	1%	0.0	0	0.00	0.00
Swatara Cr.	Susq.-Con./Lamar	22-24	5/29	15,000	1%	0.0	0	0.00	0.00
W. Br. Susq. R.	Hud./Susq.-Lamar	14	5/30	18,924	1%	1.0	1	0.53	0.52
N. Br. Susq. R.(PA)	Hudson	20	6/20	21,000	1%	0.0	0	0.00	0.00
N. Br. Susq. R.(NY)	Hudson	19	6/13	158,790	6%	10.0	15	0.63	0.62
Chemung R.	Hudson	18	6/25	198,351	8%	20.0	29	1.01	1.00
Chemung R.	Hudson	18	6/25	2,000	0%	0.0	0	0.00	0.00
			Total	2,557,721		68		0.27	

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, 1995-2002.

Stocking Site	Recovery Rate							
	1995	1996	1997	1998	1999	2000	2001	2002
Juniata R./Susq. R. @ Mont. Ferry	2.12	0.10	1.85			0.72	2.07	0.15
Juniata R.(various sites)			2.09	0.15	0.63			
Juniata R.(Susq. eggs)				0.10			1.32	0.37
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
mouth of Conodiguinet Cr.	2.96							
Conestoga R.	3.28	0.00	0.26	0.00	0.87	0.13	0.22	0.00
mouth of Conestoga Cr.	1.18							
Muddy Cr.	0.00							
Conewago Cr.				0.19	0.18	0.61	0.18	0.00
Swatara Cr.				0.20	0.69	0.00	1.15	0.00
W. Br. Susq. R.		0.09	0.86	0.00	0.00	0.17	0.09	0.53
N. Br. Susq. R.(PA)		0.34	2.02	0.21	0.19	0.40	1.06	0.00
N. Br. Susq. R.(NY)								0.63
Chemung R.								1.01
Overall	2.13	0.12	1.77	0.15	0.54	0.62	1.37	0.27
	Relative Survival							
Juniata R./Susq. R. @ Mont. Ferry	0.65	0.31	0.89			1.00	1.00	0.15
Juniata R.(various sites)			1.00	0.72	0.73			
Juniata R.(Susq. eggs)				0.49			0.64	0.37
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
mouth of Conodiguinet Cr.	0.90							
Conestoga R.	1.00	0.00	0.12	0.00	1.00	0.18	0.11	0.00
mouth of Conestoga Cr.	0.36							
Muddy Cr.	0.00							
Conewago Cr.				0.89	0.20	0.84	0.09	0.00
Swatara Cr.				0.96	0.80	0.00	0.56	0.00
W. Br. Susq. R.		0.28	0.41	0.00	0.00	0.23	0.05	0.52
N. Br. Susq. R.(PA)		1.00	0.97	1.00	0.21	0.56	0.51	0.00
N. Br. Susq. R.(NY)								0.62
Chemung R.								1.00

Appendix 2

Evaluation of the Fred Lewis haul seine fishery at Lambertville, NJ as a potential source of American shad eggs from the Delaware River, 2002.

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Introduction

The Pennsylvania Fish and Boat Commission is restoring American shad to the Susquehanna, Lehigh and Schuylkill Rivers. Production goals for American shad stocking are 10-15 million larvae annually. In order to meet that goal, the Van Dyke Hatchery relies upon delivery of good quality, fertilized eggs from the Hudson and Delaware Rivers. Eggs from the Hudson River typically exhibited viability of more than 70% while those from the Delaware River exhibited viabilities ranging from 27 to 62% (Hendricks, 1996, 1997, 1998, 1999, 2000). Hendricks (2000) studied accuracy of viability estimates for the Delaware River and found that methods used prior to 1999 overestimated viability by an average of 12%, when compared to counts of sub-sampled eggs. The inflated viability of Delaware River eggs was due to the presence of large numbers of small dead eggs which did not layer out, could not be removed by siphoning and were counted as live.

In an effort to improve viability, Hendricks (1995) attempted using water from the Van Dyke Hatchery to water harden Delaware River eggs prior to delivery to the hatchery. Results were inconsistent in that viability of eggs water hardened in Van Dyke water was higher in three replicates and lower in two. Other procedural modifications were made to attempt to improve viability including: use of turkey basters to remove blood and fecal material from eggs; use of live males first, then fresh dead males; holding spawners in tubs with water; use of a pump to circulate water during water hardening; use of a flow through egg box for water hardening; and use of medical grade oxygen for shipping eggs. Despite these improvements, viability of American shad eggs from the Delaware River remained low.

One potential problem is low concentration of calcium ions in Delaware River and Van Dyke incubation water. Total hardness of Delaware River water is approximately 20 mg/L while at Van Dyke it is 10-12 mg/L. Yamamoto and Kobayahsi (1996) noted early developmental problems in chum salmon in low calcium water. They found that $CaCl_2$ concentrations in the external medium should be 25mM or more to induce close contact of blastomeres and the formation of an enveloping layer. Spade and Bristow (1999) reported that increasing water hardness for the first 48 hours of incubation from 40 to 200mg/L by addition of $CaCl_2$ increased hatch rate of striped bass from 54% to 70%.

In 2000, Hendricks (2001) investigated the potential for improving viability of Delaware River American shad eggs by use of calcium chloride during water hardening and transport, holding adult male shad in chilled salt water until stripping, use of chilled whole sperm, and use of isotonic salt solutions during sperm activation. River conditions for the experiment were poor, resulting in the capture of only 3 ripe females and 3 ripe males. As a result, only one replicate could be conducted. The highest egg viability was achieved by sperm activation in river water and water hardening and transport in 200mg/L $CaCl_2$ (78.2%). The lowest egg viability occurred with activation in 6g/L NaCl and water hardening in river water (58.7%). Egg viability for the control was 65.9%. The results suggested that use of $CaCl_2$ in water hardening and transport showed promise.

In 2001 we followed up on the work of Hendricks (2001) and replicated trials of water hardening and transport of shad eggs in 200 mg/L $CaCl_2$ (Hendricks, 2002). The study consisted of 12 treatments and 12 controls (3 replicates per night for 4 nights). Viability of eggs water hardened and shipped in 200 mg/L $CaCl_2$ (test) ranged from 0.0 to 43.1 percent, while viability of controls ranged from 0.0 to 38.9 percent. Overall viability of test lots was 22.2 percent, compared to 18.1 percent for controls. Viability for test lots exceeded that of controls for 8 of the 12 replicates. Both the Sign Test and Wilcoxin's Signed-Rank Test (Ott, 1977, α=.05) indicated that water hardening and shipping in 200 mg/L $CaCl_2$ results in significantly higher viability than controls, but though significantly different, the difference was only 4.1%.

The results also demonstrated that there was a high degree of variability, with no trend, between the production lots and experimental lots. For one shipment, viability of production eggs was 13 percent higher than any of the experimental lots, but for another shipment, viability of production eggs was well below that of most experimental lots. Variability within treatments, on any given collection night was also high. The difference in viability between replicates was as high as 31 percent and was often more than 20 percent. This high degree of variability between lots, irrespective of the test treatment, suggests that there is a high degree of variability in either egg or sperm quality between individual fish. This could be due to the condition of the individual fish, at the time of spawning. On the Hudson River, where egg viabilities are consistently in the 70 to 80% range, it is thought that the condition of the male is critical to fertilization rate (Mark Plummer, The Wyatt Group, personal communication). Live males result in high egg viabilities, while dead males produce low viabilities.

Examination of hatchery records from 1985 to 2001 (Figure 1) revealed that the annual number of egg shipments from Smithfield Beach has risen, while the number of liters of eggs per shipment has declined, reflecting the additional effort required to collect eggs. The number of eggs per liter has also gone up while egg viability has gone down; evidence of the declining quality of Delaware River eggs. The most revealing statistic is that from 1985 to 1993, one to three shipments (nights of fishing) were required to collect one million viable eggs. Between 1999 and 2001, seven to ten shipments were required to collect one million viable eggs (Figure 2).

This study explored the potential of obtaining fertilized American shad eggs from the Fred Lewis commercial haul seine fishery at Lambertville, NJ. The Lewis haul seine fishery operates from late March until fish are no longer available, usually in mid-May. Hauls are made beginning at 5 PM and ending when orders for fish have been fulfilled (Steve Meserve, operator of the Lewis haul seine fishery, personal communication). Ripe female shad are frequently collected, once spawning begins.

Obtaining eggs from the Lewis haul seine fishery has several potential advantages over gill netting at Smithfield Beach. Use of freshly caught fish from the haul seine may improve egg viability, when compared to those caught in gill nets, put in washtubs and delivered to the shore-based spawning site as much as 30 minutes after initial capture. In addition, the haul seine site may be suitable for a pump operated, flow-through holding tank, which would ensure that spawners are kept in prime condition prior to stripping. With haul seining, a three-person crew (two spawners and a driver) would be required, compared to a five-person crew for gill netting (two boat crews, two persons each, plus a driver). In addition, no boats or gill nets would be required for haul seining. Since haul seining starts at 5PM and is completed by dark, while gill netting does not begin until dark, the crew would be finished earlier, and require less adaptation to night work and unusual sleep routines. This is particularly important to the driver who may arrive at Van Dyke as early as 1:00AM, compared to 4:00AM for gill netting.

Materials and Methods

American shad were captured by haul seine. Two seines were tied together; both were 300 ft X 8 ft deep, one with 3 inch stretch mesh and one with 4 inch stretch mesh. The net was played out by boat, angling in an arc downstream, while the inshore end was anchored by one person. Both the boat and anchor-person moved downstream, keeping the net taught, and covering approximately ½ mile along the East bank of the river, above Lambertville. The net was hauled ashore at the lower end of Lewis Island. The catch was enumerated and all American shad checked for ripeness by applying gentle pressure on the abdomen.

Results and Discussion

Efforts to participate in the Lewis Haul Seine Fishery were hampered by high water events associated with abundant rainfall (Figure 3). Water temperature first became conducive to shad spawning (16C) on April 14 and rose steadily to 21C on April 19. Cooler weather (and later high water) caused a decline in water temperature to well below the threshold for shad spawning until May 7 when temperature reached 17C. We attempted to schedule Wednesday, May 8, for our first effort, but sufficient crew members were not available to work the net. We postponed the effort until May 10, 2002. Unfortunately, a cold front had moved through the area on May 9 and, although May 10 was sunny, it was apparently not warm enough to induce shad spawning. Maximum water temperature on May 10 was 18C. Two hauls were made between 6:40 PM and 8:20 PM. A total of 21 shad were collected, however all 6 of the females collected were green and no eggs were collected. A second trip could not be scheduled due to activities at Van Dyke. In addition, catches of shad in the Lewis Fishery were declining and it was evident that the run was nearly over, at least in the lower river.

From discussions with the Lewis haul seine crew, it is unlikely that the number of eggs collected at the Lambertville site would be sufficient to justify further attempts at that location. Haul seining may, however, be a viable option for collection of eggs at sites upstream, if sites suitable for haul seining could be found.

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Figure 1. Trends in Delaware River American shad egg collections, 1985-2001.

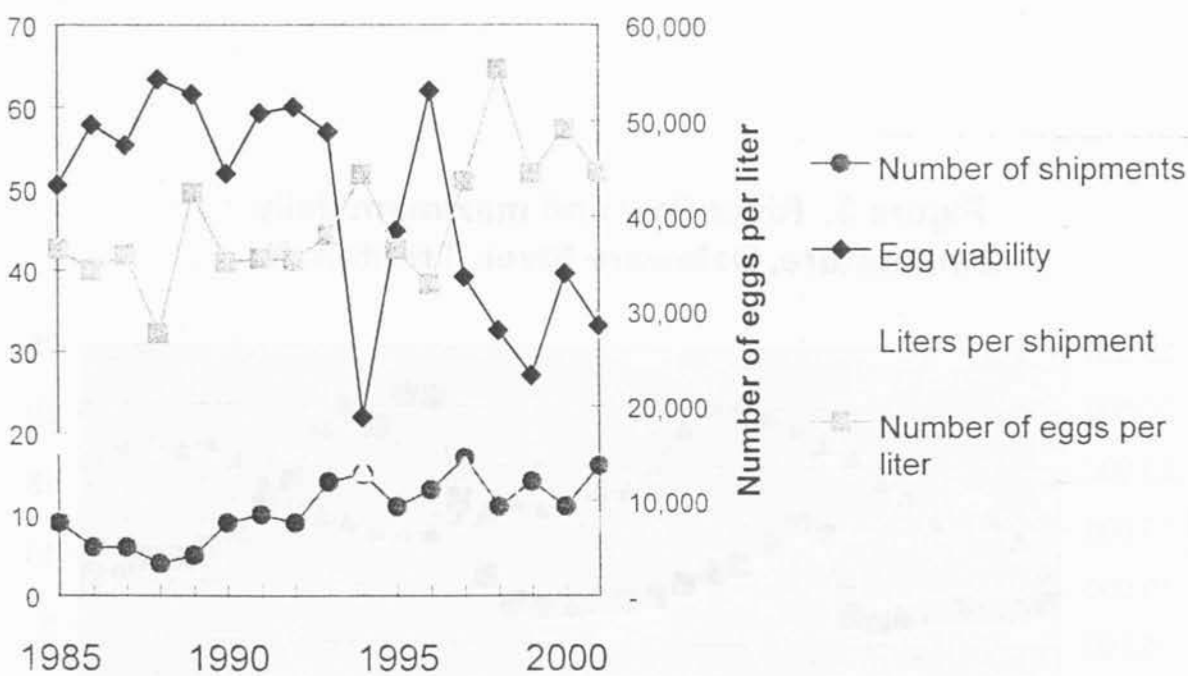


Figure 2. Number of shipments (nights fishing) required to collect 1 million viable American shad eggs, Delaware River, 1985-2001.

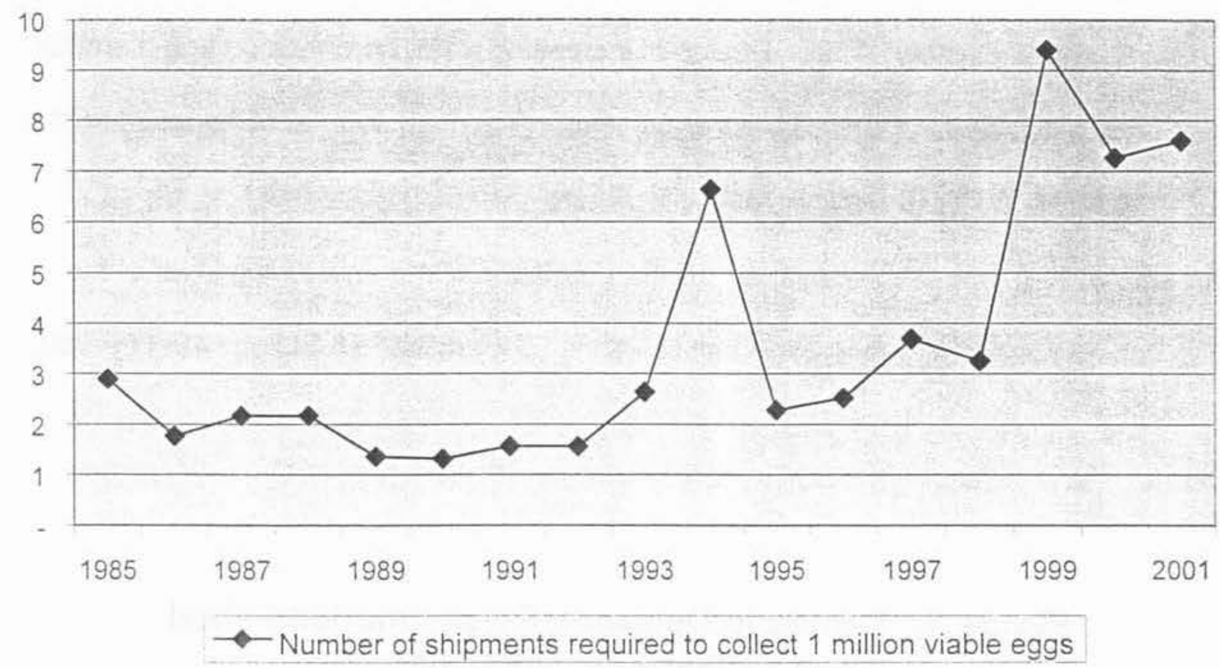
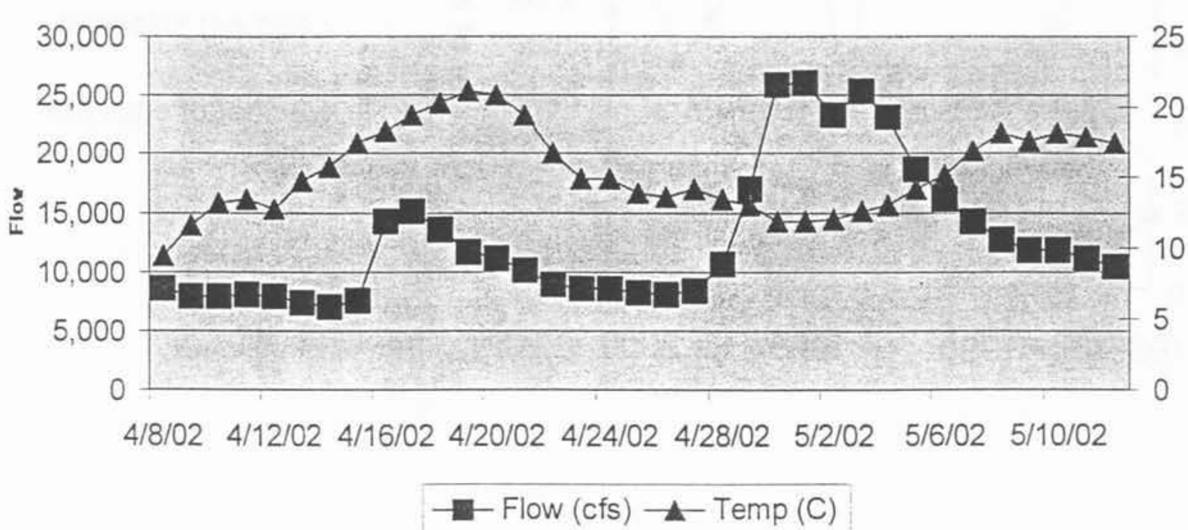


Figure 3. River flow and maximum daily temperature, Delaware River, Trenton, NJ.



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

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INTRODUCTION

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 (PFBC) and United States Fish and Wildlife Service (USFWS) facilities 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.

The Conowingo West Lift continued to be used as a source of adult American shad and river herring to support monitoring activities and tank spawning. Some 9,347 adult shad were collected at the Conowingo West Lift. The majority of these were retained or transported to Lamar hatchery for tank spawning. Unlike previous years, no pre-spawn alosids were transported and released upstream.

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 2002 spring migration, Conowingo East Lift passed 108,001 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 17,522, 11,705 and 1,525 American shad, respectively. Only 2,100 river herring were passed at Conowingo Dam and few herring were passed at Holtwood.

During the 2002 production season, the PFBC Van Dyke Research Station for Anadromous Fish released 2.58 million shad larvae in the Susquehanna Basin, Pennsylvania. This was well below the 10-20 million production goal and nearly 3 million fewer larvae than were stocked in 2001. Most larvae were released between 28 May and 28 June in the following locations and numbers:

Juniata River (various sites)	2,122,732 fry
Conodoguinet Creek	2,000 fry
Conestoga River	18,924 fry
Swatara Creek	15,000 fry
North Branch of Susquehanna River (NY)	158,790 fry
Chemung River (NY)	200,351 fry
North Branch of Susquehanna River (PA)	21,000 fry
West Branch of Susquehanna River	50,000 fry

METHODS

Sampling for juvenile American shad was conducted at several 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 conducted once each week on 15 dates beginning mid-July and continuing through October. 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.

Haul Seining - Tributaries

The Conestoga River, Little Conestoga Creek, West Conewago Creek, Swatara Creek, and Conodoguinet Creek were sampled by seine on a weekly basis from late-July through August (5 dates). Six stations were sampled in each of the five tributaries. Seven consecutive hauls were conducted at each station, on each day of sampling, using a seine measuring 30 ft X 6 ft with 3/8 in stretch mesh.

Push-netting

Push-netting for juvenile alosids was conducted at various sites in the upper portion of Conowingo pool beginning early June and ending in early-July for a total of 13 sampling dates. A total of 10 stations were sampled on each date (five minute push per station). The push-net utilized was a 5-ft beam trawl with a 60-in square mouth opening lashed to a 4-ft 11-in by 4-ft 11-in steel frame. The net was made of No. 63 knotless 1/4-in stretch mesh netting. It was tailored and tapered to a length of 7-ft terminating at a 12-in canvas collar cod-end. The net was attached to the front of an 18-ft jon-boat. For each survey the push-net was suspended into the water and pushed into the current for five minutes. Push-netting was conducted during the evening hours in deep pools or runs and along shorelines of islands in upper Conowingo pool and in the vicinity of Muddy Run Pump Storage Station.

Electrofishing

Electrofishing was conducted at two upper river reaches located on the Susquehanna River between Clarks Ferry and the Fabri-Dam at Sunbury, and the Juniata River between Amity Hall and Huntingdon. Electrofishing employed the use of a 14 or 18-ft jon-boat and variable voltage electrofisher with the anode mounted on the bow. Sampling consisted of several short electrofishing runs per date at each site beginning at sunset and ending after dark. Both reaches were sampled on eight dates during the months of August and September.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Sampling at Holtwood Dam inner fore-bay was conducted using a fixed 8-ft square lift-net beginning in mid-September and continuing every three days through early December (26 total dates). 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 2001.

Intake screen sampling for impinged alosids at Peach Bottom Atomic Power Station was conducted three times per week from 14 October to 6 December for a total of 23 samples. Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosids twice weekly from 18 October to 25 November for a total of 11 samples.

Susquehanna River Mouth and Flats

Maryland DNR sampled 12 stations and made 57 hauls in the upper Chesapeake Bay using haul seines in the summer and fall.

Disposition of Samples

Juvenile shad from all collections at or above Conowingo 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

No juvenile American shad were captured in 84 hauls at Columbia resulting in a Geometric Mean Catch-Per-Unit-Effort (GM CPUE) of zero (Table 1).

Haul Seining - Tributaries

No juvenile American shad were collected by haul seine in tributaries.

Push-netting

No juvenile American shad were captured in approximately 650 minutes of push-netting.

Electrofishing

River reaches on the Susquehanna and Juniata rivers were sampled for a combined total of 978 minutes of electrofishing time resulting in the capture of no juvenile American shad.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner fore-bay resulted in the capture of 68 juvenile American shad in 260 lifts (Table 2). Shad were captured over a narrow range of temperatures and river flows between 15 and 27 October. The first juvenile shad captured occurred on 15 October at a water temperature of 15.0°C and a river flow of 32,400 cfs. The peak collections occurred on 18 and 21 October at a water temperature of 13.5 and 12.5°C and a river flow of 58,000 and 36,600 cfs, respectively. All of the juveniles were captured over a two-week period in October, when river temperature was less than or equal to 15.0°C (Table 2 and Figure 1). Total length of specimens ranged from 113 to 160 mm; over 91% were 111 to 145 mm TL. GM CPUE (individual lift) was 0.09; GM CPUE (daily combined lifts) was 0.15 (Table 3). No juvenile river herring were captured by lift-net in 2002.

Peach Bottom intake screens produced 18 juvenile American shad, 2 blueback herring, and 5 alewives (Tables 4 and 5). Peak catch for shad occurred on two dates, 18 and 30 October, when 5 juveniles each were captured. Cooling water strainers at Conowingo produced 6 juvenile American shad and 4 alewives (Table 6). Peak catch for shad occurred on 21 October when 3 juveniles were captured.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 49 juvenile American shad in the upper Chesapeake Bay during summer and fall 2002 (Table 7).

Otolith Mark Analysis

Results of otolith analysis are presented in Table 8. Otoliths from 86 juvenile American shad taken in the summer and fall collections were analyzed for hatchery marks. Of these, 69 (78.1%) were marked (hatchery origin) and 19 (21.9%) were wild. All otoliths analyzed were collected from juvenile shad captured at Holtwood Dam or downstream at Peach Bottom and Conowingo. Recapture of shad from various stocking sites is discussed in Job III. Of 48 juvenile shad otoliths processed from upper Chesapeake Bay collections (Maryland DNR), only one was determined to be of hatchery origin, exhibiting a single mark at day 3.

DISCUSSION

Spring river conditions for the Susquehanna River basin during 2002 could be characterized by high flows and below normal water temperatures. Fish passage at Holtwood and York Haven were severely impaired by persistent high river flows and constant spilling which adversely affected attraction at the fishway entrances. River flow measured at Harrisburg never dropped below about 38,000 cfs during May with peaks well over 60,000 cfs during the first and third weeks. Between May 15 and 26, flows were high enough to (up to 200,000 cfs) to threaten inundation of crowder motors and most projects were shutdown during this critical migration period. By comparison, in May 2001, river flows at Harrisburg never exceeded 20,000 cfs. During summer and early fall of 2002, severe drought conditions persisted in the Susquehanna drainage. Beginning in October, drought conditions were alleviated by higher than normal precipitation throughout the remaining portion of 2002.

Abundance – Main Stem

Comparison of relative abundance of juvenile alosids in the Susquehanna River from year to year remains difficult due to the opportunistic nature of sampling and wide variation in river conditions, which may influence catches. Based on river haul seine and lift-net catch rates, abundance of juvenile American shad in 2002 was the lowest recorded in recent history.

Geometric Mean CPUE of zero for haul seine (individual lifts, combined daily lifts) is the lowest value ever recorded for that gear type since 1990. Likewise, GM CPUE of 0.09 by lift-net (individual lifts) is the lowest recorded since this estimate was required by ASMFC in 1997 (Table 3). GM CPUE of 0.15 by lift-net (combined daily lifts) was the second lowest recorded since 1985 and well below the ten-year average of 0.722. Low juvenile shad abundance in 2002 is most likely attributed to limited natural reproduction resulting from poor fish passage performance and poor hatchery production.

In-Stream Movements and Out-migration Timing

Generally, out-migration of juvenile American shad is episodic in nature. It typically occurs when the water temperature falls below 15.6° C and river flow increases, with the majority of the out-migration occurring over a four-week period. In 2002, out-migration, based on juvenile shad captured at Holtwood, Peach Bottom, and Conowingo, occurred during the two-week period from 15 October to 1 November when the river temperature was 15.0° C or lower and flows were greater than 36,600 cfs. Catches corresponded with declining temperatures and periods of increased river flows. Shad stocked in the North Branch of the Susquehanna River and Chemung River in New York were first captured by lift-net on 18 October, suggesting a movement of 315 miles in 127 days or less. The timing of the out-migration was consistent with that observed during previous years, however, the duration was contracted. In 2001, juvenile shad were captured well into December. In 2002, lift netting was terminated four weeks early due to the lack of shad captured.

Stock Composition and Mark Analysis

Of the 86 otoliths analyzed from collections above Conowingo Dam, 19 (22%) were wild and 69 (78%) were hatchery fish (Table 8). This compares to 43% wild fish in 2001 collections, and 2%

- 58% from 1991 to 2000. In 2002, no juvenile shad were captured above Holtwood, compared to 126 wild fish and 274 hatchery fish captured above Holtwood in 2001.

Push-netting

No juvenile alosids were captured by push-net in 2002, compared to 2 juvenile shad and 134 blueback herring captured by push-net in 2001. Holtwood passed only 17,522 (16.4%) of the 108,001 adult American shad passed at Conowingo. This suggests that some 90,479 adult shad remained in Conowingo Pool. Poor catches of juvenile shad by push-net may reflect that Conowingo pool provides poor spawning habitat for American shad and/or juvenile shad are adept at avoiding capture by push-net. Low catches of juvenile blueback herring reflects low numbers of adults passed at Conowingo (2,100). In contrast, Alosid catches in 2001 suggest that push netting is an effective method of sampling alosids, specifically, blueback herring in Conowingo pool. It is hoped that increases in Alosid abundance associated with stock restoration will enhance the effectiveness of push-netting in the future.

Blueback herring

Decreased passage of adult blueback herring resulted in lower catches of juveniles. In 2002, the Conowingo East Lift passed only 2,100 blueback herring, while Holtwood passed only 13. This compares to a total of 284,921 and 1,300 passed by the Conowingo East Lift and Holtwood in 2001, respectively. Combined catches of juvenile blueback herring at Peach Bottom and Conowingo totaled 2 in 2002, compared to 187 in 2001. No juvenile river herring were captured by lift-net in 2002, resulting from of the absence of adult spawners upstream of Holtwood Dam.

SUMMARY

1. Juvenile American shad were successfully collected only by lift-net. For the first time since 1990, no juvenile American shad were collected by haul seine.
2. Lift-netting GM CPUE (combined daily lifts) of 0.15 was the second lowest recorded for that gear type since 1985.
3. Push-netting catches suggest poor production of blueback herring in Conowingo pool.
4. Peak out-migration, based on lift-net catches and impingement samples, occurred during the last 2 weeks of October and was associated with increased river flows and decreasing water temperature.
5. Otolith analysis determined that 22% of the juveniles collected above Conowingo Dam were of wild origin as compared to 40% observed in 2001.
6. Juvenile production in the Susquehanna River basin was poor and was influenced by decreased numbers of adult fish passed by fish passage facilities and poor hatchery performance.

ACKNOWLEDGMENTS

Normandeau Associates (Drumore, PA) were contracted by the PFBC to perform juvenile collections. Many individuals supplied information for this report. Gina Russo-Carney and Ken Woomer processed shad otoliths.

Table 1. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990-2002.

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)
1990	87	285	4.40	1.23		0	0.15	0.11
1991	144	170	1.01	0.54		80	0.48	0.35
1992	92	269	4.24	1.45		146	2.49	0.78
1993	111	218	1.90	1.22		174	1.61	1.01
1994	110	390	4.74	2.29		254	3.19	1.38
1995	48	409	8.92	7.89		58	1.29	1.06
1996	105	283	2.89	2.05		157	1.61	1.20
1997	90	879	9.77	6.77	3.36	136	1.51	1.24
1998	94	230	2.51	1.03	0.50	5	0.05	0.05
1999	90	322	3.58	1.16	0.67	13	0.15	0.13
2000	90	31	0.34	0.26	0.14	0	0	0
2001	90	377	4.19	3.04	1.52	119	1.32	1.25
2002	84	0	0	0	0	0	0	0

Table 2. Number and percent composition of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 24 September through 8 December 2

Date:	24 Sep	27 Sep	30 Sep	03 Oct	06 Oct	09 Oct	12 Oct	15 Oct	18 Oct	21 Oct	24 Oct	27 Oct	30 Oct	02 Nov	05 Nov	08 Nov
Water Temp (°C):	23.0	22.5	21.0	21.0	21.0	20.5	19.0	15.0	13.5	12.5	12.0	11.5	10.0	7.5	7.0	8.0
Secchi (in):	40	25	35	35	32	32	26	31	28	34	34	36	31	50	54	52
River Flow (cfs):	5,920	11,150	21,300	17,400	10,200	7,520	17,800	32,400	58,200	36,600	24,300	23,600	33,350	33,700	24,600	24,500
Start Time (hr):	1840	1847	1839	1838	1845	1821	1811	1830	1756	1745	1742	1630	1633	1630	1621	1651
End Time (hr):	1942	2006	2009	1956	2009	1951	1945	1949	1924	1925	1915	1815	1755	1755	1729	1837
American shad	-	-	-	-	-	-	-	1	33	33	-	1	-	-	-	-
Alewife	-	-	-	-	-	-	-	-	3	3	1	1	-	-	-	-
Gizzard shad	1,725	1,014	662	399	284	464	246	1,979	1,327	555	28	1	11	-	-	-
Comely shiner	-	-	26	-	-	-	-	25	-	-	6	-	-	-	-	-
Spottail shiner	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Spotfin shiner	164	43	12	32	112	-	-	-	73	85	39	7	2	5	1	27
Bluntnose minnow	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Banded killifish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Channel catfish	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-
Redbreast sunfish	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	9	2	-	-	-	1	38	9	2	-	1	1	1	-
Largemouth bass	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
Total	1,889	1,057	711	433	397	464	246	2,006	1,475	685	79	10	14	6	2	29
No. of Species	2	2	6	3	3	1	1	4	6	5	6	4	3	2	2	

Table 2. Continued.

Date:	11 Nov	14 Nov	17 Nov	20 Nov	23 Nov	26 Nov	29 Nov	02 Dec	05 Dec	08 Dec		
Water Temp (°C):	9.5	11.0	9.0	8.0	7.0	6.5	4.0	3.5	1.0	0.5		
Secchi (in):	55	48	39	25	25	54	58	55	70	76		
River Flow (cfs):	23,900	33,400	36,200	76,400	54,000	52,600	41,100	32,800	26,600	19,300		
Start Time (hr):	1641	1623	1623	1611	1607	1554	1602	1558	1607	1555		
End Time (hr):	1754	1751	1723	1722	1725	1713	1713	1714	1716	1714	TOTAL	%
American shad	-	-	-	-	-	-	-	-	-	-	68	0.7
Alewife	-	-	-	-	-	-	-	-	-	-	8	0.1
Gizzard shad	-	18	6	87	-	1	-	-	-	-	8,807	90.7
Comely shiner	-	1	-	6	-	-	-	-	-	-	64	0.7
Spottail shiner	-	-	-	-	-	-	-	-	-	-	2	0.0
Spotfin shiner	15	38	2	25	-	-	-	-	-	-	682	7.0
Bluntnose minnow	1	1	-	-	-	-	-	-	-	-	3	0.0
Banded killifish	-	1	-	-	-	-	-	-	-	-	1	0.0
Channel catfish	-	-	-	-	-	-	-	-	-	-	2	0.0
Redbreast sunfish	-	-	-	-	-	-	-	-	-	-	1	0.0
Bluegill	-	1	2	3	-	-	-	-	-	-	70	0.7
Largemouth bass	-	-	-	-	-	-	-	-	-	-	3	0.0
Total	16	60	10	121	0	1	0	0	0	0	9,711	100.0

Table 3. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2002.

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)	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	286	556	0.86	0.43		**	**		35
1990	290	3,988	13.75	3.67		70	0.24	0.18	72
1991	370	208	0.56	0.39		19	0.05	0.05	71
1992	250	39	0.16	0.12		14	0.06	0.05	43
1993	250	1,095	4.38	1.20		669	2.79	0.86	56
1994	250	206	0.82	0.48		35	0.15	0.13	71
1995	115	1,048	9.11	1.26		83	0.72	0.32	34
1997	300	1,372	4.57	0.88	0.61	100	0.33	0.23	46
1998	300	180	0.60	0.37	0.22	9	0.03	0.03	67
1999	300	490	1.63	0.78	0.50	19	0.06	0.07	40
2000	300	406	1.35	0.61	0.18	4	0.01	0.01	43
2001	299	1,245	4.18	1.37	0.43	538	1.81	0.45	73
2002	220	68	0.31	0.15	0.09	15	0.07	0.05	13

* Required by ASMFC

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

Table 4. Number of fish collected during intake screen sampling by unit at Peach Bottom Atomic Power Station, Fall, 2002.

Species	Unit 2	Unit 3	Total
American shad	13	5	18
Blueback herring	2	0	2
Alewife	3	2	5
Gizzard shad	72,630	871,749	944,379
Common carp	4	2	6
Golden shiner	2	0	2
Comely shiner	3	9	12
Bluntnose minnow	1	8	9
Spotfin shiner	5	6	11
Spottail shiner	0	1	1
Quillback	1	3	4
White catfish	0	1	1
Yellow bullhead	0	1	1
Channel catfish	41	88	129
Rock bass	7	14	21
Redbreast sunfish	15	20	35
Green sunfish	22	25	47
Pumpkinseed	5	16	21
Bluegill	1,690	9,673	11,363
Smallmouth bass	20	25	45
Largemouth bass	1	8	9
White crappie	1	3	4
Black crappie	0	1	1
Yellow perch	4	20	24
TOTAL	*74,470*	*881,680*	*956,150*

Table 5. Number of juvenile American shad collected during intake screen sampling by unit at Peach Bottom Atomic Power Station, Fall, 2002.

Date	Unit 2	Unit 3	Total
18 Oct	4	1	5
23 Oct	2	1	3
28 Oct	0	1	1
30 Oct	4	1	5
01 Nov	2	1	3
06 Nov	1	0	1
TOTAL	*13*	*5*	*18*

Table 6. Species and number of fish collected during cooling water intake sampling at Conowingo Dam, Fall, 2002.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	3	3	6
Alewife	1	3	4
Gizzard shad	6,553	8,899	15,452
Comely shiner	15	24	39
Spotfin shiner	12	31	43
Quillback	1	0	1
Channel catfish	2	0	2
Redbreast sunfish	0	2	2
Green sunfish	1	0	1
Bluegill	19	60	79
Yellow Perch	2	0	2
TOTAL	*6,609*	*9,022*	*15,631*

Table 7. Catch, effort, and catch-per-unit-of-effort of juvenile American shad by location from the upper Chesapeake Bay during the 2002 Maryland DNR Juvenile Finfish Haul Seine Survey.

LOCATION	ROUND 1		ROUND 2		ROUND 3		TOTALS		
	Catch	#Hauls	Catch	#Hauls	Catch	#Hauls	Catch	#Hauls	CPUE
A. Permanent Sites									
Howell Pt.	0	2	0	2	0	2	0	6	0.0
Worton Cr.	0	2	0	2	0	2	0	6	0.0
Ordinary Pt.	0	2	0	2	0	2	0	6	0.0
Parlor Pt.	0	2	0	2	0	2	0	6	0.0
Elk Neck Pk.	4	2	0	2	4	2	8	6	1.3
Welch Pt.	5	2	18	2	8	2	31	6	5.2
Hyland Pt.	0	2	0	2	0	2	0	6	0.0
TOTALS	9	14	18	14	12	14	39	42	
CPUE	0.64		1.29		0.86		0.93		
B. Auxiliary Sites									
Carpenter Pt.	0	1	0	1	0	1	0	3	0.0
Plum Pt.	0	1	5	1	0	1	5	3	1.7
Spoil Is.	0	1	0	1	0	1	0	3	0.0
Tydings Est.	0	1	4	1	1	1	5	3	1.7
Tolchester	0	1	0	1	0	1	0	3	0.0
TOTALS	0	5	9	5	1	5	10	15	
CPUE	0.00		1.80		0.20		0.67		
C. Grand Totals	9	19	27	19	13	19	49	57	
CPUE	0.47		1.42		0.68		0.86		

Table 8. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2002.

Collection Site	Coll. Date	Immersion marks: Day 3 — Jun. R./ Susq. R.	Days 3,6,9 — Jun. R./ Susq. R.*	Days 3,6, 12,15 — Conodo- guinet Cr.	Days 3,6, 9,15 — W. Cone- wago Cr.	Days 3,6,9, 15,18 — Swat- ara Cr.	Days 3,9, 12,15 — Conest- oga Cr.	Days 3,9,12 — W. Br. Sus. R.	Days 3,6,12, 15,18 — N. Br. Sus. R.(PA)	Days 3,6,9 12,18 — N. Br. Sus. R.(NY)	Days 3,12,15 — Chemung	Hatchery Total	Wild	Total Processe	Total Collected
Holtwood	10/15/02	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1	1
	10/18/02	11.34	2.06	0.00	0.00	0.00	0.00	1.03	0.00	3.09	6.19	23.72	9.28	32	33
	10/21/02	11.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	9.00	27.00	6.00	33	33
	10/27/02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	1	1
Peach Bottom	10/18/02	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.00	5.00	0.00	5	5
Impingement	10/23/02	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	3.00	0.00	3	3
	10/28/02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1	1
	10/30/02	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	3.00	2.00	5	5
	11/1/2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	2.00	0.00	1	2
Conowingo	10/21/02	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	2	2
Strainers	10/25/02	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	2	2
Holt./P. Bot./Con.		29.34	8.06	0.00	0.00	0.00	0.00	1.03	0.00	10.09	20.19	68.72	19.28	86	88
Percent		33.3%	9.2%	0.0%	0.0%	0.0%	0.0%	1.2%	0.0%	11.5%	22.9%	78.1%	0.22		

*Susquehanna River source eggs

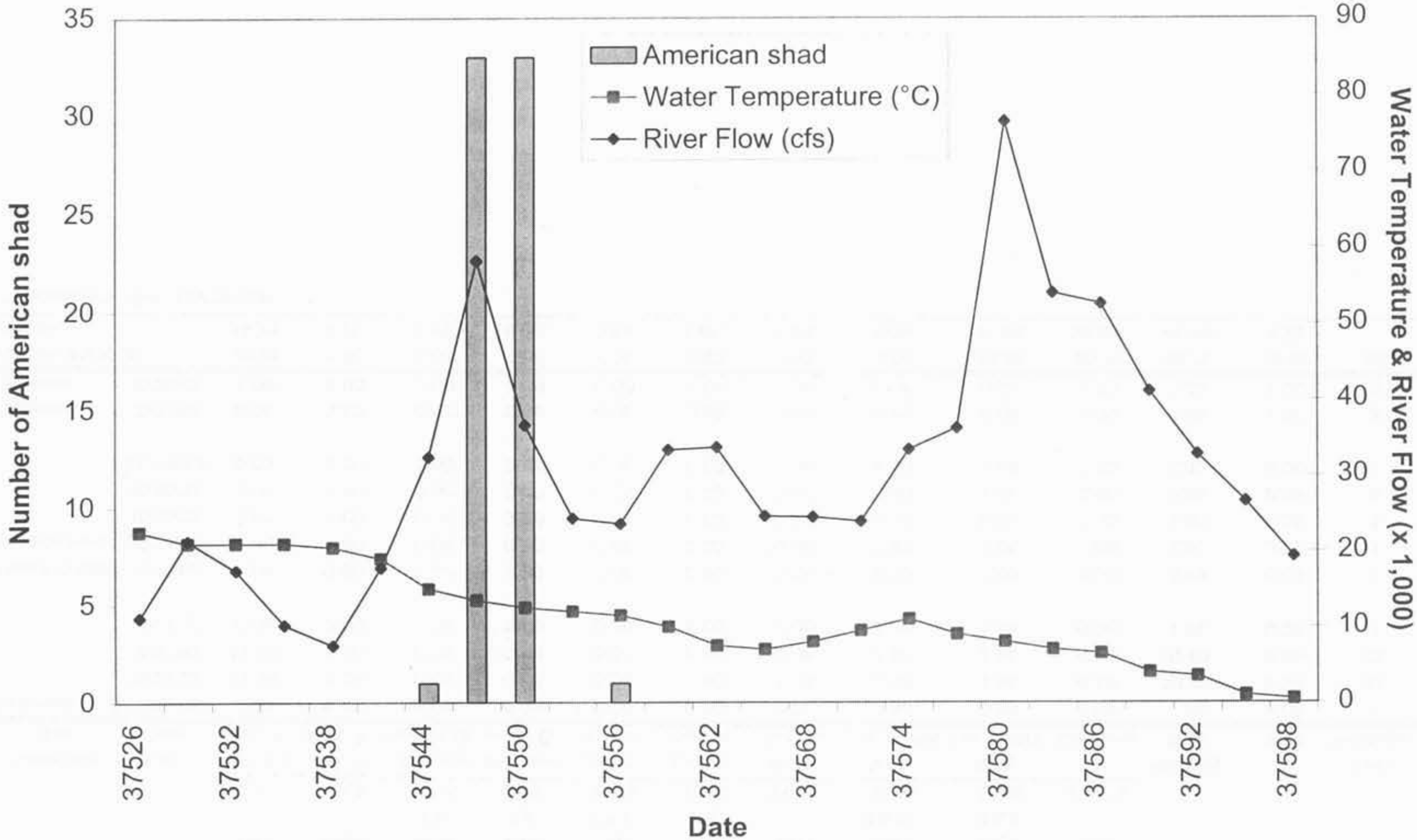

Figure 1. A plot of water temperature (°C) and river flow (cfs, x 1,000) in relation to the lift net catch of juvenile American shad from the inner forebay of Holtwood Power Station, September - December, 2002.

Job V - Task 1
MONITORING FOR THE PRESENCE OF ADULT ALOSIDS AT THE BASE OF SELECTED DAMS AND TRIBUTARIES IN THE SUSQUEHANNA BASIN

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INTRODUCTION

The Susquehanna River anadromous fish restoration effort has undertaken various activities in an attempt restore migratory alosids to the Susquehanna River Basin. Cornerstones of this effort have been the development of fish passage facilities at the lower Susquehanna hydroelectric projects, stock restoration through the culture and stocking of hatchery reared American shad fry, and the transport and stocking of pre-spawn American shad and river herring (blueback herring and alewife) collected at Conowingo Dam West Fish Lift.

Fish passage facilities were completed at York Haven Dam in 2000, re-opening portions of the upper Susquehanna and tributaries to spawning runs of migratory fishes. Completion of a fishway at the Sunbury Fabri-dam in 2004 will re-open habitat in the North Branch of the Susquehanna to New York and the West Branch of the Susquehanna to Lock Haven, Pennsylvania. Utilization of newly accessible spawning habitat is essential if target restoration goals of three million adult American shad and 15 million river herring above Conowingo Dam are going to be reached. Since 1995, the Pennsylvania Fish and Boat Commission (PFBC) has stocked uniquely marked shad fry in an attempt to establish sub-populations imprinted to specific tributaries. It is hoped that these stockings will expand the distribution of alosids beyond the main stem Susquehanna and Juniata Rivers while hastening overall stock restoration in the basin.

This study was designed to monitor the distribution and abundance of adult alosids within the Susquehanna River Basin. In 1999, the study focused on sampling selected tributaries that were accessible to adult alosids downstream of York Haven Dam. This included Muddy Creek and West Conewago Creek in York County, and Fishing Creek, Peters Creek, Little Conestoga Creek, and the Conestoga River in Lancaster County. The number of tributaries sampled was expanded in 2000 to include those accessible to adult alosids with the completion of fish passage facilities at York Haven Dam. These included Conodoguinet Creek in Cumberland County, and Swatara Creek in Dauphin/Lebanon County. The main stem Susquehanna River was also sampled at the base of the Fabri-dam near Sunbury to assess fry stockings in the West and North branches of the Susquehanna River. Due to the lack of success at capturing adult alosids at Fishing Creek and Peters Creek, they were removed from sampling in 2001. The return of adult shad to Muddy Creek and the Conestoga River was documented in 1999-2001. These streams were not sampled in 2002 because of concerns that electrofishing may disrupt spawning behavior among American shad and river herring. Information obtained in this study provides insights on fidelity to natal waters, and allows us to prioritize blockages for fish passage, and refine restoration strategies for American shad and river herring.

METHODS

Distribution and relative abundance of adult alosids were evaluated by conducting daytime electrofishing surveys using various gear types in the Susquehanna River and selected tributaries at or near the base of the first upstream blockage to migration.

Five surveys each were conducted on West Conewago Creek and Little Conestoga Creek between 5 June and 2 July 2002. Originally, sampling was scheduled on the Susquehanna River at the base of the Fabri-Dam, Conodoguinet Creek, and Swatara Creek. However, due to the low numbers of adult alosids passed at York Haven Dam, sampling in those waters was canceled.

Otoliths from captured adult American shad were to be analyzed for tetracycline marks to determine origin (hatchery versus wild) and stocking location (for hatchery fish).

RESULTS

No adult alosids were captured in West Conewago Creek and Little Conestoga Creek during 348 and 326 minutes of electrofishing, respectively.

DISCUSSION

Extreme high flows in Spring 2002 greatly impacted fish passage efficiency at the hydroelectric facilities on the Susquehanna River. Holtwood and York Haven passed only 16.2% (17,522) and 1.4% (1,525), respectively, of the total number of American shad passed at Conowingo Dam. Virtually no river herring were passed at Holtwood. Surveys upstream of York Haven Dam were not conducted because the minimum 10,000 shad passed required to trigger sampling activities was never reached. The low numbers of alosids passed at Holtwood, high flows in May and June, and elevated water temperatures in the late season, contributed to the inability to capture alosids in West Conewago and Little Conestoga creeks. Until 2002, American shad had been documented, albeit few in number, in West Conewago Creek every year since the onset of sampling in 1999. Passage efficiency at Holtwood and York Haven must improve if upper basin restoration goals are going to be achieved.

Job V., Task 2. Analysis of adult American shad otoliths, 2002

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Abstract

A total of 182 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2002. Based on tetracycline marking 34% of the 182 readable otoliths were identified as wild and 66% were identified as hatchery in origin. Double marked fish (released below Conowingo Dam) represented 1.7% of the marked fish in the Conowingo West Lift samples.

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 1986-1996 year classes, stocking of approximately 212 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 133 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.64 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1996 year class is not fully recruited. 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 first planted below Conowingo Dam in 1986.

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. This report presents results of evaluation of otoliths from adult American shad collected in 2002.

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad to enter the West lift. 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 and one otolith was mounted for mark analysis in Permount® on a microscope slide, while the other was mounted for ageing on clear tape in two part rod-building epoxy.

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

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

Historical fish lift catch data was compiled from SRAFRC Annual Progress

Reports for the years 1972 through 2002. Age composition data was gathered as follows: for 1996 to 2002, age composition data was collected from the aforementioned otolith analysis. For 1991-1995, age composition data was 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 finglerlings 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 182 shad was sacrificed for otolith analysis from the West Lift catch at Conowingo Dam in 2002. No samples were collected from the East Lift since it was operated in fish passage mode. There were no lost, broken, or unreadable otoliths (Table 1). A total of 62 (34%) otoliths exhibited wild microstructure and no tetracycline mark. One hundred and twenty (66%) exhibited tetracycline marks including single, double, triple, quadruple, and quintuple immersion marks. No specimens exhibited feed 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 1989-2002 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish have shown an increasing trend since 1993 (Figure 2).

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 3). Overall mean age was 4.4 years for males and 5.5 years for females. For wild fish, mean ages were 4.5 for males and 5.6 for females (Table 4). For hatchery fish, mean age was 4.5 for males and 5.5 for females. Overall sex ratio was 0.67 to 1, males to females. Length frequencies and mean length at age are tabulated in Tables 5 to 8. As expected, females were larger than males. Age and length distributions were similar for wild and hatchery fish.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 9. 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 1995 are not fully recruited and are not included in the analysis. For the period 1986-1996, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 164 to 620, with an overall value of 212 (Table 10). This is a maximum estimate since the 1996 year class is not fully recruited. L/A was highest (431-620) for the early cohorts (1986 – 1989). During 1990 to 1996, L/A improved to 64-289, presumably due to improvements in fish culture practices. L/A will continue to decrease since L/A for the 1997 cohort is already below the overall L/A.

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 11). For the period 1986-1996, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 40 to 386, with an overall value of 133. Again, this is a maximum estimate since the 1996 year class is not fully recruited. 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. 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 aging, and highlights the problems with aging American shad.

A similar analysis was tabulated for wild fish (Table 12). For the period 1986 to 1995, transport of an average of 0.64 adults was required to produce one returning adult, above 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.

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

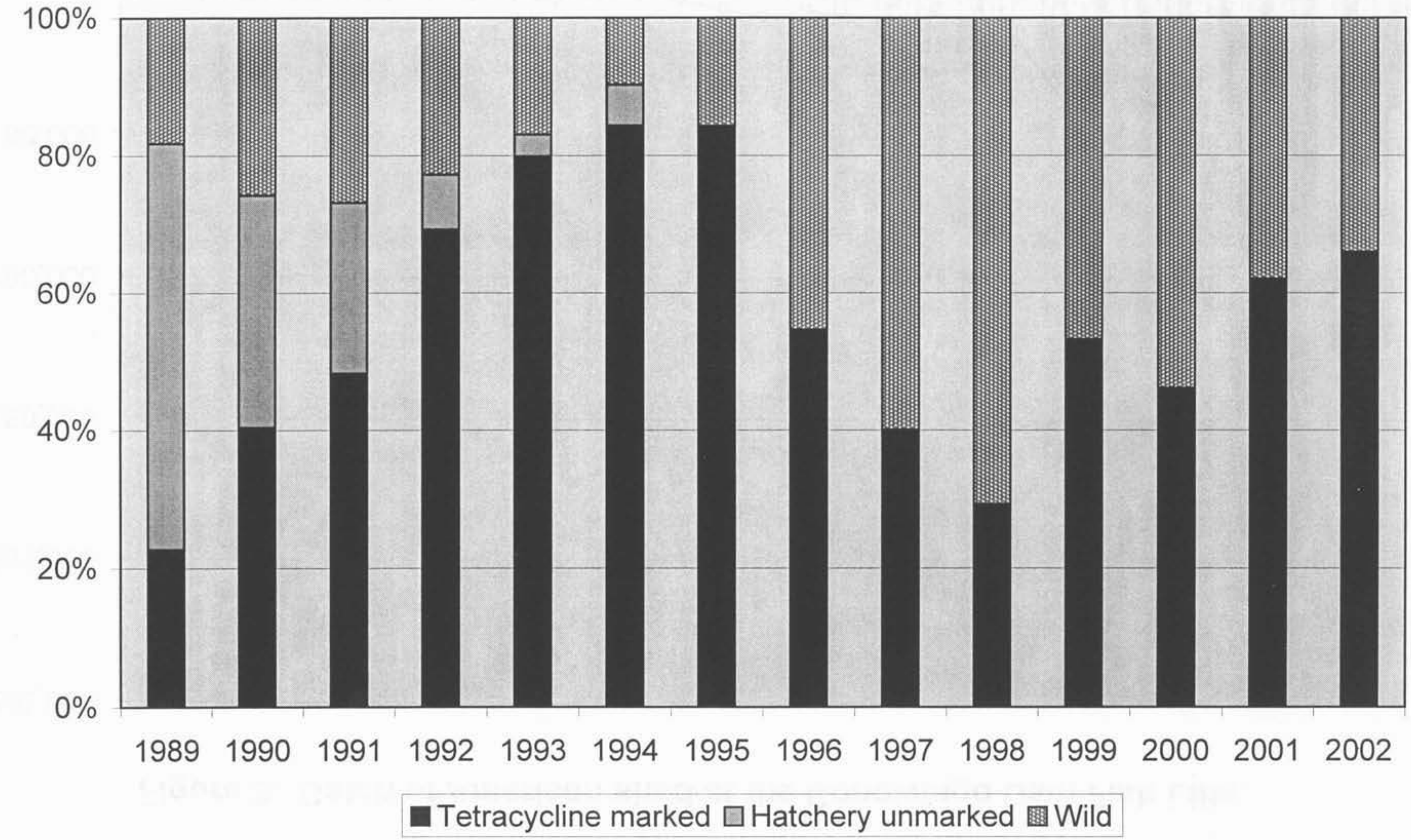

Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

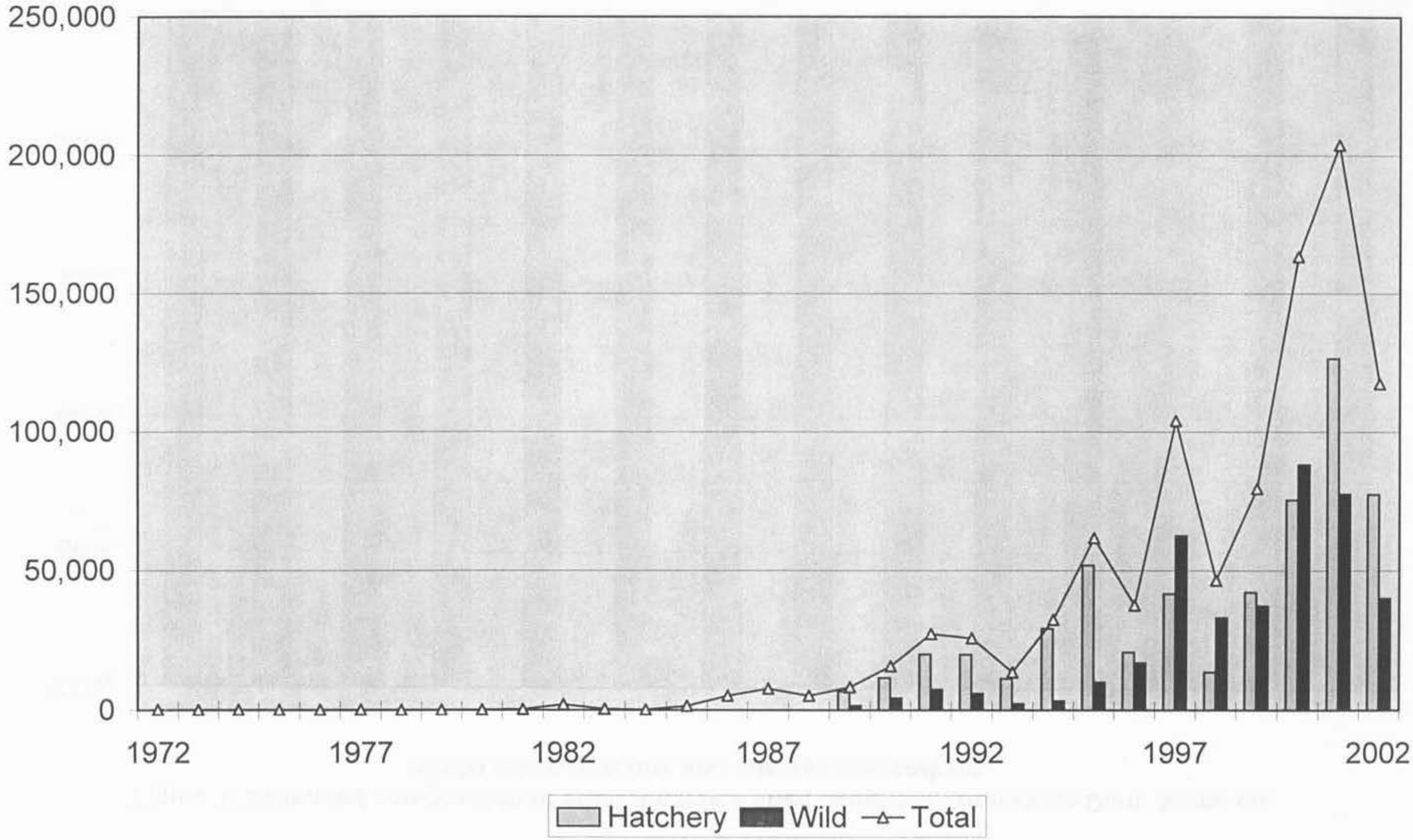

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2002.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

Conowingo Dam		N	%
Wild Microstructure, No TC Mark		62	34%
Hatchery Microstructure			
No TC Mark*			0%
Single TC Mark	Day 3 or 5	87	48%
Double TC Mark	Days 5,9, 3,6 or 3,7	2	1%
	Days 3,17		0%
	Days 6,12		0%
Triple TC Mark	Days 3,6,9	3	2%
	Days 5,9,13	1	1%
	Days 3,13,17	13	7%
	Days 3,9,12	3	2%
	Days 9,12,15	4	2%
	Days 11,14,17 or 12,15,18	2	1%
Quadruple TC Mark	Days 3,13,17,21	2	1%
	Days 3,9,12,15	1	1%
	Days 5,9,13,17 or 3,6,9,12	1	1%
	Days 5,9,13,21		0%
Quintuple TC Mark	Days 3,6,12,15,18	1	1%
	Total Hatchery	120	66%
	Total readable otoliths	182	
	Unreadable Otoliths**	0	
	Total	182	
Other sites			
Conowingo Pool	Day 3 or 5	1	

*Includes otoliths in which autofluoresence may obscure mark and poor grinds.
**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
Totals		1,597	60	151	6	25	1	241	1,031	34	3,045

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

Table 3. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2002.

Age	2	3	4	5	6	7	8	9	??	Totals	Mean
Male		16	15	31	9	2		1	1	75	4.5
Female			13	43	42	9	3		2	112	5.5
Unknown										0	
Totals	0	16	28	74	51	11	3	1	3	187	5.1

Table 4. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2002.

Age	2	3	4	5	6	7	8	9	??	Totals	Mean
Male- Wild		6	3	7	3					19	4.4
Male- Hatc.		10	12	24	6	2		1	1	56	4.5
Female- Wild			5	14	18	4	1		1	43	5.6
Female- Hatc.			8	29	24	5	2		1	69	5.5
Totals	0	16	28	74	51	11	3	1	3	187	5.1

Table 5. Length frequency (mm, FL) by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2002.

Sex	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	Total
Male	2	13	4	14	23	12	7				75
Female				1	9	28	47	21	5	1	112
Unknown											0
Totals	2	13	4	15	32	40	54	21	5	1	187

Table 6. Length frequency (mm, FL) by sex and origin of adult American shad sacrificed for otolith a
Conowingo West Fish Lift, 2002.

Sex	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	Total
Male- Wild	1	4	1	3	18	2	3				32
Male- Hatc.	1	9	3	11	5	10	4				43
Female- Wild					3	11	19	9	1		43
Female- Hatc.				1	6	17	28	12	4	1	69
Totals	2	13	4	15	32	40	54	21	5	1	187

Table 7. Mean fork length (mm) at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2002.

Sex	Age 3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)	9	(n)
Male	371	(16)	416	(15)	438	(31)	465	(9	450	(2)			482	(1)
Female			470	(13)	484	(43)	488	(42)	509	(9)	510	(3)		

Table 8. Mean fork length (mm) at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2002.

Sex	Age 3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)	9	(n)
Male- Wild	369	(6)	406	(3)	451	(7)	469	(3)					482	(1)
Male- Hatc.	371	(10)	418	(12)	434	(24)	463	(6)	450	(2)				
Female- Wild			468	(5)	485	(14)	481	18)	503	(4)	512	(1)		
Female- Hatc.			472	(8)	483	(29)	493	(24)	514	(5)	508	(2)		

Table 9. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-2002.

										Hatchery Release Site			Wild
										Above Dams		Below Dams	
	Fish lift	% Age composition								larvae	fingerlings		
Year	catch	9	8	7	6	5	4	3	2	%	%	%	%
1988	5,146	0.0	0.0	4.0	31.7	38.1	21.2	4.7	0.4	71% *		6% *	23%
1989	8,218	0.0	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719	0.0	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%		1%	26%
1991	27,227	0.0	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	2%	5%	27%
1992	25,721	0.0	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	1%	4%	23%
1993	13,546	0.0	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	2%	18%	17%
1994	32,330	0.0	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	1%	8%	10%
1995	61,650	0.0	0.0	3.2	12.4	51.9	28.5	4.0	0.0	77%	1%	6%	16%
1996	37,513	0.0	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%	1%	6%	45%
1997	103,945	0.0	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%	2%	5%	60%
1998	46,481	0.0	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370	0.0	0.5	1.1	8.1	33.5	46.5	10.3	0.0	48%	1%	5%	47%
2000	163,331	0.0	0.0	1.0	9.9	27.6	51.0	10.4	0.0	40%	0%	6%	54%
2001	203,776	0.0	0.0	2.0	21.4	50.5	24.0	2.0	0.0	56%	0%	4%	38%
2002	117,348	0.5	1.6	6.0	27.7	40.2	15.2	8.7	0.0	65%	0%	1%	34%

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

Table 10. Recruitment of hatchery larvae, stocked above dams, to the Conowingo Fish Lifts, 1986- 1996.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
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
2002								413	1,240	4,548	21,088	30,599
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,963	15,830	26,225	35,945	65,458	116,580	64,961
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
Number of larvae to return 1 adult:	620	431	445	591	172	289	192	249	179	153	64	123
Overall number of larvae to return 1 adult (1986-1996):				212								

Table 11. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 1996.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
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
2001								0	0	0	0	0
2002								0	0	0	0	0
Total recruits to lifts:	285	211	262	350	524	560	548	1,153	845	225	43	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
Number of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	165	0	0	

Overall number of fingerlings to return 1 adult (1986-1995): 133

Table 12. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986- 1996.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
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
2001								0	1,580	16,585	39,093	18,559
2002								217	652	2,390	11,080	16,077
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,822	21,400	49,169	52,026	61,812	98,912	43,804
Adults transported/1000:	4.17	7.20	4.74	6.47	15.08	24.66	15.67	11.72	28.68	56.37	33.83	103.95
No. 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	0.34	2.37

Overall number of adults transported to return 1 adult (1986-1995): 0.64

JOB V, Task 3
EFFECTS OF HORMONE IMPLANT USE IN MALES, STOCKING DENSITY, AND MALE TO FEMALE RATIO UPON TANK SPAWNING PERFORMANCE OF AMERICAN SHAD

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Background

In 1998, the Northeast Fishery Center (NEFC) began a cooperative effort to develop and conduct tank spawning technology with American shad. Annual goals were to refine tank spawning methodology, to provide 5 to 10 million fertilized shad eggs for Pennsylvania Fish and Boat Commission's Van Dyke Shad Hatchery, and to stock one to two million oxytetracycline (OTC) marked fry in the West Branch drainage of the Susquehanna River.

Tank spawning technology development at the Northeast Fishery Center (NEFC), as reported by Fletcher and Millard (2002), determined that American shad captured at Conowingo Dam and transported to NEFC for spawning are subject to a series of stressors which impact survival and reproduction. Hormone implanted American shad stocked at a male to female ratio of 1.5 to 1 in the NEFC tank spawning system, survived and produced a program-sufficient number of eggs (>24,000) per female when water quality was maintained at 3 ppt salinity, 18.3° C, and 8.0 mg/L dissolved oxygen. Trials designed to evaluate egg production per female relative to hormone type and carrier - (Luteinizing Hormone-Releasing Hormone analogue (LHRHa) encapsulated in ethyl vinyl acetate copolymer (EVAC); and LHRHa and Salmon Gonadotropin Releasing Hormone analogue (SGnRHa) supplied in cholesterol, cellulose carrier)

- showed no difference in total numbers of eggs produced. Fletcher and Millard (2002) also determined that 86 % of the total numbers of eggs spawned and 92 % of all viable eggs were released in a primary pulse within four days of hormone implant. Tank spawn egg viability in 2001 was unacceptably low and ranged between 19 % at the NEFC to 33 % at Conowingo Dam where shad were not subjected to transport. At Conowingo, similar hormone implant techniques were used, and ambient flow through water was employed. In-river strip-spawning of naturally gravid AMS has also demonstrated high variance in egg viability, for example 77 % in Hudson River eggs *vs* 21% egg viability from Delaware River efforts (personal communication, Mike Hendricks, PFBC, 2001).

Although it has been observed that upon capture milt may be readily expressed from male American shad and that some female shad appear to be close to spawning, attempts to obtain reproduction in the absence of hormone implants have yielded no production at the NEFC. This differs from results obtained at Waldoboro Shad Hatchery in Maine (personnel communication, Sam Chapman, 2001) where successful spawning is accomplished without hormone implants. In 2000, a trial was conducted at the NEFC to determine whether the use of hormone implants are required for effective tank spawning in male American shad (Fletcher 2001). Although statistical analysis did not reveal a treatment difference, the results were influenced by relatively poor brood stock survival in the initial portion of the study which was improved by modifying the culture system from freshwater to 3 ppt salinity.

Previous spawning trials conducted at the NEFC have set the target male to female stocking ratio at - 1.5 : 1 - which differs from the tank spawning ratio of - 2:1- utilized by Manning Hatchery of the Maryland Department of Natural Resources for tank spawning (Richardson and Minkkinen 1996).

A variety of stocking rates have been employed in trials conducted at the NEFC since 1998; however, broodstock spawning density has not been evaluated.

Objectives

The present study examines effects of three variables upon egg production and viability by:

(1) Determining the effect of SGnRHa implant use in male shad (with *vs.* without) as measured by egg viability and number of eggs produced per available female.

(2) Determining the effect of brood stock density in spawning tanks as measured by egg viability and number of eggs produced per available female.

(3) Determining the effect of stocking ratios of male to female American shad as measured by egg viability and number of eggs produced per available female.

Methods

Normandeau Associates Inc. of Drumore, PA collected American shad at the West Lift of the Conowingo Dam and held the shad overnight in circular 2.5 m diameter flow through tanks. Broodstock were transported for five hours to Lamar, PA in a 3,800 L circular tank equipped with pumped flow and water conditioned to 5 ppt salinity. Twelve deliveries of approximately 100 AMS each were received at NEFC between April 22 and June 5, 2002. The shad tank spawning system employed water recirculation, heat exchange, packed column, oxygen injection, ultraviolet light treatment, and sodium chloride supplementation, and received a constant inflow of makeup water to achieve an exchange rate of approximately once per day. Nominal system operating parameters were: 3 ppt salinity, 18.3 °C and 8.0 mg/l dissolved oxygen. The experimental design for American shad male hormone use, broodstock ratio, and stocking density trials conducted in 2002 is detailed in Table 1. For each shipping date AMS were split equally between two spawning tanks at the NEFC and processed as follows:

(1) Upon arrival, all female AMS received a cholesterol based implant containing 150 ug SGnRHa - Ovaplant ® S 150 Syndel Laboratories Ltd., into the dorsal musculature. Males for only one of the two tanks received implants.

(2) American shad from a particular shipment were placed into either two 5,200 L (3.1 m diameter) or two 11,200 L (3.7 m diameter) circular tanks to provide stocking densities of about 1 AMS per 104 L or 1 AMS per 224 L respectively.

(3) Two brood stock sex ratios were evaluated: Shipments numbers 1, 2, 5, 6, 9, and 10 supplied a 2.5 : 1 ratio (~ 72 males and 28 females); and deliveries 3, 4, 7, 8, 11, and 12 provided a 1.5 : 1 ratio (~ 60 males and 40 females).

Daily records of broodstock mortality, egg production, water temperature, salinity, and oxygen levels were maintained. Experimental egg production data was derived from primary pulses which occurred typically 2 to 3 days post-implant. Reproduction was evaluated in terms of total eggs and number of viable eggs produced per female. Eggs were removed daily from saran collection socks. Primary egg production from shipments 1-8 and 10-12 were placed in oxygenated bags and transported in coolers to the Van Dyke Shad Hatchery for production. Eggs from shipment nine were reared at the NEFC. Eggs were disinfected with 50 mg/L active ingredient iodophor for 10 minutes, enumerated via Von Bauer count and viability was evaluated at the receiving facility. Spawning data was evaluated by factorial analysis of variance. Data from shipments one and two were excluded from the analysis since eggs were not partitioned in shipments to Van Dyke Shad Hatchery to allow determination of egg viability.

Results

Overall broodstock survival to release of primary spawning pulse was 97.2 % for females and 99.8 % for males. There was no apparent pattern to the mortalities.

***A. Male hormone implant efficiency*:**

Mean egg production (SD) per female at 24,860 (1,562) eggs and mean number of viable eggs per female at 3,306 (1,496) eggs in tanks where males were implanted with SGnRHa was greater ($P < 0.05$) than production from non-treated male tanks at 13,948 (2,242) and 354 (158) eggs respectively (Figures 1 and 2). The resultant percentage of viable eggs obtained from both treatments is lower at 13 % and 3 % than the overall viability result of 19 % from trials in 2001.

***B. Stocking density*:**

American shad stocked at equal numbers into 3.1 m and 3.7 m circular tanks provided spawning densities of 1 AMS per 104 L and 1 AMS per 217 L. These treatments did not produce statistically different total numbers of eggs per female ($P = 0.3041$, Fig. 3.). Mean total egg production per female (SD) was 21,675 (2,063) in the 3.1 m high density tank rate and 18,813 (2,906) in the 3.7 m low density tank rate. The mean number of viable eggs per female (SD) at 406 (183) from the high density tank was less ($P = 0.0774$, Fig. 4) than production from the low density tank at 3,255 (1,504) with respective viability rates of 2 % and 17 %.

***C. Male to female ratio*:**

No effect upon reproductive success was determined for American shad stocking ratios of 2.5 males per female or 1.5 males per female, in terms of eggs per female or viable eggs per female, (Fig. 5 and Fig. 6). Average total egg production per female (SD) for the ratio of 2.5:1

was 20,866 (2,688) eggs and 19,830 (2,422) eggs for the ratio 1.5:1. While mean number of viable eggs per female (SD) was 2,105 (1,803) at 2.5:1 and 1,647 (697) at 1.5:1 which represents 10% and 8% viability respectively.

Additional observations

Values of total (Fig. 7) and viable eggs per female (Fig. 8), in trials measuring the effect of hormone use for male AMS graphically present outcomes obtained for separate spawning shipments. Results in particular for viable eggs on spawning dates May 12-13 and May 28-29 demonstrate variation independent of tank spawning activity treatments.

Production

Approximately 8.2 million eggs were collected from 1,224 American shad brood stock utilized in the tank spawning trials. Egg viability across all trials was 10%. Egg incubation was conducted primarily at the Van Dyke Shad Hatchery - 7.4 million eggs. An additional 0.6 million eggs were provided to Van Dyke following completion of NEFC trials. Secondary egg takes (non-primary pulse spawns) and eggs from the May 28 shipment (0.8 million) were incubated and reared at the Northeast Fishery Center. The NEFC stocked 51,350 fry into Bald Eagle Creek (West Branch Susquehanna River) with OTC marks at days 3, 9, and 12.

Summary and Conclusions

Total and viable egg production per female were significantly increased ($P \leq 0.05$) in those tanks where male American shad received Salmon Gonadotropin Releasing Hormone analogue implants. Results indicate that continued use of hormone implants for male American shad would be beneficial to tank spawning operations.

American shad stocked at rates of 1 per 104 L and 1 per 217 L did not produce statistically different total numbers of eggs per female. Greater production of viable eggs per female was observed for the lower density at an alpha level of 0.1. Evaluation of broodstock densities in future tank spawning efforts may warrant further examination.

No effect upon reproductive success was found between stocking ratios of 2.5 or 1.5 males per female, in terms of eggs per female or viable eggs per female. Production costs for hormone implants may be reduced by 29% by utilizing the stocking ratio of three males to two females *vs.* five males to two females.

The Northeast Fishery Center stocked 51,350 fry into Bald Eagle Creek, West Branch of the Susquehanna River and provided 8.0 million eggs to the Van Dyke Shad Hatchery.

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Fletcher, John and Michael Millard. 2002. Effect of hormone selection and water salinity upon tank spawning performance of American shad. Job V - Task 4. In Susquehanna River Anadromous Fish Restoration Committee. 2001. Restoration of American Shad to the Susquehanna River, Annual Progress Report. U.S. Fish and Wildlife Service, Harrisburg, Pennsylvania. Pages 5-80 to 5-89.

Richardson, Brian M. and Steven P. Minkkinen. 1996. 1995 experimental American shad (*Alosa sapidissima*) culture. Job III, Part 2. In Susquehanna River Anadromous Fish Restoration Committee. 1996. Restoration of American Shad to the Susquehanna River, Annual Progress Report. U.S. Fish and Wildlife Service, Harrisburg, Pennsylvania. Pages 3-27 to 3-34.

Table 1. Experimental layout for American shad density, broodstock ratio, and male hormone use

Shipment	1a	1 b	2 a	2 b	3 a	3 b	4 a	4 b	5 a	5 b	6 a	6 b
Density 1 (5,200 Liter)	D 1	D 1			D 1	D 1			D 1	D 1		
Density 2 (11,200 Liter)			D 2	D 2			D 2	D 2			D 2	D 2
Ratio 1 M : F 36:14	R 1	R 1	R 1	R 1					R 1	R 1	R 1	R 1
Ratio 2 M : F 30:20					R 2	R 2	R 2	R 2				
Male Gn yes	Y		Y		Y		Y		Y		Y	
Male Gn no		N		N		N		N		N		N

Shipment	7 a	7 b	8 a	8 b	9 a	9 b	10 a	10 b	11 a	11 b	12 a	12 b
Density 1 (5,200 Liter)	D 1	D 1			D 1	D 1			D 1	D 1		
Density 2 (11,200 Liter)			D 2	D 2			D 2	D 2			D 2	D 2
Ratio 1 M : F 36:14					R 1	R 1	R 1	R 1				
Ratio 2 M : F 30:20	R 2	R 2	R 2	R 2					R 2	R 2	R 2	R 2
Male Gn yes	Y		Y		Y		Y		Y		Y	
Male Gn no		N		N		N		N		N		N

Fig. 1 Effect of Hormone Use for Male American Shad upon Spawning as Measured by Eggs Produced Per Female

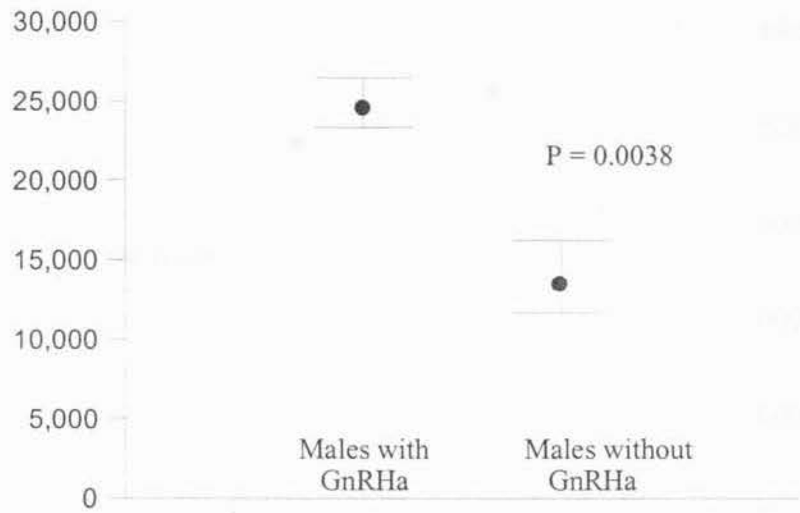


Fig. 2 Effect of Hormone Use for Male American Shad upon Spawning as Measured by Viable Eggs Produced Per Female

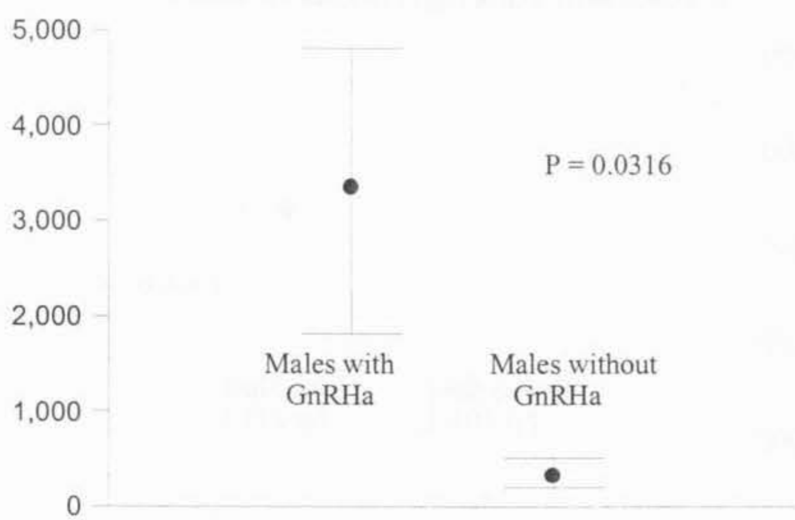


Fig. 3 Effect of Tank Stocking Density upon Spawning as Measured by Eggs Produced Per Female

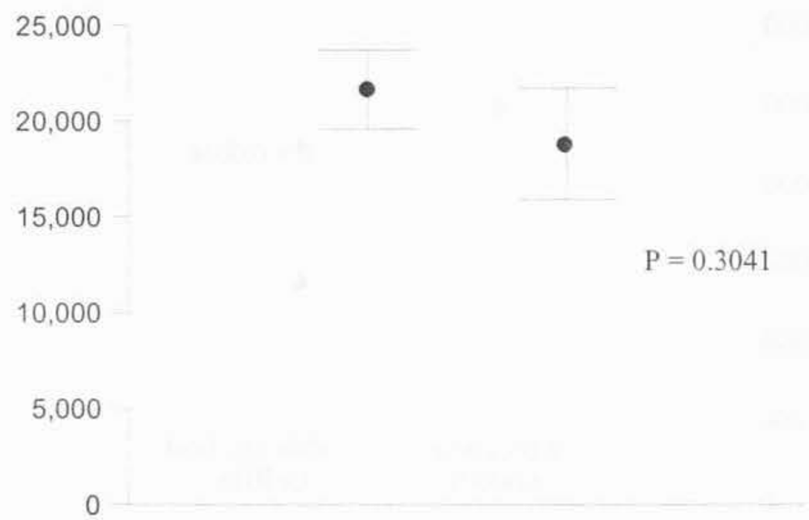
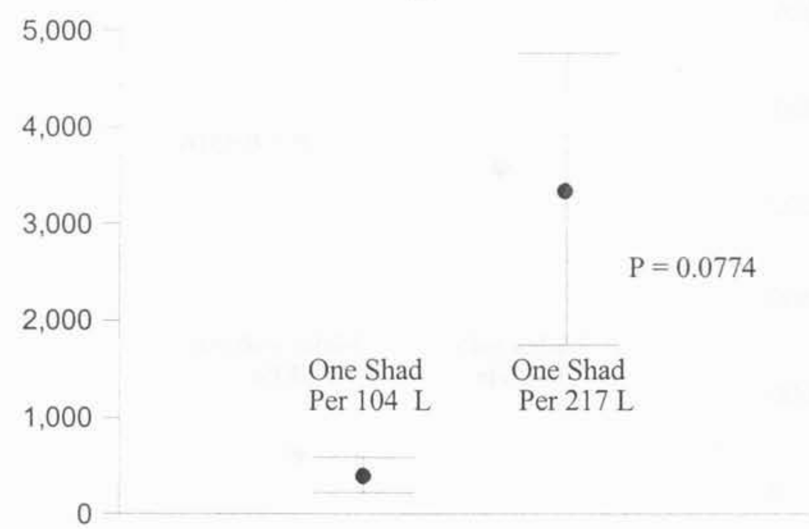


Fig. 4 Effect of Tank Stocking Density upon Spawning as Measured by Viable Eggs Produced Per Female



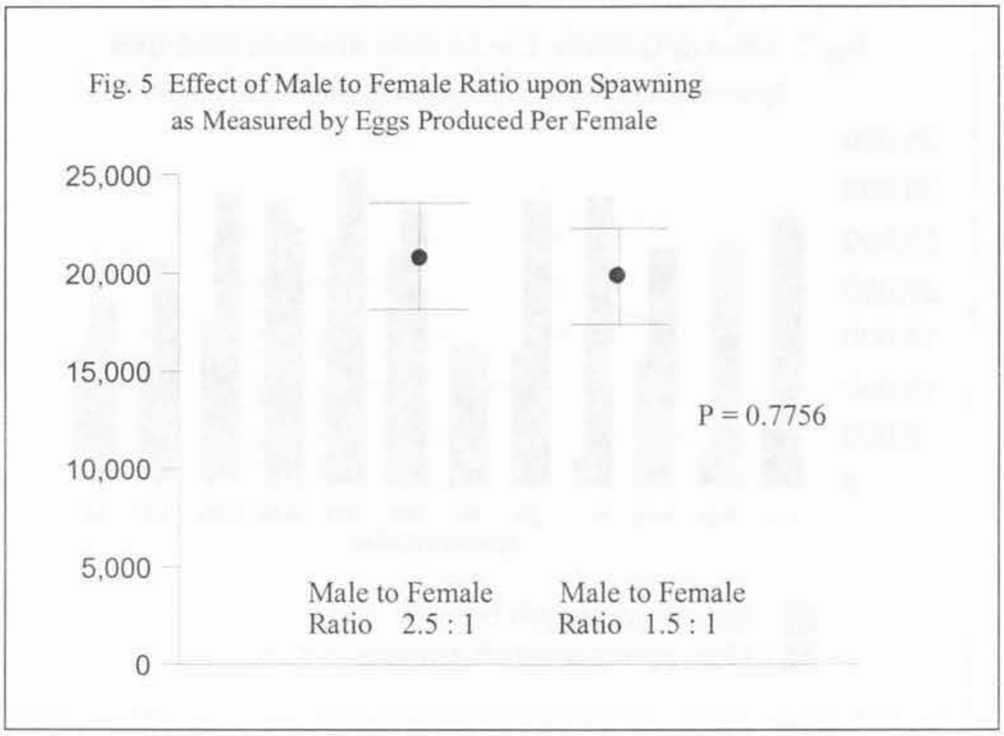


Fig. 5 Effect of Male to Female Ratio upon Spawning
as Measured by Eggs Produced Per Female
25,000
20,000
15,000
10,000
5,000
0
P = 0.7756
Male to Female
Ratio 2.5 : 1
Male to Female
Ratio 1.5 : 1

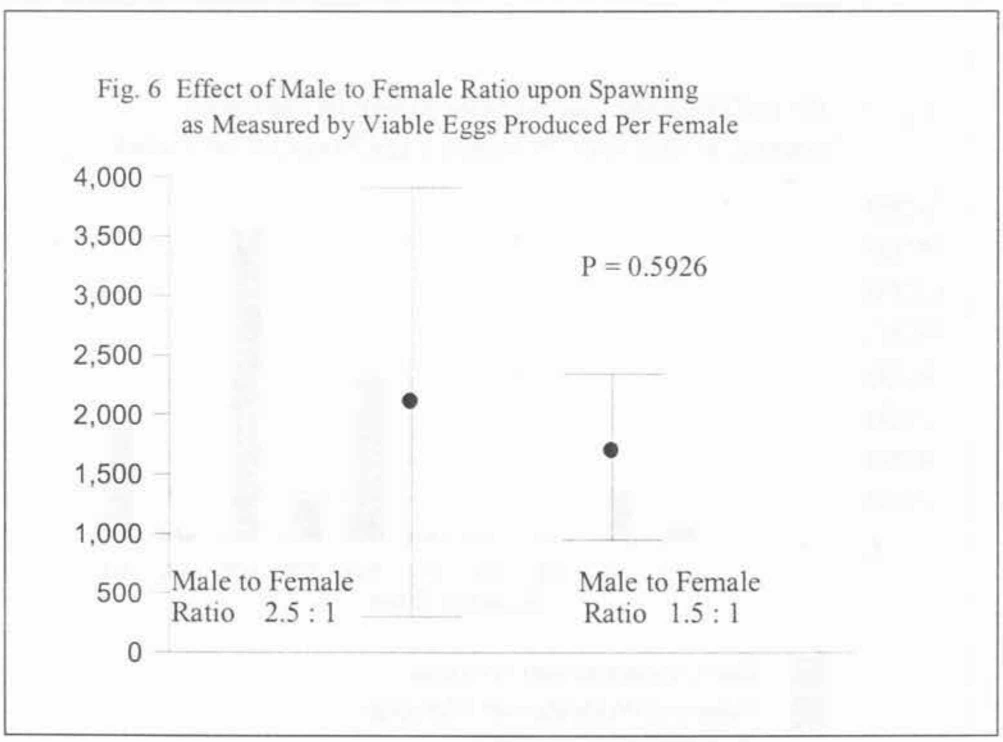


Fig. 6 Effect of Male to Female Ratio upon Spawning
as Measured by Viable Eggs Produced Per Female
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
P = 0.5926
Male to Female
Ratio 2.5 : 1
Male to Female
Ratio 1.5 : 1

Fig. 7 Effect of Hormone Use for Male American Shad upon Spawning as Measured by Eggs produced per Female

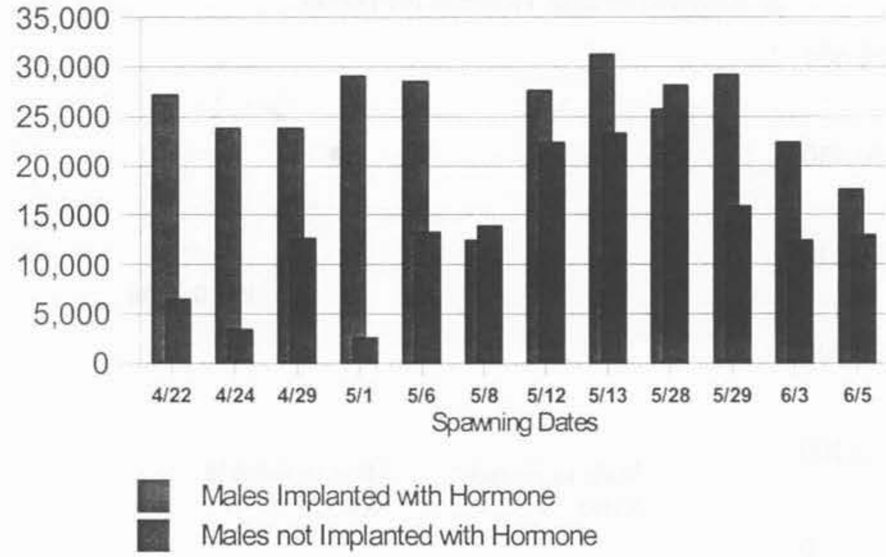
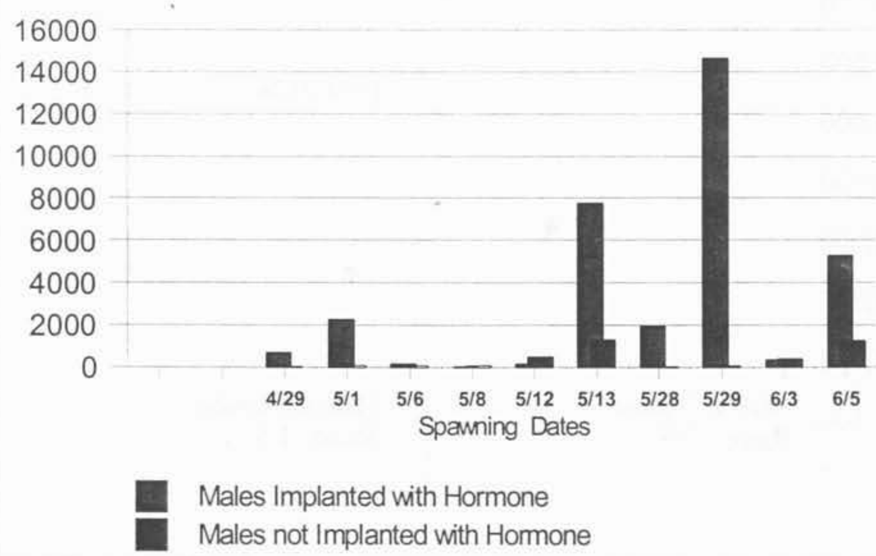


Fig. 8 Effect of Hormone Use for Male American Shad upon Spawning as Measured by Viable Eggs Produced Per Female



JOB VI. POPULATION ASSESSMENT OF AMERICAN SHAD IN THE UPPER CHESAPEAKE BAY

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301 Marine Academy Drive, Stevensville, MD 21666

Introduction

The American shad fishery in Maryland waters of the Chesapeake Bay was closed in 1980. Since then, the Maryland Department of Natural Resources (MDNR) has monitored the number of adult American shad present in the upper Chesapeake Bay during the spring spawning season. Besides providing an estimate of relative abundance of the adult spawning population, this mark-recapture effort also provides length, age, sex, and spawning history data for this stock. The information obtained through these activities is provided to the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) to aid in restoration of American shad to the Susquehanna River.

Methods and Materials

Collection procedures for adult American shad in 2002 differed from previous years as no pound nets were set in the upper Bay. Hook and line sampling in the Conowingo tailrace, however, remained unchanged from 2001 (Figure 1). Tagging procedures in 2002 were also unchanged from 2001 in that hook and line captured fish were marked with uniquely colored tags in order to differentiate between gear types, tagging locations, and fish marked in previous years. All other adult data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Results

Hook and line effort commenced on 17 April and ended 29 May. Of the 812 adult American shad angled, 780 (96%) were tagged and 166 (21%) subsequently recaptured (Table 1). Recapture data for the 2002 season is summarized as follows:

Location	Year/Tag Type #	Location	Year/Tag Type #
East Lift:	2002 h&l tags = 133	West Lift:	2002 h&l tags = 33
	2001 h&l tags = 55		2001 h&l tags = 22
	2001 pnd tags = 3		2001 pnd tags = 1
	2000 h&l tags = 4		2000 h&l tags = 1

In addition, sport anglers returned one tag from a fish marked in the tailrace during 2001 and three pound net tagged fish also marked in 2001.

Since our hook and line marking effort did not begin until 17 April and some American shad captured by the west lift were returned to the tailrace, only individuals collected by the east lift from April 17 through June 7 were used in the 2002 Petersen tailrace calculation. The R value for the Petersen statistic also does not reflect any fish marked prior to 2002 and subsequently recaptured or any tagged fish caught by sport anglers regardless of the year marked.

The 2002 adult American shad Petersen estimate for the Conowingo tailrace population was 555,597 (Table 2, Figure 2), and has been increasing exponentially since 1984 (r^2=0.90, P=<0.001). A 3% adjustment for tag loss was included in this calculation.

Prior to 1997, all 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, both total counts and numbers of tagged shad were recorded by two trained observers stationed at the east lift viewing chamber. 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.

Effort, catch, and catch-per-unit-effort (CPUE) by hook and line and the two fish lifts during 2002 and previous years (expressed as arithmetic means) is presented in Table 3. Relative abundance of American shad can also be estimated and associated trends noted by examining these annual CPUE's. Measures of relative abundance for hook and line and the Conowingo fish lifts were calculated as the geometric means (based on log e transformations) of fish caught per angling hour and fish caught per lift hour, respectively. This data was log e transformed and geometric means used in order to normalize the data.

Analysis of the CPUE estimates indicates that the catch of adult American shad has been increasing exponentially in both gear types over time: hook and line (1984-2002) $r^2 = 0.81$, $P = <0.001$; fish lifts (1980-2001) $r^2 = 0.61$, $P = <0.001$ (Figure 3). Comparisons of the CPUE estimates to the tailrace Petersen estimates for these respective years also indicates that hook and line and fish lift CPUE's were correlated with log e transformed tailrace estimates (r^2=0.87 P=<0.001, r^2=0.72 P=<0.002, respectively; Table 4). The increases in both hook and line and fish lift CPUE's over time and their associated positive correlations with the Petersen tailrace estimates continued in 2002 indicating that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay also continued in 2002.

DNR biologists subsampled 335 of the 812 American shad collected by hook and line for age and spawning history determination. A length-at-age was developed by determining the proportional age per 20 mm length groups by sex and applying that proportion to the total number at length. For 2002, males were present in age groups 3-7 while females were found in age groups 3-8 (Table 5). The 1998 year-class of males (age IV) was the most abundant age group sampled accounting for 30% of the total catch. For females, the 1996 (VI) and 1997 (V) cohorts were the most abundant age groups accounting for 29% and 28%, respectively, of the total catch. Age frequency modes occurred at age 5 for males and at age 6 for females. The overall incidence of repeat spawning in male American shad decreased from 25.6 % in 2001 to 21.5 % in 2002 while female American shad repeat spawning increased from 27.1% in 2001 to 48.0% in 2002. Since no pound net sampling occurred in 2002, no adult otoliths were collected by DNR personnel.

Table 1. Number of American shad captured and tagged by location and method of capture from the Conowingo tailrace, 2002.

Gear Type	Location	Catch	Number Tagged
Hook and Line	Conowingo Tailrace	812	780
Fish Lifts	Conowingo Tailrace	108,001 East 9,347 West	
	TOTALS	118,160	780

Table 2. Relative population estimate of adult American shad in the Conowingo tailrace during spring, 2002 using the Petersen statistic.

Chapman's Modification to the Petersen statistic -

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

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

For the 2002 survey -

C = 98,217 [note: C excludes all shad observed at Conowingo prior to tagging]
R = 133
M = 757*

Therefore -

$$N = \frac{(98{,}218 + 1)(757 + 1)}{(133 + 1)} = \mathbf{555{,}597}$$

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

Using Chapman (1951):

$$N^* = \frac{(C+1)(M+1)}{R_t + 1}$$ where R_t = tabular value (Ricker, p. 343)

$$\text{Upper } N^* = \frac{(98{,}218 + 1)(757 + 1)}{112.23 + 1} = 657{,}505 \quad @ \; .95 \text{ confidence limits}$$

$$\text{Lower } N^* = \frac{(98{,}218 + 1)(757 + 1)}{157.61 + 1} = 469{,}386 \quad @ \; .95 \text{ confidence limits}$$

* M adjusted for 3% tag loss

Table 3. Arithmetic means of catch, effort, and catch-per-unit-effort (CPUE) for adult American shad collected by hook and line (1982-2002) and fish lift (1980-2002).

A. Hook and Line

Year	Hours Fished	Total Catch	CPUE		Population Estimates	
			CPBH*	HTC**	Upper Bay	Tailrace
1982	****	88	-	-	37,551	-
1983	****	11	-	-	12,059	-
1984	52.0	126	2.42	0.41	8,074	3,516
1985	85.0	182	2.14	0.47	14,283	7,876
1986	147.5	437	2.96	0.34	22,902	18,134
1987	108.8	399	3.67	0.27	27,354	21,823
1988	43.0	256	5.95	0.17	38,386	28,714
1989	42.3	276	6.52	0.15	75,820	43,650
1990	61.8	309	5.00	0.20	123,830	59,420
1991	77.0	437	5.68	0.18	139,862	84,122
1992	62.8	383	6.10	0.16	105,255	86,416
1993	47.6	264	5.55	0.18	47,563	32,529
1994	88.5	498	5.63	0.18	129,482	94,770
1995	84.5	625	7.40	0.14	333,891	210,546
1996	44.3	446	10.10	0.10	203,216	112,217
1997	58.0	607	10.47	0.10	708,628	423,324
1998	20.3	337	16.60	0.06	487,810	314,904
1999	52.0	823	15.83	0.06	685,058	583,198
2000	44.0	730	16.59	0.06	1,357,400	957,249
2001	65.8	972	14.77	0.07	693,033	560,912
2002	60.0	812	13.53	0.07	-	555,597

* Catch-per-boat-hour

** Hours to catch one American shad

*** Hours fished not recorded

Table 3, continued.

B. Conowingo Fish Lifts (West/East)

Year	Lift	Hours Fished	Total Catch	Catch Per Lift Hour	Population Estimates Upper Bay	Tailrace
1980	W	117	139	1.18	5,531	-
1981	W	178	328	1.84	9,357	-
1982	W	336	2,039	6.07	37,551	-
1983	W	262	437	1.67	12,059	-
1984	W	192	167	0.87	8,074	3,516
1985	W	421	1,546	3.67	14,283	7,876
1986	W	449	5,195	11.57	22,902	18,134
1987	W	532	7,667	14.41	27,354	21,823
1988	W	529	5,169	9.77	38,386	28,714
1989	W	480	8,311	17.31	75,820	43,650
1990	W	617	15,964	25.87	123,830	59,420
1991	E	648	13,897	21.46		
	W	681	13,330	19.57		
	T	1,329	27,227	20.49	139,682	84,122
1992	E	732	15,386	21.02		
	W	698	10,335	14.81		
	T	1,430	25,721	17.99	105,255	86,416
1993	E	464	8,203	17.68		
	W	505	5,343	10.58		
	T	969	13,546	13.98	47,563	32,529
1994	E	575	26,715	46.46		
	W	535	5,615	10.50		
	T	1,110	32,330	24.07	129,482	94,770
1995	E	706	46,062	65.24		
	W	744	15,588	20.95		
	T	1,450	61,650	42.52	333,891	210,546
1996	E	454	26,040	57.36		
	W	285	11,473	40.26		
	T	739	37,513	50.76	203,216	112,217

Table 3, continued.

B. Conowingo Fish Lifts (West/East)

Year	Lift	Hours Fished	Total Catch	Catch Per Lift Hour	Population Estimates Upper Bay	Tailrace
1997	E	640	90,971	142.14		
	W	349	12,974	37.17		
	T	989	193,945	105.10	708,628	423,324
1998	E	433	39,904	92.16		
	W	226	6,577	29.10		
	T	659	46,481	70.53	487,810	314,904
1999	E	467	69,712	149.28		
	W	235	9,658	41.10		
	T	702	79,370	113.06	685,058	583,198
2000	E	368	153,546	417.24		
	W	207	9,785	47.27		
	T	575	163,331	284.05	1,357,400	957,249
2001	E	360	193,574	537.71		
	W	195	10,940	56.10		
	T	555	204,514	368.49	693,033	560,912
2002	E	441	108,001	244.90		
	W	117	9,347	79.89		
	T	558	117,348	210.30	-	555,597

Table 4. Pearson Product Moment Correlation (r_p) for the annual Conowingo tailrace Petersen population estimates, and, geometric mean CPUE's for two gear types (1984-2002) where N = number of years.

	Hook & Line	Fish Lifts
r_p	0.87	0.72
N	19	19
P	<0.001	<0.001

Table 5. Catch (N), age composition, number and percent repeat spawners, mean fork length and length ranges by sex and age group for adult American shad collected by hook and line during 2002.

Males					Females			
Age Group	N	Number Repeats	Mean Length	Length Range	N	Number Repeats	Mean Length	Length Range
III	12	0	346	334-390	0	0	0	0
IV	63	0	379	350-445	29	0	423	377-446
V	53	3	419	380-459	44	14	455	430-476
VI	36	22	454	424-478	46	31	482	455-505
VII	13	13	455	454-491	36	28	504	470-543
VII	0	0	0	0	3	3	509	505-518

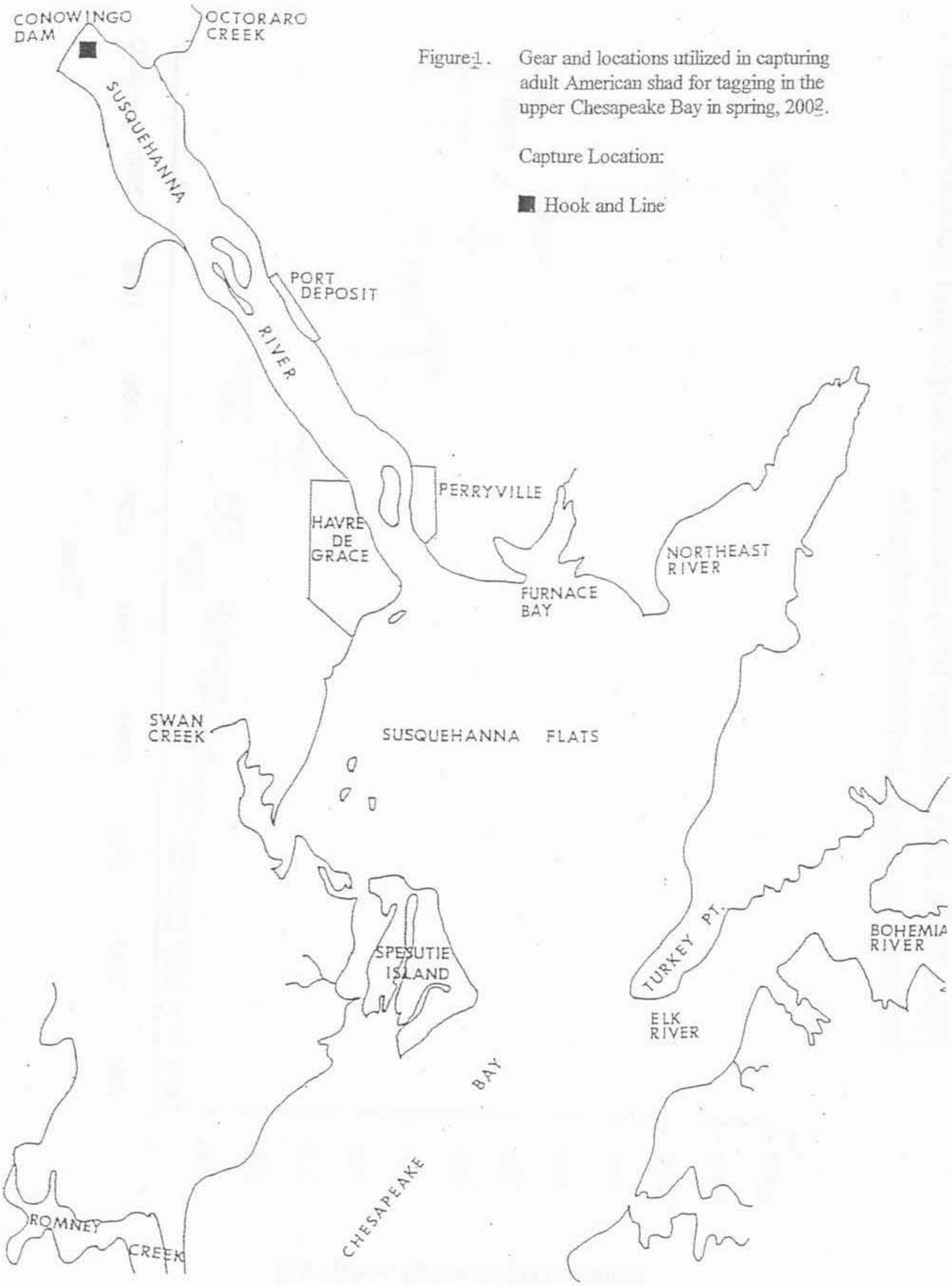


Figure 1. Gear and locations utilized in capturing adult American shad for tagging in the upper Chesapeake Bay in spring, 2002.

Figure 2. Conowingo Dam tailrace population estimates of American shad, 1984-2002. Bars indicate 95% confidence ranges and numbers above indicate the yearly population estimate.

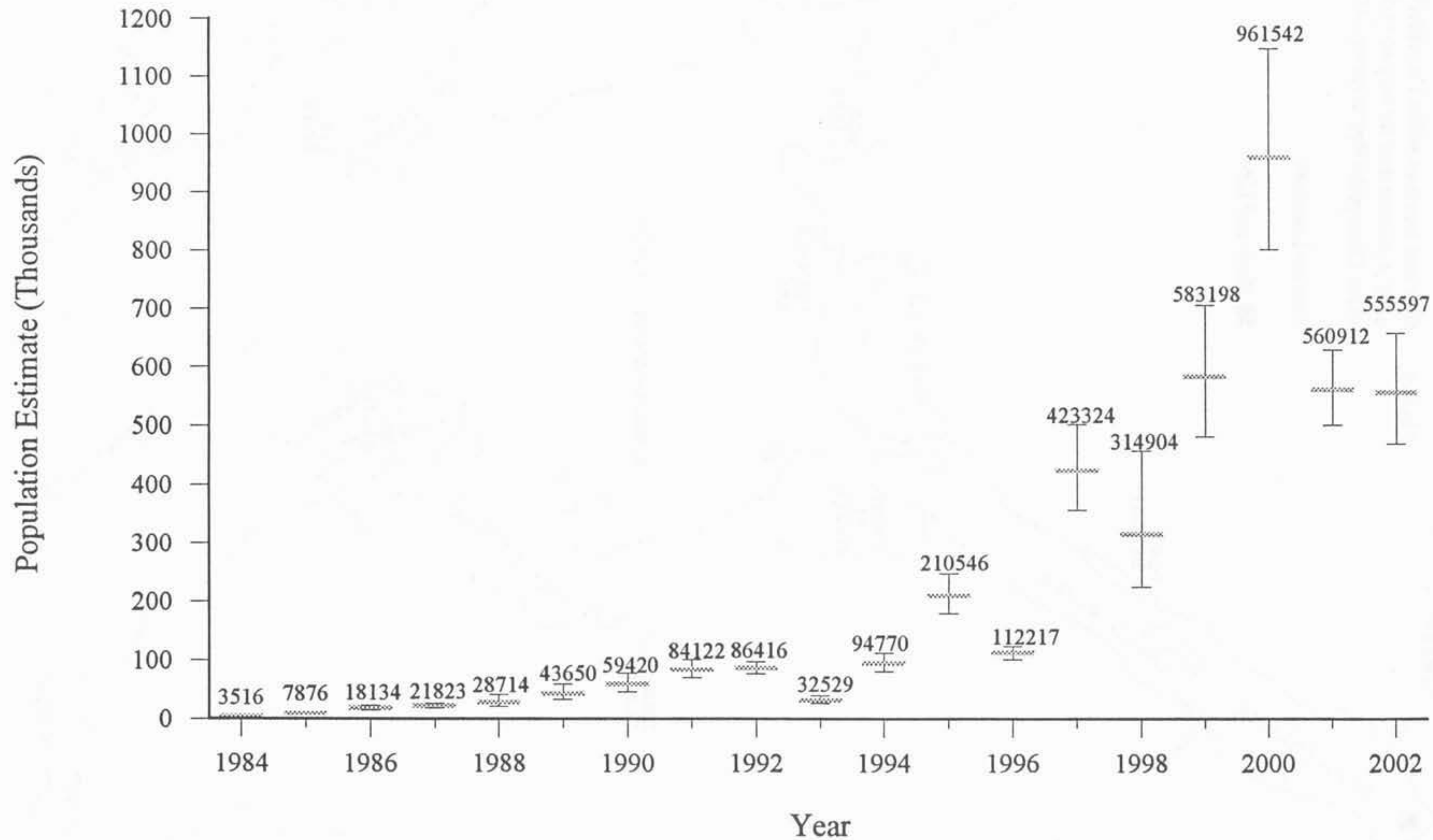
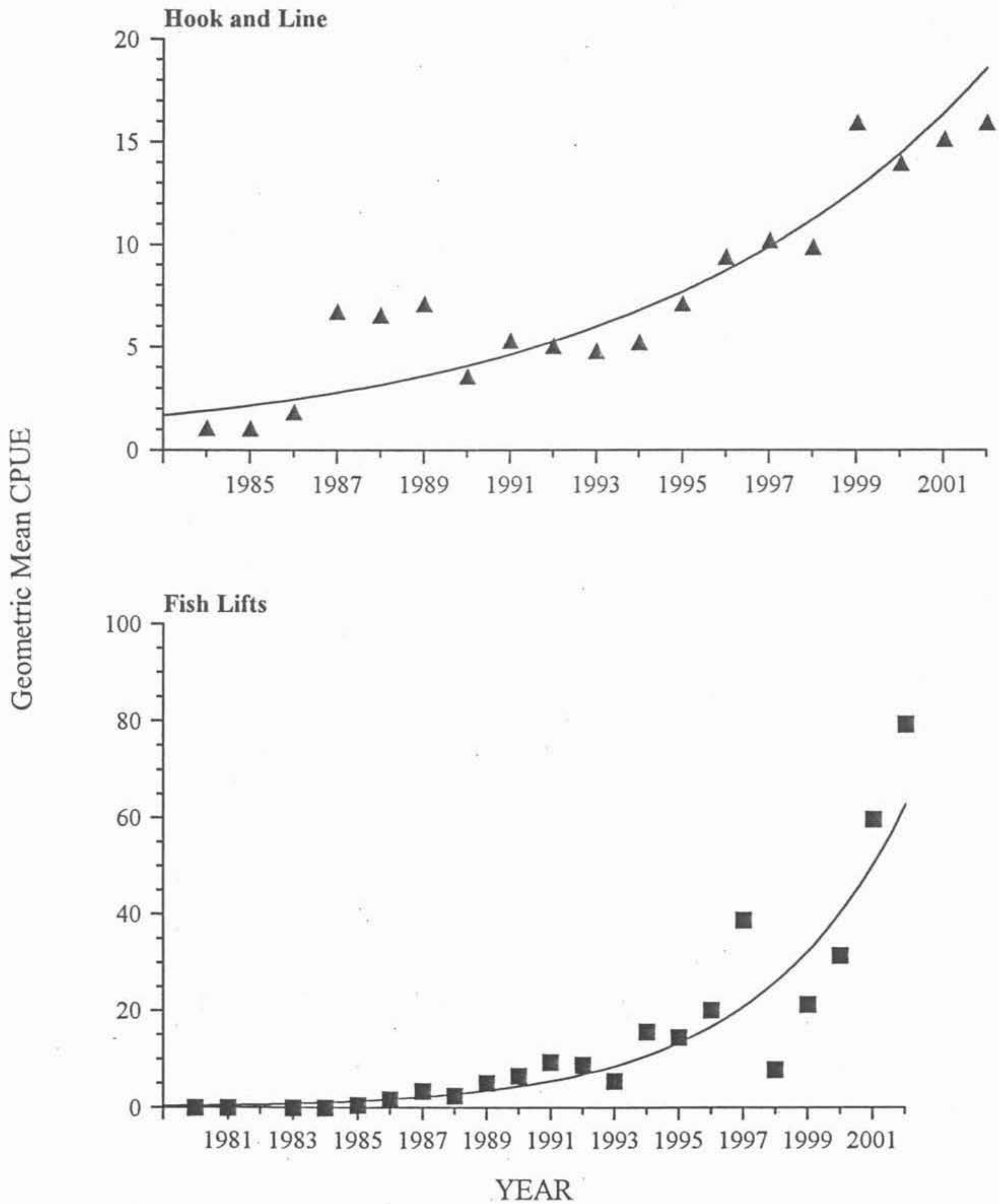


Figure 3. Regression analysis of geometric mean catch-per-unit-efforts (CPUEs) of American shad sampled by pound net, hook and line, and Conowingo fish lifts in the upper Chesapeake Bay, 1980-2002.



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