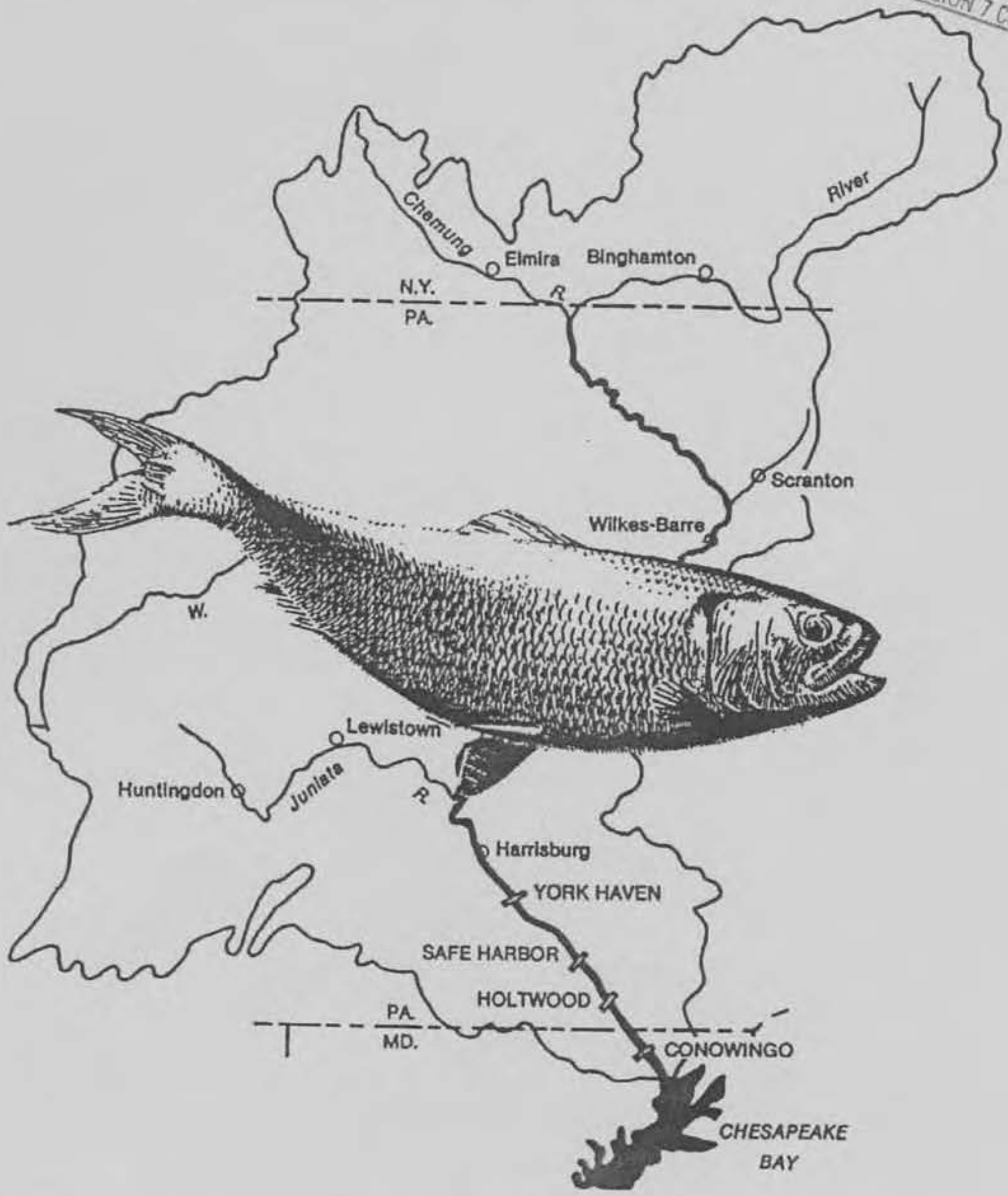
Restoration of American Shad to the Susquehanna River

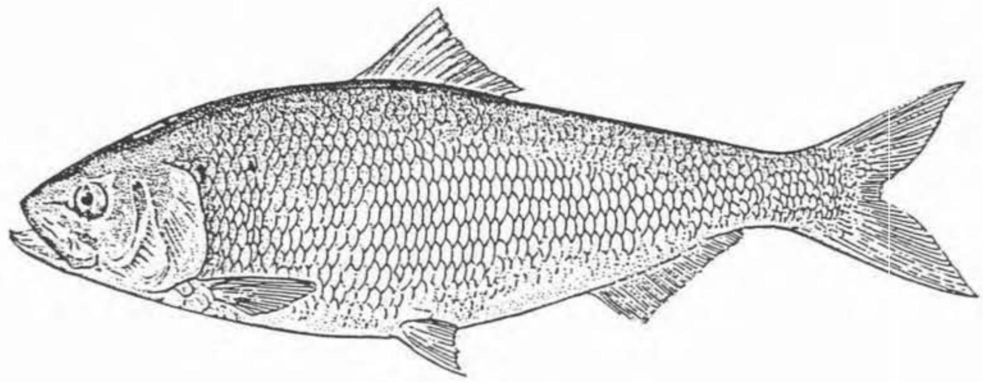
Annual Progress Report
2001



Susquehanna River
Anadromous Fish Restoration Committee

February 2002

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2001

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 2002

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EXECUTIVE SUMMARY

This 2001 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 2001 was characterized by relatively high river flows and lack of fish in early April which delayed startup of operations at the Conowingo East lift until April 23. As flows fell, shad suddenly appeared in abundance on April 25 and a new record passage total was achieved by May 10. During this 16-day period shad passage averaged about 10,000 per day with record days on May 4-5 of 24,000-26,000 fish. As flows further dropped and water temperature increased to the low-70s, catch decreased to an average 1000 shad/day after May 17 until operations terminated on June 6. For the season the East lift operated 43 days, made 559 lifts and passed 921,916 fish. These included 429,461 gizzard shad, a new record 193,574 American shad, 284,921 blueback herring (mostly in 3 days, May 3-5), and 7,458 alewives. Maryland DNR tags observed here totaled 365, of which 308 were year 2001 fish tagged in the tailrace.

The Conowingo West lift operated on 41 days from late April through early June, fishing for 195 hours and making 425 separate lifts. Total catch amounted to 309,804 fish including 218,124 gizzard shad, 10,940 American shad, 16,320 blueback herring, and 7,824 alewives. Sex ratio in the American shad run was 0.7 : 1.0 favoring females. Every 50th shad collected throughout the season was killed for otolith analysis and a scale sample.

A total of 5,049 blueback herring were stocked in the Conestoga River, Little Conestoga Creek, and Conodoguinet Creek with very low mortality. Conestoga and Little Conestoga also received 1,820 alewives. Other transfers from the West lift included 823 shad provided to Maryland DNR and 970 delivered to USFWS-Lamar, both for tank spawning. Fifty-two DNR tags were recovered.

The tailrace lift at Holtwood operated on 41 days during April 27 through June 8, fishing for 371 hours and making 615 lifts. Because of persistent low flows and the early placement of flashboards, the spillway lift only operated on 17 days making 146 lifts in 132 hours. A record total of 109,976 American shad were passed - 101,947 at the tailrace and 8,029 at the spillway. Other fish in combined Holtwood collections included 1,300 blueback herring, 188,098 gizzard shad, and 10,801 others. Peak passage day for American shad was May 7 (12,341 fish). DNR tags observed numbered 203 of which 73% were 2001 tagged fish from the Conowingo tailrace. Shad passage rate at Holtwood in 2001 was over 56% of those passed at Conowingo East lift, a substantial improvement from 2000 when only about 19% were recorded.

The Safe Harbor fish lift operated for 309 hours during 39 days between April 30 and June 12 and made 581 lifts. Total fish passage was 262,416 fish including a new record 89,816 American shad, 710 blueback herring, 13 alewives (from tributary stockings) and 151,873 gizzard shad. Peak day of American shad passage was May 8 (7,107). Safe Harbor passed almost 82% of the shad passing Holtwood and 58 DNR tags were observed.

Fish ladder operations began at York Haven's East Channel Dam on May 3 and continued for 37 days until June 8. Shad were observed passing this site every day and peak passage occurred on May 10 (1,393 fish). For the season, total fish passage amounted to 143,820 fish including 16,200 American shad (18% of Safe Harbor passage), 89,272 gizzard shad and 35,820 others. Only a few DNR tags were observed. The required 4,000 cfs overnight spill at the main dam when river flow exceeded 23,000 cfs was altered periodically (to 1,000 cfs) to test shad response at the fishway the next day. It was observed that morning shad numbers actually improved under the reduced flow scenario and this will be further evaluated in 2002.

Maryland DNR collected shad for tag and release from a pound net at Rocky Point in the Flats and by angling in the Conowingo tailrace. Catch per effort at the pound net was the highest recorded since sampling began here in 1980. Total catch from both gears was 2,992 shad of which 1,297 were tagged and released. Using recapture information primarily from the East lift, shad population indices were calculated for the upper Bay (693,033 fish) and Conowingo tailrace (560,912), both reductions from 2000 estimates. This probably reflects the increase in numbers of tags seen at the lift due to water clarity (low flows). Scale analysis from combined pound net and angling samples showed that most males were aged 4-5 with 25.6% repeat spawning (compared to 4.7% in 2000), and most females were ages 5-6 with 27.1% repeat spawners (compared to 13.7% last year).

Based on analysis of 208 readable otoliths from adult shad taken at Conowingo West lift, 129 (62%) were of hatchery origin and 79 (38%) were wild. This compares to 46% hatchery and 54% wild in 2000. The majority of hatchery fish (99 or 77%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River or mainstem Susquehanna below Sunbury. Others were fairly evenly split between double (12 fish), triple (9 fish), or quadruple marks (9 fish). 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 recruited year-classes of 1986-1996, it took 284 stocked larvae, 134 stocked fingerlings, and/or 0.79 transplanted or passed adults to produce each adult return to Conowingo Dam.

Electrofishing for adult shad in the Susquehanna watershed produced 45 fish including 24 at the inflatable dam at Sunbury, 17 in the Conestoga River near Lancaster, and two each in Muddy Creek and West Conewago Creek. Nine of 12 adult shad taken in upstream tributary locations carried hatchery marks, whereas 11 of 16 examined from collections at Sunbury were unmarked.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River and PFBC completed Delaware River egg collections. PA contracting problems resulted in a delayed start on the Hudson and abbreviated collections amounted to only 3.919 million eggs (compared to 14.9 million in 2000) with 77% viable. The Delaware produced 6.35 million eggs (compared to 3.8 million in 2000), but with only 20.5% viability. In a first attempt at tank spawning at Conowingo Dam, Normandeau Associates produced 5.81 million eggs of which 33% were viable.

Spawning trials at Lamar (USFWS) were conducted in a 3 ppt salinity recirculation system to assess the effectiveness of three different hormone implants for inducing tank spawning of American shad. No differences in egg production per female per spawning day between hormone treatments were detected. Better egg quality was indicated for days three and four post-implant with 86% of the total spawn and 92% of viable eggs having occurred on those days. Brood stock survival, egg production per female, and egg viability rates were greater for tank-spawn operations using 3 ppt salinity as compared to a similar freshwater system. Adults held in fresh water exhibited significant post-spawn increases in cortisol and glucose and decreases in sodium and chloride when compared to pre-spawn levels. Approximately 8.5 million eggs were collected from 965 shad brood stock of which 1.6 million (19%) were viable.

Van Dyke produced a total of 6.525 million fry of which 5.203 million were stocked in the Susquehanna drainage as follows: 0.98 M in the Juniata River; 2.82 M in the mainstem below Sunbury: 0.68 M in the North Branch; 22,000 in the West Branch; and 0.70 M in four lower river tributaries. The PFBC also reared and stocked 676,000 shad fry for the Lehigh River and 491,000 for the Schuylkill River, and they provided 49,400 fry to the State of Delaware for stocking the upper Nanticoke River and 105,400 for New Jersey's stocking of the Raritan River. Lamar stocked about 307,000 shad fry in the West Branch. All fish were distinctively marked with tetracycline.

Juvenile shad were collected at numerous sites with several gears during July-December, 2001. Haul seining at Columbia produced 337 shad in 90 hauls on 15 dates (CPUE 4.19). Only 13 juveniles were taken by seine in tributaries (6 - Swatara and 7 - Conestoga); 11 by electrofishing (6 - Juniata and 5 - Susquehanna); and 4 by push netting in Conowingo Pond (along with 132 bluebacks). Lift netting at Holtwood produced 1,245 juvenile shad in 300 lifts with most fish being taken after November 15. Peach Bottom screens produced 63 shad and 105 bluebacks, while intake strainers at Conowingo provided 6 shad and 82 blueback herring. During July-September seine sampling in the upper Chesapeake Bay, Maryland DNR collected only 23 juvenile shad (compared to 409 in 2000 with comparable effort) - but blueback herring were very abundant.

Otoliths from a total of 779 juvenile shad were examined for hatchery marks from combined collections made at and above Conowingo Dam. Of these, 60% were hatchery marked (compared to 98% in 2000), with the majority (88%) carrying marks indicating that they were stocked at various locations in the Juniata and mainstem Susquehanna rivers. Most of the remaining hatchery fish examined came from stockings in the North Branch and Swatara Creek with very small numbers from the West Branch and other tributaries. In terms of relative survival from stocking site to recovery, Juniata and mainstem Susquehanna (Hudson source) produced the best results followed by the same release sites using Susquehanna eggs. Swatara Creek and North Branch were also well represented but all other stocking sites produced relatively poor recovery rates.

A major telemetry study was completed in 2001 using funds from PPL, SECO, PBAPS, and SRAFRC. A total of 204 adult shad were radiotagged and tracked from Conowingo Dam to and through Holtwood Dam using eleven receiver locations. All tags used distinct frequencies and receivers were located at Conowingo tailrace and East lift exit, Broad Creek, Peach Bottom APS, Muddy Run intake and power canal, Deepwater Island, Holtwood spillway, tailrace, fish lift entrance and exit. Of the 204 tagged fish which passed Conowingo, 184 were detected at one or more of the upstream monitors, with 111 being first detected at Broad Creek or Peach Bottom; 68 at Muddy Run or Deepwater; and 5 at Holtwood. Seventeen of the remaining 20 fish returned to Conowingo and passed through that project of which only 4 (2% of test fish) passed downstream within 24 hours. Overall, 136 of 204 fish reached the Holtwood tailrace, 86 entered the fish lift channel (with many repeated forays), and 46 actually passed Holtwood (i.e., 22.5% of all test fish; 33.8% of those that reached Holtwood).

Considerable movements were recorded between Holtwood tailrace and the Muddy Run pump intake area with some fish making five or more round trips. Movement was from Muddy Run to Holtwood in the morning and back in the evening. Seven tagged shad were entrained and located in the Muddy Run power canal. Over 100 tagged fish were detected in the Unit One corner of the Holtwood tailrace and these made repeated forays to the fish lift entrance - but few successfully used the lift.

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 and electrofishing collections 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 adult shad blood chemistry analysis, hormone efficacy trials and tank spawning and production at Lamar. Costs related to Conowingo West fish lift operations including trucking of shad and herring and tank spawning were paid from a SRAFRC contributed funds account administered by USFWS. This account also paid for hormones and supplies at Lamar, and helped co-fund the telemetry study with SECO and PPL. Contributions to the special account in 2001 came from Peach Bottom APS, Maryland DNR, and PFBC.

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

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JOB I – Part 1

SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY, SPRING 2001

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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 2001 operation were: (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway and trough effectiveness and make modifications as feasible.

CONOWINGO OPERATION

Project Operation

The Conowingo Hydroelectric Station, built in 1928, is located at river mile 10 on the Susquehanna River (RMC 1992). The powerhouse has a peaking generating capacity of 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 9 June, respectively.

Fishway Operation

East lift operation began on 23 April and generally operated on an every day basis. Operations were delayed on 11 May due to the crowder cables snapping. Lift operation resumed on a daily basis on 12 May. Operations were delayed on 27 May due to the hopper door becoming twisted and inoperable. Operations resumed 28 May with continuous operation until the season ended on 6 June. During the following days of operation, (1, 3, 8, 10, 15, 17, and 23 May), lift operation was interrupted for approximately 2 to 3 hrs to collect American shad for a radio telemetry study. The lift was operated a total of 43 days during the 2001 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 2001 were similar to those described in RMC (1992) and Normandeau Associates, Inc. (1998). 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 2001 season.

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 921,916 fish of 29 species and 1 hybrid was passed upstream into Conowingo Pond. Gizzard shad (429,461), blueback herring (284,921) and American shad (193,574) were the dominant species passed, comprising 46%, 31%, and 21% respectively of the season total; the three species together accounted for 98% of the total fish passed. Other common fishes included alewife (7,458), white perch (2,659), carp (1,276), and striped bass (543). Alosids (American shad, blueback herring, and alewife) comprised nearly 53% of the total catch. Peak passage occurred on 4 May when 311,984 fish, or 34% of the season total, were passed.

American Shad Passage

The East lift captured and passed 193,574 American shad (Table 1). The first shad was passed on 23 April. Collection and passage of shad varied daily with nearly 68% (131,432) of the shad captured and passed during the ten day period between 29 April and 8 May. The lift captured and passed over 10,000 American shad on five separate days. On 28 of the 43 days of operation, American shad passage exceeded 1,000 fish. Peak passage occurred on 5 May when 26,415 American shad were passed.

American shad were collected at water temperatures of 52.7 to 74.3°F and at natural river flows of 11,400 to 62,400 cfs (Table 2 and Figure 1). More than 85% of the American shad were collected at river flows less than 32,000 cfs (Table 2 and Figure 1). The average daily river flow during the operational season was 22,686 cfs.

The hourly passage of American shad for the East lift is given in Table 3. Most shad passed (185,700) through the fishway from 0900 to 1859 h. Peak hourly passage of shad (27,608) occurred between 1200 to 1259 h. Generally, shad passage was steady, all hour periods from 0900 to 1759 h had passage greater than 15,000 shad.

Alosids

A total of 7,458 alewife was captured and passed (Table 1). The majority of alewife (7,361) passed between 23 April and 4 May. The remaining 97 alewife were captured and passed on 9 May. No hickory shad were captured.

A total of 284,921 blueback herring were captured and passed (Table 1). Most blueback herring (94%) were passed on 4 May at a water temperature of 69.9°F and river flow of 24,800 cfs.

SUMMARY

Despite a delayed start due to cold water temperatures and high river flows, the East lift catch during the first two weeks of the season yielded nearly 148,000 American shad. The East lift successfully passed 193,574 American shad by the season's end. The total number of American shad passed during the 2001 season surpassed all previous years of operation (Table 4).

One modification was made prior to the start of the 2001 season. A 30 inch diameter fiberglass hopper extension chute was installed to direct fish upstream in the trough. The new chute will continue to be evaluated and improved upon if necessary for future operation. A total of 697 American shad lift mortalities (0.4% of the total shad passed), were observed this season, similar to the lift mortalities (0.3% of the total shad passed) observed in 2000.

Fish viewing conditions were greater than those encountered in 2000 due to improved water clarity as a result of low river flows. Improved water clarity allowed technicians to view well over 26 inches of the viewing area throughout the season. Visual counting accuracy was maximized by utilizing two people during periods of increased fish passage and/or poor viewing conditions.

RECOMMENDATIONS

- 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.

- 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.

- Inspect all cables and limit switches to meet design specifications, and continue to evaluate effectiveness of modifications to the trough valve grating and hopper chute.

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Normandeau Associates, Inc. 2000. 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 2001.

Date	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*
Hours of Operation	*6.00*		*8.80*	*8.80*	*8.80*	*10.80*	*10.80*	*10.70*
Numbers of Lifts	*7*		*12*	*17*	*18*	*12*	*25*	*17*
Water Temperature (°F)	*52.7*		*55.4*	*59.0*	*59.0*	*59.0*	*60.0*	*62.6*
American shad	5		2,602	5,071	6,351	2,484	14,235	7,770
Blueback herring					25	11	17	
Alewife	28		302	187	75	15	13	7
Gizzard shad	6,165		9,043	8,317	25,637	19,267	15,991	18,391
Sea lamprey	2		2	4	7	6	10	17
Rainbow trout				1				
Brown trout			1			1		
Comely shiner						3	1	
Carp						1		
Quillback			4	10	7	13		2
White sucker	4		10	7	11	13	1	3
Shorthead redhorse	5		48	88	110	45	2	10
Spottail shiner						11		
Yellow bullhead								
Brown bullhead								
Channel catfish					1			2
American eel								
White perch	1		3	1	26	8	8	61
Striped bass								
Splake								
Redbreast sunfish								
Green sunfish								1
Bluegill	2				1	1		5
Rock bass				2		4		2
Smallmouth bass	4		9	15	21	20	27	26
Largemouth bass					1		1	4
White crappie								1
Black crappie								
Yellow perch			1		3			2
Walleye	1		3		2	2		
TOTAL	*6,217*	*0*	*12,028*	*13,703*	*32,278*	*21,905*	*30,306*	*26,304*

Table 1

Continued.

Date	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*
Hours of Operation	*4.40*	*10.50*	*4.50*	*9.90*	*11.00*	*10.80*	*9.80*	*5.50*
Numbers of Lifts	*9*	*20*	*9*	*33*	*33*	*24*	*18*	*14*
Water Temperature (°F)	*62.0*	*66.2*	*67.1*	*69.9*	*68.9*	*69.9*	*69.9*	*69.0*
American shad	7,412	15,624	6,585	24,111	26,415	18,343	5,952	4,985
Blueback herring		101	6,688	266,801	8,074	1,650	493	114
Alewife		187	1,687	4,860				
Gizzard shad	8,578	15,475	5,807	16,104	13,975	28,540	12,257	21,778
Sea lamprey	7	15	8	24	23	28	34	6
Rainbow trout								
Brown trout						1		
Comely shiner								
Carp		1	4	19	18		3	5
Quillback		2		4	7		6	5
White sucker				1	1	2	1	1
Shorthead redhorse		8	1	6	5	3	16	9
Spottail shiner			3					
Yellow bullhead								
Brown bullhead								
Channel catfish			1		2			
American eel								
White perch	15	77	69	10	302	993	248	47
Striped bass				3	1	1	1	7
Splake								
Redbreast sunfish				1				1
Green sunfish						2	1	
Bluegill		3	1	4	2		2	
Rock bass			1		3	1	2	3
Smallmouth bass	6	19	10	34	60	20	5	14
Largemouth bass			2	1	2	1		3
White crappie								
Black crappie					1			
Yellow perch	1		1			7	1	4
Walleye		1		1	5			
TOTAL	***16,019***	***31,513***	***20,868***	***311,984***	***48,896***	***49,592***	***19,022***	***26,982***

Table 1

Continued.

Date	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Hours of Operation	*10.00*	*10.50*	*9.00*	*10.50*	*9.30*	*10.00*	*10.00*	*10.00*
Numbers of Lifts	*22*	*18*	*10*	*20*	*15*	*15*	*13*	*15*
Water Temperature (°F)	*71.6*	*74.3*	*74.3*	*74.3*	*73.4*	*72.5*	*71.6*	*70.0*
American shad	5,481	4,006	2,706	5,785	4,013	3,708	2,358	3,677
Blueback herring	291	132	18	70	120	48	26	22
Alewife	97							
Gizzard shad	19,039	12,250	10,918	17,476	26,190	13,807	13,426	14,145
Sea lamprey	10	6	3	12	3	2	10	5
Rainbow trout				2			1	1
Brown trout					4			
Comely shiner								
Carp	34	10	8		1		59	4
Quillback	7	60	6	2	1	1		1
White sucker	2	7		1				
Shorthead redhorse	9	3	2	3		1	1	4
Spottail shiner					300	4		
Yellow bullhead		1						
Brown bullhead	3							
Channel catfish	3			3	1	4	1	1
American eel						1		
White perch	663	31			69	1	4	5
Striped bass	5	5	2	10	3	20	20	11
Splake				1				
Redbreast sunfish		2		3	1	2	4	3
Green sunfish			1			1		
Bluegill		1		2	1	3	2	
Rock bass	5			1		1	2	5
Smallmouth bass	32	11	5	12	6	9	5	1
Largemouth bass						6	1	7
White crappie								
Black crappie								
Yellow perch	4	2			2	1		
Walleye	10	3		7	9	3	6	4
TOTAL	***25,695***	***16,530***	***13,669***	***23,390***	***30,724***	***17,623***	***15,926***	***17,896***

Table 1

Continued.

Date	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*
Hours of Operation	*9.50*	*9.30*	*9.80*	*9.50*	*8.80*	*10.00*	*9.80*	*9.50*
Numbers of Lifts	*11*	*10*	*10*	*12*	*9*	*13*	*11*	*11*
Water Temperature (°F)	*68.9*	*70.7*	*70.7*	*70.7*	*68.9*	*69.5*	*71.6*	*70.2*
American shad	1,847	1,272	1,416	1,692	824	1,565	1,129	710
Blueback herring	4	3	4	3	23	48	29	9
Alewife								
Gizzard shad	9,625	11,897	11,750	8,442	6,486	6,290	4,150	1,140
Sea lamprey	2	1	2	3	4	3	5	
Rainbow trout								1
Brown trout								
Comely shiner								
Carp	2		4		3	4	3	6
Quillback		5	2		2		2	4
White sucker								1
Shorthead redhorse						1		1
Spottail shiner								
Yellow bullhead								
Brown bullhead								
Channel catfish	1							
American eel								
White perch	2	3	1			1	2	5
Striped bass	8	16	17	4	32	51	42	19
Splake								
Redbreast sunfish			2			2	2	
Green sunfish								
Bluegill		1		2	1	2		2
Rock bass		1						
Smallmouth bass	5	1	2	2	3	1	4	4
Largemouth bass					1			1
White crappie								
Black crappie								
Yellow perch						1		
Walleye	5	3	1	2	5	10	2	1
TOTAL	***11,501***	***13,203***	***13,201***	***10,150***	***7,384***	***7,979***	***5,370***	***1,904***

Table 1

Continued.

	25 May	26 May	27 May	28 May	29 May	30 May	31 May	1 Jun
Hours of Operation	*9.00*	*7.00*	*1.50*	*6.60*	*7.50*	*6.50*	*6.30*	*6.80*
Numbers of Lifts	*9*	*6*	*2*	*7*	*9*	*8*	*6*	*7*
Water Temperature (°F)	*70.0*	*70.7*	*71.6*	*71.6*	*71.5*	*71.5*	*69.9*	*69.9*
American shad	611	444	25	312	368	343	132	414
Blueback herring	4	10	1	14				50
Alewife								
Gizzard shad	2,287	1,518	14	4,220	3,390	681	35	254
Sea lamprey	1	2		1				
Rainbow trout								
Brown trout				1				
Comely shiner								
Carp	2	3		7	666	17	1	
Quillback	9	2			76			
White sucker								
Shorthead redhorse					1			
Spottail shiner								
Yellow bullhead								
Brown bullhead		1					1	
Channel catfish	1				6			1
American eel							1	1
White perch	2	1						
Striped bass	25	21	15	15	62	11	36	21
Splake								
Redbreast sunfish	1	2		1	3	3	3	
Green sunfish								
Bluegill	2	2			4	4	1	
Rock bass								
Smallmouth bass	4			1	2	1	1	
Largemouth bass								
White crappie								
Black crappie								
Yellow perch	1				1			
Walleye	1	1			2			1
TOTAL	***2,951***	***2,007***	***55***	***4,572***	***4,581***	***1,060***	***211***	***742***

Table 1

Continued.

Date	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	***Total***
Hours of Operation	*7.00*	*7.00*	*4.50*		*3.50*	***359.8***
Numbers of Lifts	*6*	*7*	*5*		*4*	***559***
Water Temperature (°F)	*69.7*	*72.5*	*70.7*		*70.0*	
American shad	396	297	66		32	***193,574***
Blueback herring		16	2			***284,921***
Alewife						***7,458***
Gizzard shad	530	337	2,716		1,123	***429,461***
Sea lamprey						***268***
Rainbow trout						***6***
Brown trout						***8***
Comely shiner						***4***
Carp		1	377		4	***1,267***
Quillback			1			***241***
White sucker						***66***
Shorthead redhorse						***382***
Spottail shiner						***318***
Yellow bullhead						***1***
Brown bullhead						***5***
Channel catfish					1	***29***
American eel						***3***
White perch						***2,659***
Striped bass	10	13	21		15	***543***
Splake						***1***
Redbreast sunfish	3		4		3	***46***
Green sunfish						***6***
Bluegill		1	2		1	***55***
Rock bass						***33***
Smallmouth bass		1			1	***404***
Largemouth bass						***31***
White crappie						***1***
Black crappie						***1***
Yellow perch		1				***33***
Walleye						***91***
TOTAL	***939***	***667***	***3,189***	***0***	***1,180***	***921,916***

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 2001.

Date	American Shad Catch	MDDNR 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
23 Apr	5	0	62,400	52.7	26	10	C	310	21.5-23.0	106.8	0
24 Apr	0	-		49.1			C				0
25 Apr	2,602	*3YL*	59,500	55.4	26	10	C	310	21.5-23.0	107.1	0
26 Apr	5,071	*1YL,2O*	5,200	59.0	28	10	C	310	21.5-23.1	107.4	0
27 Apr	6,351	*1GR,1OR*	47,700	59.0	28	10	C	310	23.0	108.0	0
28 Apr	2,484	*1CH,2OR*	42,100	59.0	26	10	C	310	17.5-23.0	108.2	0
29 Apr	14,235	*2OR,1GR,5PK*	37,900	60.0	26	10	C	310	17.5-23.1	108.0	0
30 Apr	7,770	*3CH,3PK,1OR*	34,900	62.6	26	10	C	310	17.5-23.2	108.0	0
1 May	7,412	*1PK,1OR,1CH*	32,500	62.0	26	2	C	310	17.5-17.9	107.4	0
2 May	15,624	*4PK*	29,200	66.2	26	10	C	310	18.0-23.0	107.8	0
3 May	6,585	*1CH,5PK*	28,500	67.1	26	10	C	310	17.0-23.0	107.9	0
4 May	24,111	*29PK,5CH,3OR*	24,800	69.9	30	7	C	310	17.5-23.0	107.2	0
5 May	26,415	*36PK,6CH,3OR*	21,300	68.9	30	6	C	310	18.0-21.0	107.0	0
6 May	18,343	*35PK,5CH,2OR*	19,200	69.9	32	5	C	310	18.0	106.8	0
7 May	5,952	*10PK,1CH,1OR*	20,900	69.9	30	10	C	310	16.5-23.0	107.7	0
8 May	4,985	*9PK,1CH*	18,800	69.0	30	3	C	310	16.5-18.5	106.7	0
9 May	5,481	*14PK,3CH*	17,500	71.6	30	6	C	310	18.5-21.0	107.0	0
10 May	4,006	*16PK,1CH*	17,700	74.3	30	5	C	310	16.5-21.0	106.2	0
11 May	2,706	*4PK,1CH*	16,600	74.3	30	7	C	310	16.5-23.0	107.2	0
12 May	5,785	*30PK*	16,100	74.3	28	5	C	310	16.5-18.5	105.5	0
13 May	4,013	*16PK,2CH*	15,000	73.4	30	5	C	310	17.5-18.0	106.4	0
14 May	3,708	*12PK*	13,700	72.5	26	2	C	310	16.5-18.0	106.4	0
15 May	2,358	*10PK*	13,300	71.6	26	4	C	480	16.5-21.0	107.4	0
16 May	3,677	*8PK*	13,100	70.0	26	5	C	480	18.0-21.0	106.2	0
17 May	1,847	*5PK*	12,700	68.9	24	4	C	310	16.5-18.5	105.5	0

Table 2

Continued.

Date	American Shad Catch	MDDNR 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
18 May	1,272	*8PK*	12,400	70.7	24	4	C	310	16.5-18.5	106.3	0
19 May	1,416	*9PK*	11,400	70.7	27	6	C	310	18.0-21.5	106.4	0
20 May	1,692	*7PK*	11,400	70.7	30	5	C	310	18.0	105.4	0
21 May	824	*6PK,1OR*	11,500	68.9	30	2	C	300	18.0	104.6	0
22 May	1,565	*13PK,1OR*	12,500	69.5	30	6	C	300	18.0-21.0	106.0	0
23 May	1,129	*8PK*	13,300	71.6	30	2	C	310	18.5-19.0	106.3	0
24 May	710	*1PK*	14,700	70.2	30	2	C	300	18.0	105.4	0
25 May	611	0	13,900	70.0	30	5	C	300	18.0-21.0	106.8	0
26 May	444	*1PK*	14,600	70.7	30	4	C	300	18.5	106.6	0
27 May	25	0	19,900	71.6	30	5	C	300	18.5	107.0	0
28 May	312	*2PK*	21,200	71.6	30	5	C	310	18.5-21.0	108.0	0
29 May	368	*1PK*	23,500	71.5	30	7	C	310	21.0-22.0	108.4	0
30 May	343	0	21,600	71.5	30	7	C	310	16.5-22.0	108.0	0
31 May	132	*0*	19,000	69.9	26	5	C	310	18.0-21.0	107.2	0
1 Jun	414	0	18,100	69.9	20	5	C	310	18.0-21.5	107.5	0
2 Jun	396	0	16,700	69.7	26	4	C	310	17.5-21.0	107.5	0
3 Jun	297	0	15,800	72.5	24	4	C	310	17.5	106.9	0
4 Jun	66	0	17,800	70.7	26	5	C	310	16.0-20.0	107.3	0
5 Jun	0	0	18,900								
6 Jun	32	0	18,800	70.0	24	6	C	310	16.5-21.0	107.8	0

* Tag color: PK=pink, CH=chartreuse, OR=orange, YL=yellow, and GR=green.

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2001.

Date	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*
Observation Time - Start	*11:30*		*9:45*	*9:30*	*9:45*	*8:00*	*8:00*	*8:00*	*8:00*	*8:10*	*8:00*	*8:14*	*8:00*
Observation Time - End	*17:55*		*19:00*	*18:30*	*19:00*	*19:20*	*19:00*	*19:00*	*13:00*	*18:40*	*13:30*	*18:50*	*19:42*
Military Time (hrs)													
0700 to 0759													
0800 to 0859						279	80	333	298	600	207	44	559
0900 to 0959				93	90	136	79	278	1,358	2,064	532	307	1,143
1000 to 1059			1	166	627	104	154	766	2,350	2,865	1,899	3,100	1,685
1100 to 1159			57	504	735	122	447	1,276	1,624	2,405	2,457	4,400	1,972
1200 to 1259			238	779	521	217	627	1,764	1,782	2,300	1,168	4,640	2,341
1300 to 1359			463	701	594	159	1,159	649		1,542	322	4,050	2,486
1400 to 1459			384	638	717	98	3,800	566		1,113		3,010	2,133
1500 to 1559	1		385	447	523	60	3,300	385		736		2,100	2,211
1600 to 1659			380	626	622	216	2,013	509		790		1,140	4,003
1700 to 1759	4		367	744	917	452	1,490	710		734		730	3,895
1800 to 1859			327	373	1,005	469	1,086	534		475		590	2,609
1900 to 1959						172							1,378
Total	***5***	***0***	***2,602***	***5,071***	***6,351***	***2,484***	***14,235***	***7,770***	***7,412***	***15,624***	***6,585***	***24,111***	***26,415***

Date	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*
Observation Time - Start	*8:00*	*8:15*	*8:15*	*8:00*	*8:10*	*8:00*	*8:00*	*8:05*	*8:20*	*7:50*	*8:00*	*8:10*	*8:00*
Observation Time - End	*19:00*	*18:30*	*17:00*	*18:20*	*19:00*	*17:45*	*19:00*	*17:45*	*18:20*	*18:20*	*18:20*	*18:15*	*17:30*
Military Time (hrs)													
0700 to 0759										4			
0800 to 0859	1,244	285	72	36	613	150	242	300	28	179	158	30	109
0900 to 0959	1,965	692	282	287	662	304	522	472	509	288	440	79	101
1000 to 1059	2,258	876	458	678	473	562	560	643	333	449	414	207	108
1100 to 1159	2,489	1,058	1,183	760	256	551	632	681	324	431	445	272	110
1200 to 1259	3,216	662	1,375	831	145	786	717	501	496	291	383	309	88
1300 to 1359	1,309	681	1,101	721	291	332	341	337	306	241	319	317	167
1400 to 1459	1,520	618	489	735	259		578	230	351		419		149
1500 to 1559	1,643	417		601			568	161	409		359		213
1600 to 1659	1,040	328	25	302	320	16	207	254	386	159	330	208	144
1700 to 1759	777	235		331	592	5	627	434	401	263	280	302	83
1800 to 1859	882	100		199	395		791		165	53	130	123	
1900 to 1959													
Total	***18,343***	***5,952***	***4,985***	***5,481***	***4,006***	***2,706***	***5,785***	***4,013***	***3,708***	***2,358***	***3,677***	***1,847***	***1,272***

Table 3

Continued.

Date	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*
Observation Time - Start	*8:00*	*8:00*	*8:00*	*7:45*	*7:55*	*7:45*	*8:00*	*10:12*	*16:00*	*10:50*	*10:00*	*10:15*	*10:10*
Observation Time - End	*18:30*	*17:45*	*17:30*	*18:05*	*18:05*	*17:45*	*17:20*	*17:30*	*16:30*	*17:35*	*17:40*	*17:15*	*16:35*
Military Time (hrs)													
0700 to 0759						6							
0800 to 0859	115	151	48	53	54	39	8						
0900 to 0959	16	52	14	22	47	21	23				24	27	15
1000 to 1059	44	76	46	162	271	51	37	36		34	18	68	15
1100 to 1159	42	153	57	268	214	125	71	17	12	80	54	92	29
1200 to 1259	90	151	134	216	134	78	98	46		56	120	64	20
1300 to 1359	114	218	128	344		87	140	20		67	80	21	32
1400 to 1459	150	222	135	106		84	115	27		34	21	39	15
1500 to 1559	113	189	94	216	185	58	57	88		12	37	30	6
1600 to 1659	194	225	110	131	137	109	48	72	13	29	14	2	
1700 to 1759	355	255	58	40	73	52	14	138					
1800 to 1859	183			7	14								
1900 to 1959													
Total	***1,416***	***1,692***	***824***	***1,565***	***1,129***	***710***	***611***	***444***	***25***	***312***	***368***	***343***	***132***

Date	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	***Total***
Observation Time - Start	*10:05*	*10:15*	*11:00*	*10:10*		*10:20*	
Observation Time - End	*17:20*	*17:10*	*17:20*	*15:00*		*14:30*	
Military Time (hrs)							
0700 to 0759							***10***
0800 to 0859							***6,314***
0900 to 0959	4	3	6	6			***12,963***
1000 to 1059	113	22	54	11		3	***22,797***
1100 to 1159	143	100	45	33		8	***26,734***
1200 to 1259	70	85	52	5		12	***27,608***
1300 to 1359	25	100	16	11		9	***20,000***
1400 to 1459	21	35	76				***18,887***
1500 to 1559	28	20	40				***15,692***
1600 to 1659	10	31	8				***15,151***
1700 to 1759							***15,358***
1800 to 1859							***10,510***
1900 to 1959							***1,550***
Total	***414***	***396***	***297***	***66***	***0***	***32***	***193,574***

Table 4

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2001.

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	0.530	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	0.719	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**

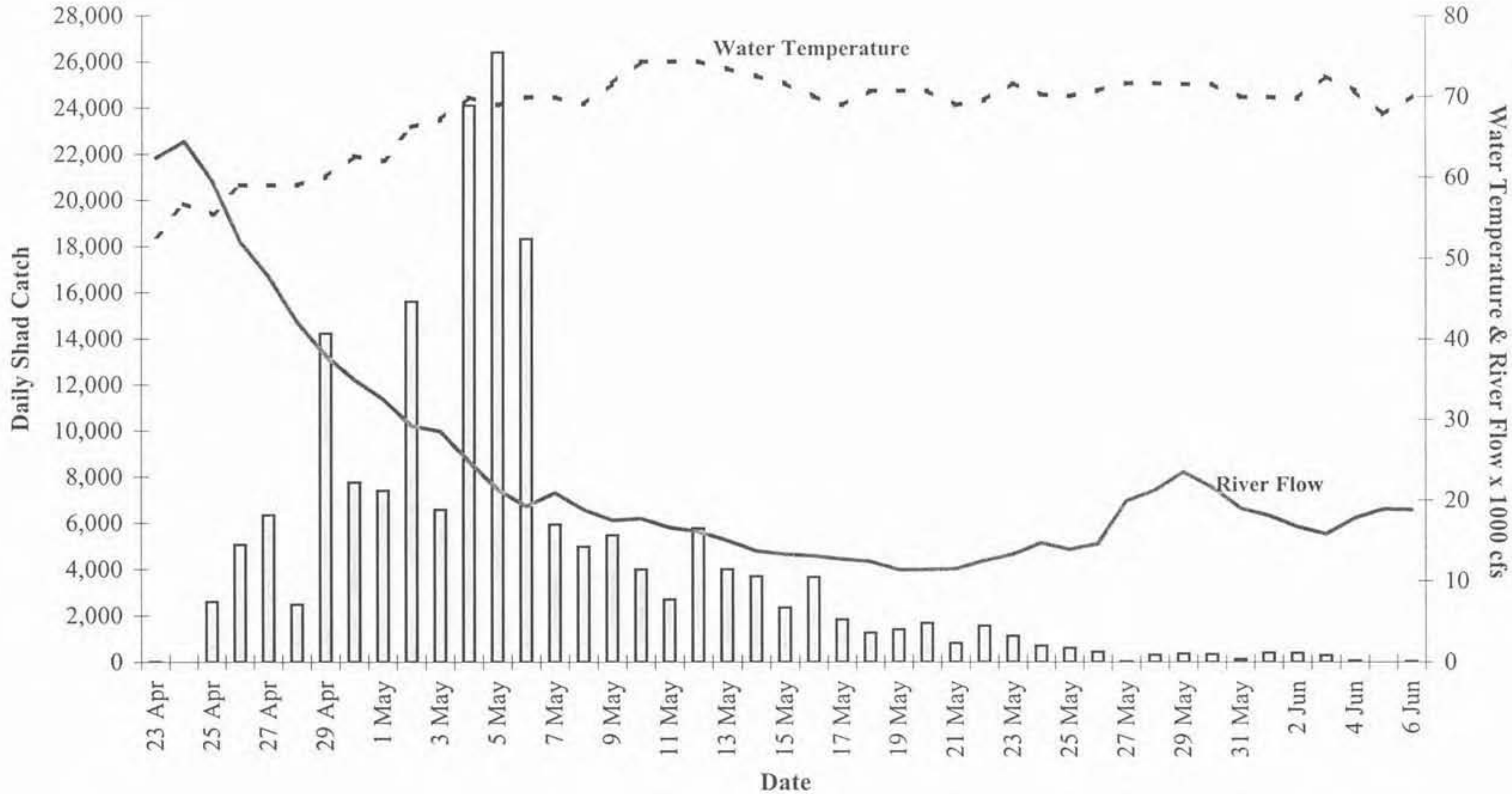

Figure 1

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 2001.

Job I - Part 2

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2001

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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 2001 (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 2001 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 2001 included collection and enumeration of shad, river herring, other migratory and resident fishes; sorting and transportation of up to 10,000 river herring to select tributaries; 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.

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, to arrange for appropriate transport and stocking from the West lift, and to conduct American shad tank spawning trials with egg delivery to Van Dyke hatchery.

Average daily river flows were relatively low during most of the trapping season ranging from about 48,000 cfs in late April 27 to about 12,000 cfs in mid-May. West lift operations began on April 27 and, except for a shutdown on May 16, proceeded every day through June 7. Total fishing effort over 41 operating days in 2001 included 425 lifts and a fishing time of 195 hours.

Shad and herring collected in the trap were counted and either placed into holding or spawning tanks. Fish in excess of transport or spawning needs were returned alive to the tailrace. When sufficient herring numbers were available they were loaded into truck-mounted 1,000 gallon circular transport tanks and hauled to stocking sites. Live shad were delivered to USFWS Northeast Fishery Center 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 2001 season. Total catch at the West lift amounted to 309,804 fish of 38 taxa (Table 1). Gizzard shad and white perch comprised 85% of this total. Alosid catch included 10,940 American shad, 16,320 blueback herring, 7,824 alewives, and 36 hickory shad. Most American shad (87%) were taken during the four-week period May 3-31 with a peak day catch of 1,240 fish on May 18. All alewives were caught on the first 7 days of operation (April 27- May 3) and most blueback herring were collected before May 6 (Table 2).

American shad transfers from the West lift included 970 fish delivered directly to USFWS-Lamar on ten dates with only four mortalities (Table 3); and 823 shad provided on five dates to Maryland DNR for tank spawning (Table 4). Normandeau Associates used 599 shad at the lift for tank spawning (see Job II, Part 3). As shown in Table 5, a total of 5,049 blueback herring were stocked in Little Conestoga Creek (1,510), Conestoga River (2,690) and Conodoguinet Creek (849). Alewife stocking (also Table 5) amounted to 1,520 fish placed in the Little Conestoga and 300 fish in the Conestoga River.

A total of 215 shad were sacrificed and provided to PFBC for otolith analysis and 52 Maryland DNR tags were recovered. Overall female to male sex ratio of shad in the West lift in 2001 was 1.0 to 0.7. Males averaged 478 mm in length and 905 g, while females averaged 524 mm and 1375 g.

Discussion

In spring 2001, high river flows persisted until the third week in April which delayed trapping operations at the West lift. As shown in the East lift report (Job I, Part 1), however, shad returns to the Susquehanna were in record abundance beginning about April 25 and continuing through the third week of May before tailing off. Of the total American shad collected at the West lift in 2001, only about one-fourth (2,392) were either hauled or provided to hatcheries or used for tank spawning on site. Most remaining shad were released alive back to the tailrace.

West lift catch per effort of about 56.5 shad per fishing hour and 26 shad per lift were the highest capture rates ever recorded at this facility. Shad catch per operating day (273) was about average for the past 10 years (Table 6). Operations and fish catch at the West lift during 1985-2001 are summarized in Table 7. Based on analysis of 208 adult shad otolith samples from Conowingo, hatchery-marked fish comprised 62% of the 2001 run, an increase from 53% 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, 2001.

Number of days	41
Number of lifts	425
Fishing time (hours : minutes)	195:10
Number of taxa	38
AMERICAN SHAD	10,940
ALEWIFE	7,824
BLUEBACK HERRING	16,320
GIZZARD SHAD	218,124
HICKORY SHAD	36
STRIPED BASS	710
White perch	44,364
American eel	437
Rainbow trout	1
Carp	994
Comely shiner	1,228
Spottail shiner	5,833
Spotfin shiner	237
Quillback	76
White sucker	12
Shorthead redhorse	132
White catfish	36
Yellow bullhead	12
Brown bullhead	136
Channel catfish	228
Rock bass	188
Redbreast Sunfish	783
Green Sunfish	28
Pumpkinseed	27
Bluegill	260
Smallmouth bass	309
Largemouth bass	14
White crappie	29
Black crappie	5
Tessellated darter	6
Yellow perch	150
Walleye	274
Sea lamprey	43
Log perch	2
Splake	3
Creek chubsucker	1
Brook trout	1
Banded darter	1
TOTAL	**309,804**

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 2001.

Date:	27 Apr	28 Apr	29 Apr	30 Apr	1 May	2 May	3 May
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Number of lifts:	5	12	19	11	16	18	8
Time of first lift:	9:50	11:05	11:15	11:40	11:15	11:45	11:10
Time of last lift:	11:45	17:32	18:25	18:05	17:30	17:45	15:05
Operating time (hours):	1:55	6:27	7:10	6:25	6:15	6:00	3:55
Average water temperature (°F):	59.6	59.6	60.1	60.8	62.2	64.4	65.8
American shad	1	10	66	38	257	220	645
Blueback herring	1,625	1,870	125	139	130	1,241	2,570
Alewife	1,625	1,900	135	139	179	3,496	350
Gizzard shad	475	18,300	37,300	31,275	32,700	28,550	20,315
Hickory shad	3	31	2	0	0	0	0
Striped bass	0	5	0	0	0	0	5
Carp	0	0	0	0	0	1	1
Other species	1,425	3,670	1,087	504	690	3,911	5,656
Total	**5,154**	**25,786**	**38,715**	**32,095**	**33,956**	**37,419**	**29,542**

Date:	4 May	5 May	6 May	7 May	8 May	9 May	10 May
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Number of lifts:	7	20	7	8	9	8	12
Time of first lift:	13:00	10:50	10:50	11:10	10:45	13:05	11:30
Time of last lift:	16:30	17:35	13:50	15:15	15:15	15:15	15:25
Operating time (hours):	3:30	6:45	3:00	4:05	4:30	2:10	3:55
Average water temperature (°F):	65.0	66.4	67.3	68.4	68.7	69.8	71.7
American shad	106	75	183	348	872	179	246
Blueback herring	7,750	765	70	0	1	0	6
Alewife	0	0	0	0	0	0	0
Gizzard shad	573	2,717	274	720	4,650	3,100	1,674
Hickory shad	0	0	0	0	0	0	0
Striped bass	2	12	11	5	6	6	1
Carp	2	165	0	0	1	197	26
Other species	1,921	8,781	4,317	6,131	6,011	797	315
Total	**10,354**	**12,515**	**4,855**	**7,204**	**11,541**	**4,279**	**2,268**

Table 2

Continued.

Date:	11 May	12 May	13 May	14 May	15 May	16 May	17 May
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Number of lifts:	9	13	8	9	2	0	8
Time of first lift:	11:10	11:20	11:10	11:35	10:55		12:50
Time of last lift:	15:40	15:45	14:15	16:35	11:15		15:25
Operating time (hours):	4:30	4:25	3:05	5:00	0:20	0:00	2:35
Average water temperature (°F):	73.6	72.3	73.6	71.3	71.2		69.6
American shad	73	566	455	334	6		339
Blueback herring	1	1	1	3	0		0
Alewife	0	0	0	0	0		0
Gizzard shad	3,885	2,320	325	3,800	550		1,645
Hickory shad	0	0	0	0	0		0
Striped bass	111	4	43	5	4		16
Carp	154	1	2	1	0		0
Other species	0	191	222	218	28	0	86
Total	**9,646**	**3,083**	**1,048**	**4,361**	**588**	**0**	**2,086**

Date:	18 May	19 May	20 May	21 May	22 May	23 May	24 May
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Number of lifts:	12	12	8	10	11	12	8
Time of first lift:	11:00	11:50	11:04	11:00	11:05	11:05	11:40
Time of last lift:	15:40	15:40	15:00	13:50	15:50	15:55	15:45
Operating time (hours):	4:40	3:50	3:56	2:50	4:45	4:50	4:05
Average water temperature (°F):	68.9	69.4	68.2	68.1	69.4	70.6	70.0
American shad	1,240	675	466	232	450	162	59
Blueback herring	0	2	0	0	0	0	0
Alewife	0	0	0	0	0	0	0
Gizzard shad	817	1,205	1,830	901	3,160	2,335	363
Hickory shad	0	0	0	0	0	0	0
Striped bass	4	11	5	15	6	22	9
Carp	0	0	0	1	1	137	4
Other species	35	75	44	81	88	117	68
Total	**2,096**	**1,968**	**2,345**	**1,230**	**3,705**	**2,773**	**503**

Table 2

Continued.

Date:	25 May	26 May	27 May	28 May	29 May	30 May	31 May
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Number of lifts:	9	9	10	11	13	14	12
Time of first lift:	11:15	12:20	11:05	10:50	10:45	10:45	9:35
Time of last lift:	15:45	16:00	15:55	15:55	18:00	17:45	15:45
Operating time (hours):	4:30	3:40	4:50	5:05	7:15	7:00	6:10
Average water temperature (°F):	69.8	69.0	70.3	70.9	71.7	71.5	70.1
American shad	95	16	363	505	26	199	601
Blueback herring	2	8	0	0	0	0	0
Alewife	0	0	0	0	0	0	0
Gizzard shad	563	916	830	1,691	790	726	331
Hickory shad	0	0	0	0	0	0	0
Striped bass	25	13	4	10	22	65	17
Carp	3	0	3	3	23	19	1
Other species	424	103	44	61	227	177	318
Total	**1,112**	**1,056**	**1,244**	**2,270**	**1,088**	**1,186**	**1,268**

Date:	1 Jun	2 Jun	3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	TOTAL
Day:	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	
Number of lifts:	6	6	7	12	12	11	11	**425**
Time of first lift:	11:30	10:57	11:40	9:35	8:40	8:55	8:35	
Time of last lift:	15:44	15:50	17:00	15:55	15:45	15:45	15:40	
Operating time (hours):	4:14	4:53	5:20	6:20	7:05	6:50	7:05	**195:10**
Average water temperature (°F):	69.6	69.7	69.9	70.3	70.6	70.2	71.0	
American shad	16	78	63	176	188	99	212	**10,940**
Blueback herring	0	9	1	0	0	0	0	**16,320**
Alewife	0	0	0	0	0	0	0	**7,824**
Gizzard shad	295	675	920	891	1,310	1,217	1,210	**218,124**
Hickory shad	0	0	0	0	0	0	0	**36**
Striped bass	52	100	29	15	7	14	29	**710**
Carp	1	0	6	31	187	20	3	**994**
Other species	116	181	402	143	408	160	201	**49,434**
Total	**480**	**1,043**	**1,421**	**1,256**	**2,100**	**1,510**	**1,655**	**309,804**

Table 3

Summary of American shad transported from the Conowingo Dam West Fish Lift, 2001.

Date	Number of Shad Transported	Location	Observed Mortality	Percent Survival
3 May	106	USFWS Lamar Hatchery	0	100.0
5 May	100	USFWS Lamar Hatchery	0	100.0
8 May	102	USFWS Lamar Hatchery	1	99.0
15 May	100	USFWS Lamar Hatchery	0	100.0
19 May	100	USFWS Lamar Hatchery	0	100.0
23 May	100	USFWS Lamar Hatchery	0	100.0
29 May	100	USFWS Lamar Hatchery	1	99.0
2 June	100	USFWS Lamar Hatchery	0	100.0
4 June	62	USFWS Lamar Hatchery	1	98.4
8 June	100	USFWS Lamar Hatchery	1	99.0
Total	**970**		**4**	**99.6**

Table 4

Summary of American shad transported by Maryland DNR from the Conowingo Dam West Fish Lift, 2001.

Date	Water Temperature (°F)	Number of Shad: Female	Number of Shad: Male	Total Number of Shad Transported
02 May	64.4	69	156	225
14 May	71.3	72	123	195
21 May	68.1	83	122	205
31 May	70.1	50	38	88
06 Jun	70.2	62	48	110
TOTAL		**336**	**487**	**823**

Table 5

Summary of alewife and blueback herring transported from the Conowingo Dam West Fish Lift, 2001.

Date	Number Collected	Water Temperature (°F)	Number Transported	Stocking Location	Observed Mortality	Percent Survival	D.O. (ppm) Start	D.O. (ppm) Finish
				Alewife				
27 April	1,625	66.7	500	Little Conestoga	0	100.0	-	-
28 April	1,870	59.6	1,020	Little Conestoga	0	100.0	-	-
2 May	3,496	64.4	200	Conestoga River	0	100.0	12.6	13.2
4 May	-	65.0	100	Conestoga River	0	100.0	12.0	13.0
TOTAL	**6,991**		**1,820**		**0**	**100.0**		
				Blueback herring				
27 April	1,625	66.7	500	Little Conestoga	1	99.8	-	-
28 April	1,900	59.6	1,010	Little Conestoga	1	99.9	-	-
2 May	1,241	64.4	800	Conestoga River	3	99.6	12.6	13.2
4 May	7,750	65.0	1,890	Conestoga River	9	99.5	12.0	13.0
6 May	-	67.3	849	Conodoguinet Creek	3	99.6	9.6	11.1
TOTAL	**12,516**		**5,049**		**17**	**99.7**		

Table 6. Catch and effort for American shad taken at the Conowingo Dam West fish lift during primary collection periods[1] in 1985-2000.

Year	Number Days	Number Lifts	Number Fishing Hrs.	Total Catch	Catch/ Day	Catch/ Lift	Catch/ Hour
1985	37	883	330.3	1531	41	2	4.6
1986	53	780	427.0	5187	98	7	12.1
1987	49	1294	480.5	7653	156	6	15.9
1988	54	1216	467.5	5133	95	4	11.0
1989	46	1075	442.4	8301	180	8	18.8
1990	62	1372	567.5	15958	257	12	28.1
1991	59	1222	526.1	13330	226	11	25.3
1992	61	1535	573.4	10333	169	7	18.0
1993	41	961	392.6	5319	130	6	13.5
1994	44	937	423.1	5607	127	6	13.3
1995	64	1216	632.2	15588	244	13	24.7
1996	27	454	253.8	11468	425	25	45.2
1997	44	611	295.1	12974	295	21	44.0
1998	26	361	175.0	6558	252	18	37.5
1999	43	709	312.6	9658	225	14	30.9
2000	31	375	190.4	9784	316	26	51.4
2001	**40**	**420**	**193.5**	**10939**	**273**	**26**	**56.5**

[1] Excludes early and late season catch and effort when less than 10 shad/day were taken.

Table 7

Operations and fish catch at Conowingo West Fish Lift, 1985-2001.

Year	Number of Days	Total Fish	Number of Taxa	American Shad	Hickory Shad	Alewife	Blueback Herring
1985	55	2.318M	41	1,546	9	377	6,763
1986	59	1.831M	43	5,195	45	2,822	6,327
1987	60	2.593M	46	7,667	35	357	5,861
1988	60	1.620M	49	5,169	64	712	14,570
1989	53	1.066M	45	8,311	28	1,902	3,611
1990	72	1.188M	44	15,964	77	425	9,658
1991	63	0.533M	45	13,330	120	2,649	15,616
1992	64	1.560M	46	10,335	376	3,344	27,533
1993	45	0.713M	37	5,343	0	572	4,052
1994	47	0.564M	46	5,615	1	70	2,603
1995	68	0.995M	44	15,588	36	5,405	93,859
1996	28	0.233M	39	11,473	0	1	871
1997	44	0.346M	39	12,974	118	11	133,257
1998	41	0.575M	38	6,577	6	31	5,511
1999	43	0.722M	34	9,658	32	1,795	8,546
2000	34	0.458M	37	9,785	1	9,189	14,326
2001	**41**	**0.310M**	**38**	**10,940**	**36**	**7,824**	**16,320**

Summary information of Conowingo West Fish Lift American shad sacrifices,2001

	Males		Females	
	Total Length (mm)	Weight (g)	Total Length (mm)	Weight (g)
Minimum	389	470	470	840
Maximum	530	1420	589	1942
Mean	477.5	905.3	523.7	1374.5

American shad sex ratio information, Conowingo West Fish Lift, 2001.

Date	Total Catch	Male	Female	Male:Female
27 Apr	1	1	--	0.0
28 Apr	10	5	5	1.0
29 Apr	66	42	24	1.8
30 Apr	38	21	17	1.2
1 May	257	67	34	2.0
2 May	220	77	51	1.5
3 May	645	57	43	1.3
4 May	106	59	47	1.3
5 May	75	62	13	4.8
6 May	183	49	13	3.8
7 May	348	59	61	1.0
8 May	872	132	86	1.5
9 May	179	58	43	1.3
10 May	246	42	58	0.7
11 May	73	39	34	1.1
12 May	566	77	53	1.5
13 May	455	27	42	0.6
14 May	334	44	59	0.7
15 May	6	2	4	0.5
17 May	339	58	50	1.2
18 May	1,240	57	51	1.1
19 May	675	53	84	0.6
20 May	466	64	74	0.9
21 May	232	38	74	0.5
22 May	450	39	72	0.5
23 May	162	39	75	0.5
24 May	59	22	37	0.6
25 May	95	35	60	0.6
26 May	16	5	11	0.5
27 May	363	30	78	0.4
28 May	505	53	126	0.4
29 May	26	7	19	0.4
30 May	199	25	98	0.3
31 May	601	26	91	0.3
1 Jun	16	5	11	0.5
2 Jun	78	30	48	0.6
3 Jun	63	12	51	0.2
4 Jun	176	27	88	0.3
5 Jun	188	11	98	0.1
6 Jun	99	28	71	0.4
7 Jun	212	15	129	0.1
Total	**10,940**	**1,599**	**2,183**	**0.7♂:1.0♀**

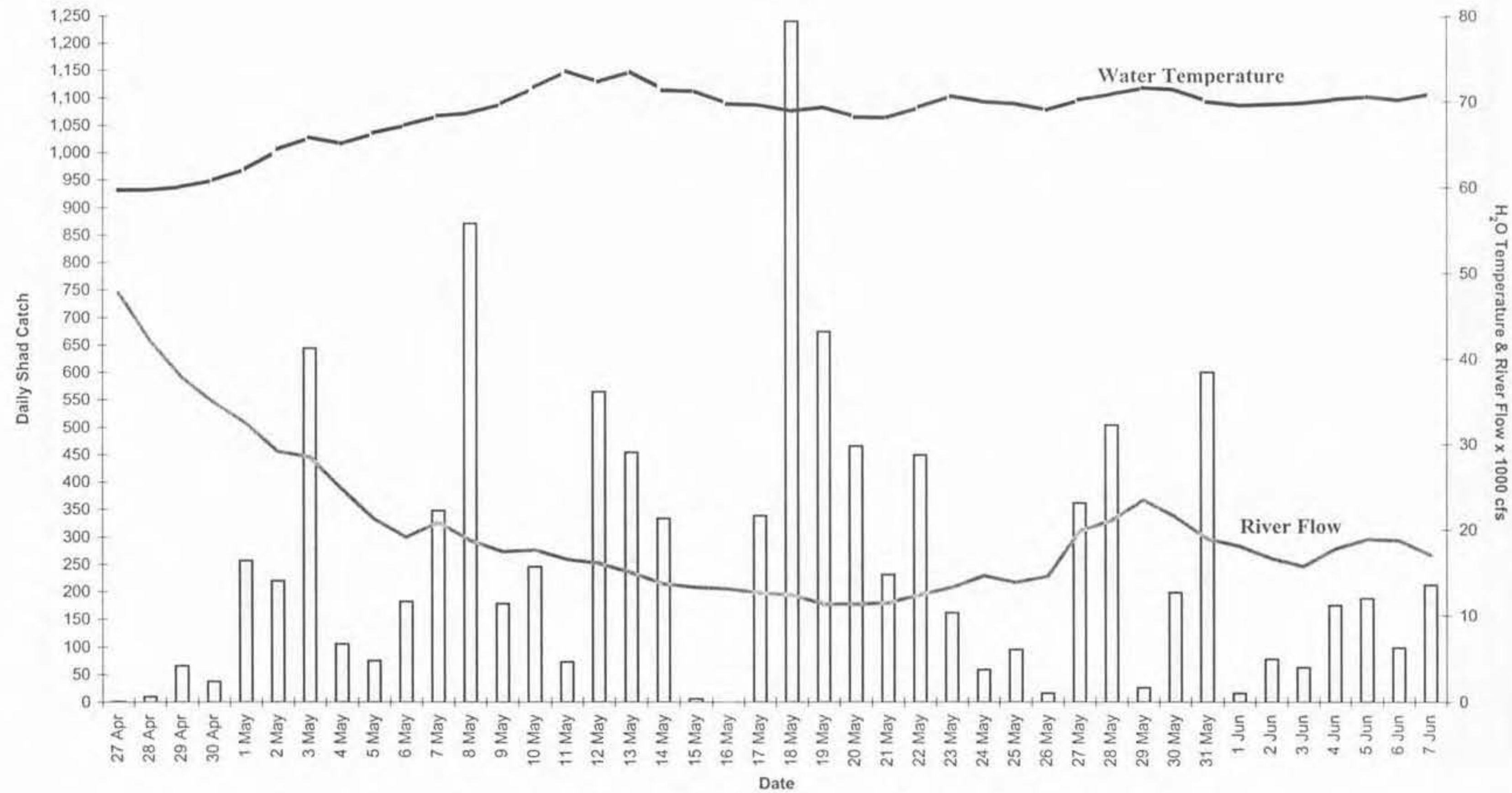

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 2001.

JOB I – Part 3

SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY, SPRING 2001

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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 fish passage facility consisting of tailrace and spillway lifts successfully operated during spring 1997, 1998, 1999,and 2000. Spring 2001 operations marked the fifth year of the fish passage effort.

Two meetings 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 during fall 2000. The meetings included discussions of, and a consensus on operation of the fishway during the 2001 spring migration season.

Objectives of 2001 upstream fishway operation were (1) monitor passage of migratory and resident fishes through the fishway; and (2) continue to assess fishway operation.

HOLTWOOD OPERATION

Project Operation

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units having a combined generating capacity of 102 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 winter or summer flash boards, operation of two rubber dams installed as part of the fishway project, and operation of the Safe Harbor Hydroelectric Station upriver from Holtwood. Holtwood fishway operations began on 27 April 2001. Plant staff installed the summer flashboards on 2 May, due to low, stable river flows. In spring 2001, spill events occurred infrequently. The two rubber dams were inflated during fishway operations in 2001 to reduce the discharge of water into the east channel of the spillway.

Fishway Design and Operation

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.

Two inflatable rubber dams, operated from the hydro control room, are an integral component of effective spillway lift operation. During fish lift operations in 2001, both the 40 ft long, 10 ft high rubber crest dam and the 300 ft long, 4 ft 9 in high rubber crest dam were 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 new 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, or a combination of A and C were used in 2001.

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 97% of the time throughout the 2001 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 limited catch of shad early in the season at Conowingo Dam delayed the start of full Holtwood operations until 27 April. We operated the tailrace lift for 41 days during the season while the spillway lift operated on 17 days. The spillway lift was not operated on a regular basis after 13 May due to the absence of spillway flows, which limited the number of American shad attracted to the spillway. Daily 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, 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

We present the diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2001 operational period in Table 1. A total of 310,175 fish of 27 taxa and one hybrid passed upstream into Lake Aldred. Gizzard shad (188,098) comprised nearly 61% of the fishes passed. American shad numbered 109,976 (35% of the total) and represented the second largest portion of the catch. The 2001 American shad total was the largest observed in the five years of fish lift operations. Other abundant fishes passed included shorthead redhorse (4,738), channel catfish (1,413), smallmouth bass (1,399), and blueback herring (1,300). Peak passage occurred on 7 May when 26,705 fish (46% American shad) were passed.

Other migratory species collected by the fishway included 1 alewife, 4 striped bass, and 11 white perch (Table 1).

American Shad Passage

The lifts passed 86,333 American shad between 1 and 16 May, representing 78% of the season total. During this peak period, the fishway collected and passed more than 5,000 shad on 8 days, and passed more than 3,000 shad on 6 days. River flows averaged 19,887 cfs during this period of operation. Peak catch occurred on 7 May when 12,341 shad were captured and passed. Following the peak, (from 17 May to 8 June), we captured a total of 19,518 shad at river flows averaging 16,150 cfs.

We passed American shad at water temperatures between 57.4°F and 71.2°F, and river flows ranging from 11,400 cfs to 47,700 cfs (Table 2 and Figure 1). Water temperature and river flows during the peak catch period (from 1 May to 16 May) averaged 68.6°F (61.7°F to 71.0°F) and 19,887 cfs (13,100 cfs to 32,500 cfs), respectively.

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 103 ft to 119 ft. Typically tailrace elevations correspond to unit operation, as well as the operation of the Muddy Run and Conowingo hydro projects. During spring 2001, most tailrace fishway operation coincided with varying turbine operation/generation due to lower than normal spring river flows. The spillway lift operated at spillway elevations of 116 ft to 123 ft. After flashboards were installed on 2 May, spillage did not occur and the spillway elevation remained at 116 ft.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164 ft to 170 ft (Table 2). Visual observations indicated that shad readily passed through the fishway into Lake Aldred at this range of forebay elevations. On 2 May, during installation of the summer flash boards, large numbers of shad passed by the counting window in 8 inches of water and through the fishway in just over 4 ft of water.

The hourly passage numbers of American shad at Holtwood is provided in Table 3. Most shad (104,860) passed through the fishway between 0900 hrs and 1859 hrs. Generally, shad passage was strong from 0900 hrs to 1859 hrs, then declined sharply until operation was ended each evening.

We completed a qualitative assessment of the relative number of shad using the tailrace and spillway lifts by viewing each hopper of fish and estimating the number of shad in each lift as they were sluiced into the trough. We summarized this information by lift, and applied results to the daily shad passage count. We determined the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 101,947 and 8,029 shad (92.7% and 7.3%), were captured in the tailrace and spillway lifts over the total spring 2001 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.

Operation and effectiveness of the spillway lift was dependent on flow conditions in the spillway, particularly the east channel. More than 56% (4,528 shad) of the total spillway catch was collected during three days of operation (1, 2, and 5 May; Table 4). Due to low spring river flows, spill events were rare in spring 2001, resulting in small numbers of shad attracted into the spillway lift area. The spillway fish lift was operated on only one occasion after 13 May.

Passage Evaluation

In 2001, our fishway evaluation efforts focused on visual observations of migrating fish movements both downriver from, and in the tailrace and spillway lifts. We hope to optimize future fishway operations by utilizing knowledge gained through these observations. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on visual observations of fish movements. Fish survival in the fishways was excellent; we observed no mortalities.

We experimented with various equipment settings in an effort to improve flows both from and within the fishway to enhance operations. As we identified favorable conditions, these were maintained. The utilization of higher entrance gate settings appeared to improve attraction flows. The use of gate No. 8 reduced the vortex in the fish trough. The low river flows this spring allowed early deployment of the "slick bar". Lift operators experimented with various flow configurations that enabled the maximum volume of attraction flow while drawing in as little debris as possible.

Daily visual surveys were conducted in the east channel of the spillway from the shore of Piney Island. On those occasions when shad were observed in the east channel area and spill was minimal, the spillway lift was able to quickly collect and pass those shad into Lake Aldred.

SUMMARY

In 2001, the Holtwood tailrace fish lift was operated for 41 days while the spillway lift operated on 17 days. The tailrace and spillway lifts were functional 97% of the time. A total of 109,976 American shad were passed into Lake Aldred, the highest total since operations started in 1997. A record total of 1,300 blueback herring and one alewife also passed through the fishway.

A low, stable, river flow appears to be critical for enhancing shad passage rates. The low flow conditions in spring 2001 were ideal for fish passage, and allowed personnel to experiment with various lift component settings that may improve passage rates in future years.

Passage and survival of fish that utilized the fishway in 2001 was excellent. The 2001 American shad passage total was the highest recorded since the fishway's start-up in 1997. Future operations of the fishway will build on the past five years of operation experience.

RECOMMENDATIONS

- 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.

- 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.

- 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.

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 2001.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*
Hours of Operation - Tailrace:	*5.20*	*7.20*	*7.50*	*8.20*	*7.40*	*0.00*	*10.70*	*9.40*	*9.60*	*10.10*	*9.60*
Hours of Operation - Spillway:	*5.20*	*7.30*	*7.30*	*8.10*	*7.40*	*10.40*	*0.00*	*9.20*	*9.50*	*9.60*	*3.90*
Number of Lifts - Tailrace:	*7*	*12*	*12*	*14*	*15*	*0*	*17*	*18*	*21*	*18*	*22*
Number of Lifts - Spillway:	*6*	*9*	*8*	*8*	*10*	*17*	*0*	*8*	*12*	*9*	*4*
Water Temperature (°F):	*57.4*	*58.4*	*59.7*	*60.5*	*61.7*	*63.1*	*65.4*	*67.7*	*70.2*	*70.9*	*71.0*
American shad	448	820	1,284	1,573	2,661	933	5,017	4,641	7,104	6,197	12,341
Blueback herring	0	0	0	0	0	0	0	0	10	0	0
Alewife	0	1	0	0	0	0	0	0	0	0	0
Gizzard shad	1,420	2,560	4,245	6,310	8,477	592	8,686	8,334	5,050	5,235	13,830
Sea lamprey	0	0	3	0	3	0	0	3	12	2	7
Rainbow trout	0	1	2	2	2	2	2	0	2	0	0
Brown trout	0	0	0	0	1	0	0	1	3	11	6
Splake (brook x lake trout)	1	1	0	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0	1	0	0
Carp	0	0	1	0	3	6	5	13	31	40	259
Quillback	15	49	11	28	14	51	14	10	176	35	13
White sucker	3	18	21	5	7	1	0	0	2	0	6
Northern hogsucker	0	0	2	0	0	0	0	0	0	0	0
Shorthead redhorse	81	150	99	55	63	89	249	176	387	136	89
Yellow bullhead	0	0	0	0	0	0	0	0	1	2	0
Channel catfish	11	3	2	10	7	2	8	10	38	33	18
White perch	0	0	0	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	2	0	0	5	3	2	8	11
Green sunfish	0	0	0	0	1	0	0	0	4	0	13
Pumpkinseed	0	0	0	0	1	0	0	1	0	0	0
Bluegill	0	0	0	0	0	0	0	1	12	5	10
Rock bass	2	3	1	10	4	0	4	1	13	1	8
Smallmouth bass	27	24	31	120	186	184	80	69	232	63	41
Largemouth bass	1	1	0	2	3	0	0	1	1	1	2
Spotail shiner	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	3	0	0	0	0	3	2	4	8	2
Walleye	4	23	5	14	7	3	15	35	33	31	49
Total	***2,013***	***3,657***	***5,707***	***8,131***	***11,440***	***1,863***	***14,088***	***13,301***	***13,118***	***11,808***	***26,705***

Table 1

Continued.

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*
Hours of Operation - Tailrace:	*10.60*	*10.60*	*10.40*	*10.10*	*9.20*	*9.20*	*10.40*	*10.80*	*10.80*	*4*	*10.5*
Hours of Operation - Spillway:	*10.30*	*9.80*	*9.80*	*9.80*	*7.60*	*4.30*	*0.00*	*0.00*	*0.00*	*0*	*0*
Number of Lifts - Tailrace:	*19*	*20*	*18*	*18*	*17*	*16*	*18*	*22*	*20*	*8*	*15*
Number of Lifts - Spillway:	*11*	*11*	*9*	*9*	*9*	*4*	*0*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*70.7*	*69.8*	*68.8*	*68.7*	*69.7*	*70.0*	*70.0*	*69.3*	*70.8*	*68.9*	*67.9*
American shad	8,120	7,923	5,175	6,165	3,976	4,461	3,894	3,935	3,790	526	2,528
Blueback herring	6	53	225	34	22	11	51	1	4	48	3
Alewife	0	0	0	0	0	0	0	0	0	0	0
Gizzard shad	8,067	15,321	6,759	9,952	5,607	1,871	6,623	6,965	5,190	1,529	3,896
Sea lamprey	2	1	7	3	2	1	2	2	1	0	0
Rainbow trout	0	7	2	1	1	1	0	0	1	0	0
Brown trout	1	0	0	1	3	0	0	0	0	0	0
Splake (brook x lake trout)	0	0	0	1	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0	0	0	0
Carp	11	174	40	13	32	7	2	19	44	2	9
Quillback	29	194	49	28	8	2	2	0	32	2	8
White sucker	0	4	0	0	0	0	0	0	0	0	0
Northern hogsucker	0	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	147	368	247	187	302	182	154	214	168	125	242
Yellow bullhead	1	0	0	0	0	0	0	0	0	0	0
Channel catfish	67	56	36	16	64	22	50	7	16	14	24
White perch	0	0	0	1	2	3	0	2	0	0	0
Striped bass	1	0	0	0	0	0	0	0	1	0	0
Redbreast sunfish	0	15	5	2	2	9	0	7	1	2	0
Green sunfish	0	3	1	0	0	0	0	0	0	0	0
Pumpkinseed	13	0	0	1	0	0	0	0	0	0	0
Bluegill	20	8	0	11	9	4	12	1	0	1	6
Rock bass	0	9	7	2	0	3	6	1	3	2	7
Smallmouth bass	66	51	34	25	22	8	20	6	9	5	18
Largemouth bass	2	3	1	3	2	0	1	0	1	0	1
Spottail shiner	0	0	0	0	0	8	0	0	0	0	0
Yellow perch	2	0	0	1	0	2	0	0	0	0	0
Walleye	51	92	58	43	53	25	31	35	62	16	33
Total	***16,606***	***24,282***	***12,646***	***16,490***	***10,107***	***6,620***	***10,848***	***11,195***	***9,323***	***2,272***	***6,775***

Table 1

Continued.

Date:	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Hours of Operation - Tailrace:	*9.8*	*7.9*	*10.20*	*11.50*	*12.50*	*9.70*	*10.20*	*10.00*	*8.00*	*11.10*	*9.00*
Hours of Operation - Spillway:	*0*	*0*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*2.30*	*0.00*
Number of Lifts - Tailrace:	*16*	*14*	*17*	*17*	*19*	*16*	*16*	*14*	*12*	*16*	*14*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*2*	*0*
Water Temperature (°F):	*66.3*	*66.3*	*66.4*	*65.4*	*65.4*	*67.7*	*67.5*	*67.4*	*66.5*	*68.4*	*68.8*
American shad	505	2,261	1,209	3,214	668	2,894	781	656	252	1,130	369
Blueback herring	0	6	0	0	2	3	5	314	5	1	0
Alewife	0	0	0	0	0	0	0	0	0	0	0
Gizzard shad	2,756	817	4,486	7,650	3,765	5,538	5,879	4,142	1,116	5,898	3,728
Sea lamprey	0	2	0	0	1	1	0	0	0	0	0
Rainbow trout	0	2	0	0	0	1	0	3	1	0	0
Brown trout	1	0	0	0	0	0	0	0	0	0	0
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0	0	0	0	0
Carp	9	3	2	1	1	26	14	1	3	2	3
Quillback	0	0	4	0	2	18	74	12	6	10	2
White sucker	0	0		0	0	0	0	0	0	0	0
Northern hogsucker	0	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	141	36	59	24	115	191	103	32	14	42	15
Yellow bullhead	0	0	0	0	0	0	0	0	0	0	0
Channel catfish	58	36	16	4	35	8	2	31	58	219	235
White perch	1	0	0	0	0	0	0	0	0	0	1
Striped bass	0	0	0	0	0	0	0	0	0	0	0
Redbreast sunfish	0	1	4	4	0	2	3	0	0	0	2
Green sunfish	0	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0
Bluegill	2	3	2	0	4	0	0	7	6	7	1
Rock bass	0	0	3	1	1	0	0	0	0	3	3
Smallmouth bass	4	3	6	1	19	1	6	3	4	19	3
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0
Spotttail shiner	0	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0	0	0	0
Walleye	13	7	15	8	4	5	6	3	1	11	16
Total	***3,490***	***3,177***	***5,806***	***10,907***	***4,617***	***8,688***	***6,873***	***5,204***	***1,466***	***7,342***	***4,378***

Table 1

Continued.

Date:	*30 May*	*31 May*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*TOTAL*
Hours of Operation - Tailrace:	*8.60*	*1.00*	*11.00*	*10.70*	*8.50*	*8.20*	*8.40*	*6.60*	*6.40*	***370.8***
Hours of Operation - Spillway:	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	***131.8***
Number of Lifts - Tailrace:	*11*	*1*	*17*	*16*	*11*	*11*	*12*	*9*	*9*	***615***
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***146***
Water Temperature (°F):	*68.4*	*67.9*	*67.2*	*67.3*	*67.0*	*67.1*	*68.7*	*69.7*	*71.2*	
American shad	123	24	1,102	621	176	145	131	91	112	***109,976***
Blueback herring	0	2	7	468	5	0	4	0	10	***1,300***
Alewife	0	0	0	0	0	0	0	0	0	***1***
Gizzard shad	1,171	13	1,778	421	285	427	1,083	399	227	***188,098***
Sea lamprey	0	0	0	0	0	0	0	0	0	***55***
Rainbow trout	1	0	0	0	0	1	1	0	0	***36***
Brown trout	0	0	0	0	0	0	0	0	0	***28***
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	***3***
Muskellunge	0	0	0	0	0	0	0	0	0	***1***
Carp	1	0	8	3	1	0	21	7	6	***823***
Quillback	0	0	0	1	0	0	14	6	1	***920***
White sucker	0	0	0	0	0	0	0	0	0	***67***
Northern hogsucker	0	0	0	0	0	0	0	0	0	***2***
Shorthead redhorse	18	0	13	6	8	1	5	4	1	***4,738***
Yellow bullhead	0	0	0	0	0	0	0	0	0	***4***
Channel catfish	20	2	47	38	6	5	59	20	0	***1,413***
White perch	1	0	0	0	0	0	0	0	0	***11***
Striped bass	0	0	2	0	0	0	0	0	0	***4***
Redbreast sunfish	4	0	6	3	0	0	0	0	2	***105***
Green sunfish	2	0	1	0	0	0	0	0	0	***25***
Pumpkinseed	0	0	0	0	0	0	0	0	0	***16***
Bluegill	2	0	4	0	4	0	0	0	0	***142***
Rock bass	2	0	2	0	1	1	0	0	0	***104***
Smallmouth bass	1	0	1	1	1	3	0	0	2	***1,399***
Largemouth bass	0	0	0	0	0	0	0	0	0	***26***
Spottail shiner	0	0	0	0	0	0	0	0	0	***8***
Yellow perch	1	0	0	0	0	0	0	0	0	***28***
Walleye	2	1	7	2	2	0	15	4	2	***842***
Total	***1,349***	***42***	***2,978***	***1,564***	***489***	***583***	***1,333***	***531***	***363***	***310,175***

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 2001.

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)
27 Apr	47,700	57.4	26	10	150		220	118-119	119-123	168-169
28 Apr	42,100	58.4	26	10	150		220	118	121-123	168-169
29 Apr	37,900	59.7	24	10	150		220	115-118	116-123	165-169
30 Apr	34,900	60.5	24	10	150		220	115-118	119-123	167-168
1 May	32,500	61.7	30	10	150		220	114-118	116-121	165-168
2 May	29,200	63.1	22	0			220		116	164
3 May	28,500	65.4	18	10	150			114-116		164-167
4 May	24,800	67.7	22	10	150		220	115-117	116	166-170
5 May	21,300	70.2	32	10	150		220	114-117	116	166-169
6 May	19,200	70.9	30	10	150		220	115-117	116	166-167
7 May	20,900	71.0	30	10	150		220/0	115-117	116	166-167
8 May	18,800	70.7	36	10	150		220	115-116	116	169-170
9 May	17,500	69.8	36	10	150		220	115	116	167-168
10 May	17,700	68.8	36	10	150		220	114-116	116	168-170
11 May	16,600	68.7	36	10	150		220	114-116	116	166-167
12 May	16,100	69.7	36	10	150		220	113-116	116	167-169
13 May	15,000	70.0	32	10	150		220/0	114-115	116	166-169
14 May	13,700	70.0	36	10	150			109-115		167-169
15 May	13,300	69.3	36	10	150	150		109-118		168-169
16 May	13,100	70.8	34	10	150	150		108-115		168-169
17 May	12,700	68.9	32	10	150	150		113-114		168-169
18 May	12,400	67.9	32	10	150			107-114		168-169
19 May	11,400	66.3	32	10	150	150		107-115		168-169
20 May	11,400	66.7	32	10	150	150		103-114		168-169
21 May	11,500	66.4	32	10	150			105-115		169-170

Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs)			Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
					A	B	C			
22 May	12,500	65.4	32	10	150			104-115		169
23 May	13,300	65.4	30	10	150	0/150		106-115		167-169
24 May	14,700	67.7	32	10	150			113-114		169
25 May	13,900	67.5	32	10	150			113-114		169-170
26 May	14,600	67.4	30	10	150			104-114		168-169
27 May	19,900	66.6	30	10	150			104-116		169
28 May	21,200	68.4	30	10	150		220/0	111-116	116	168-169
29 May	23,500	68.8	30	10	150			108-113		168-169
30 May	21,600	68.4	16	10	150			113-116		169
31 May	19,000	67.9	16	10	150			113		169
2 Jun	16,700	67.2	18	10	150	150/0		112-114		168-169
3 Jun	15,800	67.3	18	10	150			104-113		168-169
4 Jun	17,800	67.0	16	10	150			112-114		168-169
5 Jun	18,900	67.1	16	10	150			112-115		168
6 Jun	18,800	68.7	16	10	150			111.3-113		168
7 Jun	17,100	69.7	16	10	150			111.3-112.4		167.9-168
8 Jun	16,600	71.2	16	10	150			109-114		167-169

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 2001.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*
Observation Time (Start):	*13:05*	*11:00*	*10:10*	*10:40*	*11:05*	*8:25*	*8:30*	*9:42*	*9:00*	*8:32*	*9:15*
Observation Time (End):	*18:45*	*18:50*	*18:55*	*18:45*	*18:50*	*19:00*	*19:40*	*19:00*	*19:00*	*19:00*	*19:15*
Military Time (hrs)											
0600 to 0659											
0700 to 0759											
0800 to 0859						4	222			70	
0900 to 0959						86	503	186	423	354	240
1000 to 1059			1	3		154	1,003	728	979	280	1,191
1100 to 1159		24	1	154	67	52		820	930	220	1,255
1200 to 1259		63	69	203	506	104		444	718	312	906
1300 to 1359	38	124	219	320	579	152	12	412	796	435	1,358
1400 to 1459	134	107	239	352	627	112	556	342	1,052	960	1,596
1500 to 1559	101	187	432	137	375	112	742	645	793	1,153	2,032
1600 to 1659	89	134	139	252	268	58	583	295	589	1,171	1,724
1700 to 1759	44	96	90	97	149	44	465	415	511	784	880
1800 to 1859	42	85	94	55	90	55	624	354	313	458	1,023
1900 to 1959							307				136
2000 to 2059											
Total	**448**	**820**	**1,284**	**1,573**	**2,661**	**933**	**5,017**	**4,641**	**7,104**	**6,197**	**12,341**

Table 3

Continued.

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*
Observation Time (Start):	*8:05*	*8:30*	*8:45*	*8:34*	*8:20*	*8:15*	*8:20*	*8:30*	*8:00*	*8:40*	*8:10*
Observation Time (End):	*19:00*	*19:30*	*19:20*	*19:00*	*18:14*	*19:00*	*19:15*	*19:40*	*19:20*	*14:30*	*19:00*
Military Time (hrs)											
0600 to 0659											
0700 to 0759											
0800 to 0859	444	62	51	50	88	19	33	11	272	14	61
0900 to 0959	397	1,228	256	339	147	3	210	262	315	203	544
1000 to 1059	1,026	587	246	343	391	106	233	339	316	74	287
1100 to 1159	624	1,105	315	702	419	197	384	506	174	5	60
1200 to 1259	824	883	398	712	550	424	366	277	191		155
1300 to 1359	1,078	394	730	873	526	586	440	279	192	71	209
1400 to 1459	695	557	432	629	389	896	385	519	366	8	535
1500 to 1559	932	571	335	850	426	761	328	531	693		358
1600 to 1659	1,093	625	669	569	475	295	439	292	216		199
1700 to 1759	575	499	986	745	550	594	521	431	534		74
1800 to 1859	432	1,012	576	353	15	536	466	170	420		46
1900 to 1959		400	181			44	89	318	101	151	
2000 to 2059											
Total	**8,120**	**7,923**	**5,175**	**6,165**	**3,976**	**4,461**	**3,894**	**3,935**	**3,790**	**526**	**2,528**

Table 3

Continued.

Date:	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Observation Time (Start):	*8:25*	*8:30*	*8:20*	*7:15*	*8:20*	*8:20*	*8:35*	*7:00*	*6:15*	*7:50*	*8:30*
Observation Time (End):	*18:30*	*16:30*	*18:30*	*18:00*	*21:00*	*18:20*	*18:30*	*16:30*	*15:10*	*19:00*	*17:32*
Military Time (hrs)											
0600 to 0659									3		
0700 to 0759				816				207	60		
0800 to 0859	6	16	14	93	41	93	44	89	93	49	47
0900 to 0959	36	1,672	15	3	17	753	63	232	6	73	31
1000 to 1059	53	460	36	3	89	384	55	42	10	87	25
1100 to 1159	130	37	109	135	34	155	96	15	5	110	42
1200 to 1259	20	15	233	682	19	289	109	15	6	121	57
1300 to 1359	15	12	265	627	53	300	71	13	20	149	86
1400 to 1459	69	42	145	556	81	251	64	16	35	134	31
1500 to 1559	36	4	152	164	59	281	122	17	14	105	35
1600 to 1659	46	3	146	135	51	245	84	10		96	12
1700 to 1759	58		58		40	118	63			110	3
1800 to 1859	36		36		99	25	10			96	
1900 to 1959					55						
2000 to 2059					30						
Total	**505**	**2,261**	**1,209**	**3,214**	**668**	**2,894**	**781**	**656**	**252**	**1,130**	**369**

Table 3

Continued.

Date:	*30 May*	*31 May*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	
Observation Time (Start):	*8:45*	*8:20*	*8:25*	*7:45*	*7:50*	*8:45*	*8:15*	*8:23*	*8:15*	
Observation Time (End):	*17:30*	*10:00*	*19:20*	*18:30*	*16:20*	*16:45*	*16:15*	*14:50*	*16:15*	***Total***
Military Time (hrs)										
0600 to 0659										**3**
0700 to 0759				27	27					**1,137**
0800 to 0859		11	2	64	23	3	24	8	4	**2,125**
0900 to 0959	11	7	31	44	14	24	24	35	19	**8,806**
1000 to 1059	13		103	58	28	16	16	20	10	**9,795**
1100 to 1159	9		89	44	19	15	9	4	5	**9,076**
1200 to 1259	13	6	102	13	10	13	9	7	13	**9,857**
1300 to 1359	12		121	37	22	27	10	12	15	**11,690**
1400 to 1459	11		111	82	18	12	15	5	12	**13,178**
1500 to 1559	24		109	103	15	18	18		22	**13,792**
1600 to 1659	25		147	79		17	6		12	**11,288**
1700 to 1759	5		182	56						**9,777**
1800 to 1859			66	14						**7,601**
1900 to 1959			39							**1,821**
2000 to 2059										**30**
Total	**123**	**24**	**1,102**	**621**	**176**	**145**	**131**	**91**	**112**	**109,976**

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2001.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
27 Apr	448	403	45	90%	10%
28 Apr	820	656	164	80%	20%
29 Apr	1284	578	706	45%	55%
30 Apr	1573	1,494	79	95%	5%
1 May	2661	1,197	1,464	45%	55%
2 May	933	0	933	0%	100%
3 May	5017	5,017	0	100%	0%
4 May	4641	4,178	463	90%	10%
5 May	7104	4,973	2,131	70%	30%
6 May	6197	5,825	372	94%	6%
7 May	12341	12,341	0	100%	0%
8 May	8120	7,958	162	98%	2%
9 May	7923	7,131	792	90%	10%
10 May	5175	4,657	518	90%	10%
11 May	6165	6,005	160	96%	4%
12 May	3976	3,936	40	99%	1%
13 May	4461	4,461	0	100%	0%
14 May	3894	3,894	0	100%	0%
15 May	3935	3,935	0	100%	0%
16 May	3790	3,790	0	100%	0%
17 May	526	526	0	100%	0%
18 May	2528	2,528	0	100%	0%
19 May	505	505	0	100%	0%
20 May	2261	2,261	0	100%	0%
21 May	1209	1,209	0	100%	0%
22 May	3214	3,214	0	100%	0%
23 May	668	668	0	100%	0%
24 May	2894	2,894	0	100%	0%
25 May	781	781	0	100%	0%
26 May	656	656	0	100%	0%
27 May	252	252	0	100%	0%
28 May	1130	1,130	0	100%	0%
29 May	369	369	0	100%	0%
30 May	123	123	0	100%	0%
31 May	24	24	0	100%	0%
2 Jun	1102	1,102	0	100%	0%
3 Jun	621	621	0	100%	0%
4 Jun	176	176	0	100%	0%
5 Jun	145	145	0	100%	0%
6 Jun	131	131	0	100%	0%
7 Jun	91	91	0	100%	0%
8 Jun	112	112	0	100%	0%
Total	*109,976*	*101,947*	*8,029*	*92.7%*	*7.3%*

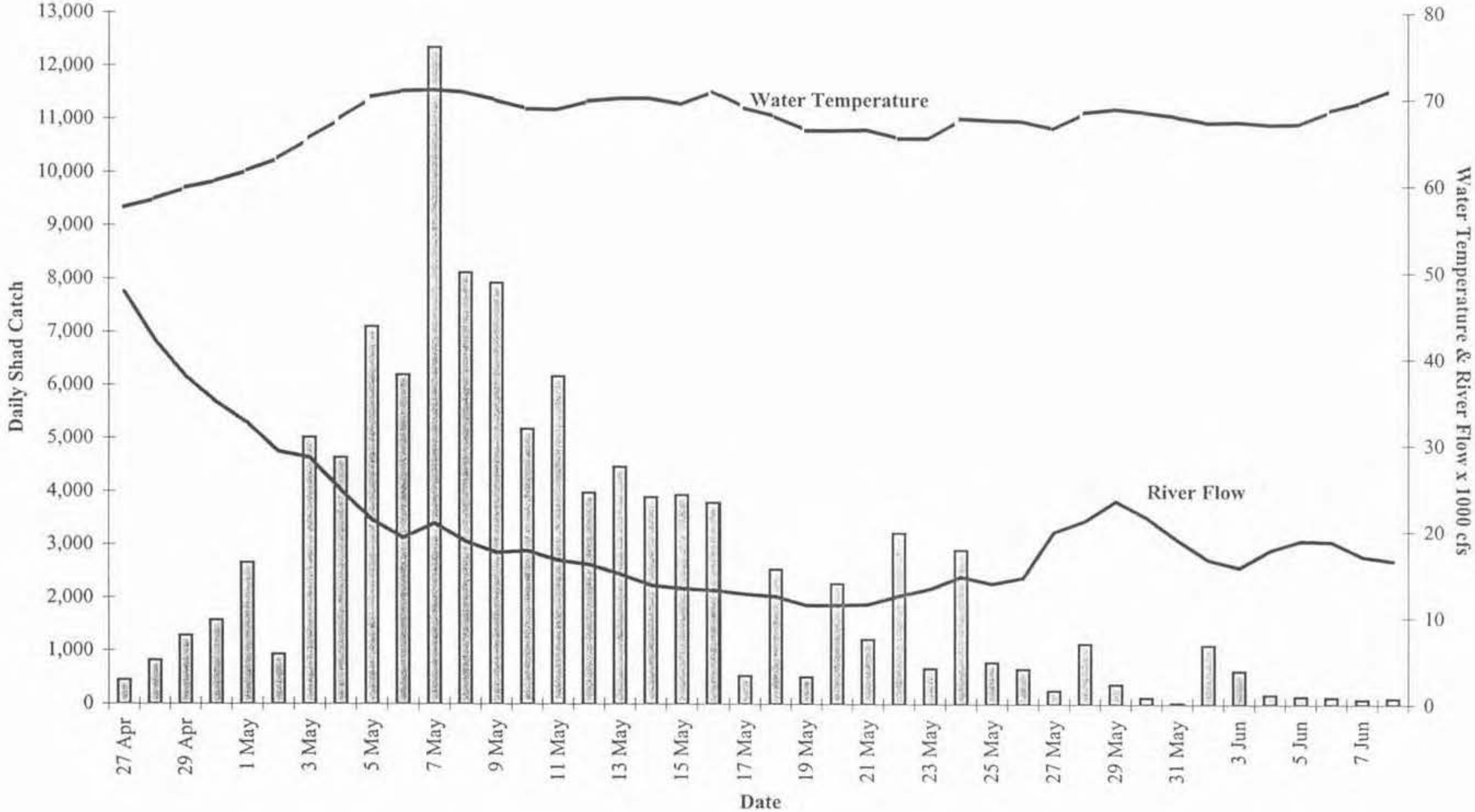

Figure 1

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 2001.

JOB I – Part 4

SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY, SPRING 2001

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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 2001 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATION

Project Operation

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

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

Fishway Design 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 2001 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 28 April.

The Safe Harbor fishway began operation on 30 April and continued until 12 June. Operation ceased on 12 June, at which time the fish catch was dwindling and the water temperature was rising; indications that the migration run was ending.

Throughout the 2001 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 2001 season, two mechanical incidences occurred; each with little loss of fishing time:

- On 6 May the trough was drawn down for inspection and to clean out debris. The trough was then refilled and fishing continued; and
- On 13 May the crowder gate broke. Fishing continued on 14 May with the broken gate. Fish that entered the downstream channel were not crowded into the hopper until the crowder gate was fixed later that day.

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 2001 by the Safe Harbor fishway is presented in Table 1. A total of 262,416 fish of 27 species and 2 hybrids passed upstream into Lake Clarke. Gizzard shad (151,873) was the dominant species passed and comprised 58% of the catch. Some 89,816 American shad were passed upstream through the fishway. Other predominant fishes passed included walleye (5,779), quillback (4,608), shorthead redhorse (3,425), and smallmouth bass (3,379). Peak passage occurred on 8 May, when 19,714 fish were passed.

American Shad Passage

The Safe Harbor fishway passed 89,816 American shad in 2001 during 39 days of operation (Table 1). Though collection and passage of shad varied daily, numbers remained relatively steady through most of May with over 90% (80,993) of the catch passing in the 24 day period prior to 24 May. Peak shad passage occurred on 8 May when 7,107 shad were captured and passed in approximately eight hours of operation.

American shad were passed at water temperatures of 58.0°F to 75.0°F and river flows of 34,900 to 11,400 cfs (Table 2 and Figure 1). Water temperature and river flow from 30 April to 23 May, the 24 day period when most shad passage occurred, averaged 69.3°F (58°F to 70.2°F) and 18,875 cfs (11,400 cfs to 34,900 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, there was a steady increase in shad catch from 0700 to 1459 hr with a sharp, then steady decrease in catch from 1500 to 1859 hr. Nearly 87% of shad (78,738) passed during the eight hour period between 0800 and 1559 hr. The highest hourly passage (10,742) occurred between 1400 and 1459 hr.

The Safe Harbor fishway passed sixty tagged American shad during the 2001 season; ten shad with chartreuse floy tags and fifty shad with pink floy tags. The fish were passed between 1 May and 7 June. The pink floy tagged shad were captured and released in Conowingo's tailrace by the MDDNR via hook and line in 2001.

Alosids

Passage of other alosids at the Safe Harbor fishway included 13 alewife and 710 blueback herring. No hickory shad were observed.

SUMMARY

The 2001 Safe Harbor fishway operating season was successful. Low river flow and large numbers of shad available in Lake Aldred allowed a record amount of American shad to pass through the Safe Harbor fishway. In 39 days, 89,816 American shad were passed into Lake Clarke, or over 82% of the American shad that were passed into Lake Aldred by the Holtwood fishway. Observations indicated that fish reaching the fishway were effectively captured and passed upstream. Other alosids (13 alewife, 710 blueback herring) were also passed by the Safe Harbor fishway.

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 2001.

Date:	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*
Hours of Operation:	*6.7*	*7.9*	*3.3*	*7.0*	*9.4*	*9.4*	*7.8*
Start Time:	*10:00*	*10:00*	*12:20*	*10:40*	*8:00*	*8:00*	*9:13*
End Time:	*16:40*	*17:55*	*15:35*	*17:40*	*17:25*	*17:23*	*17:00*
Numbers of Lifts:	*11*	*16*	*7*	*17*	*19*	*19*	*15*
Water Temperature (F):	*58.0*	*61.0*	*62.0*	*64.0*	*67.0*	*68.5*	*70.2*
American shad	1,192	1,495	1,247	1,477	3,548	2,675	3,138
Blueback herring	0	0	0	0	0	0	1
Alewife	0	1	1	3	0	3	4
Gizzard shad	2,095	3,471	2,680	2,899	5,308	5,635	4,103
Rainbow trout	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0
Splake	0	0	1	0	1	0	0
Muskellunge	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	1	0
Carp	1	5	0	30	26	50	293
Sea lamprey	1	6	0	0	0	1	0
Quillback	104	276	10	430	337	327	488
White sucker	0	0	0	0	2	0	1
Shorthead redhorse	1	565	99	508	430	404	175
Brown bullhead	0	0	0	1	0	0	0
Channel catfish	0	1	0	3	41	45	16
Yellow bullhead	1	0	0	0	3	1	0
Striped bass	0	0	0	1	0	0	0
Redbreast sunfish	1	0	0	0	30	0	0
Green sunfish	0	0	0	0	0	0	0
Pumpkinseed	0	1	0	7	10	23	24
Bluegill	1	2	0	17	9	21	43
Rock bass	5	1	4	38	159	69	37
Smallmouth bass	228	385	192	573	537	410	290
Largemouth bass	4	2	2	10	7	2	7
White crappie	0	0	0	0	1	0	0
Black crappie	0	0	0	0	0	0	0
Yellow perch	0	2	0	0	4	3	2
Walleye	11	58	28	136	377	500	242
Total	***3,645***	***6,271***	***4,264***	***6,133***	***10,830***	***10,170***	***8,864***

Table 1

Continued.

Date:	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*
Hours of Operation:	*9.5*	*8.0*	*9.3*	*9.6*	*10.8*	*10.8*	*9.3*
Start Time:	*8:00*	*9:15*	*8:10*	*8:10*	*6:30*	*6:40*	*7:00*
End Time:	*17:27*	*17:15*	*17:25*	*17:45*	*17:17*	*17:25*	*16:17*
Numbers of Lifts:	*21*	*21*	*21*	*21*	*21*	*23*	*21*
Water Temperature (F):	*70.0*	*69.0*	*69.0*	*68.0*	*68.0*	*68.0*	*68.0*
American shad	5,541	7,107	4,526	5,960	6,801	6,842	5,255
Blueback herring	0	0	0	0	9	67	119
Alewife	0	0	0	1	0	0	0
Gizzard shad	5,999	11,510	7,036	11,865	7,526	7,259	6,110
Rainbow trout	1	0	0	0	0	0	3
Brown trout	0	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0
Tiger muskie	0	1	0	0	0	0	0
Carp	61	45	20	32	50	31	20
Sea lamprey	1	5	1	1	2	2	4
Quillback	520	178	236	108	367	83	142
White sucker	3	6	2	1	3	0	0
Shorthead redhorse	608	155	56	12	24	56	11
Brown bullhead	0	0	0	0	0	0	1
Channel catfish	56	16	9	28	31	33	8
Yellow bullhead	0	0	0	0	0	0	0
Striped bass	2	0	0	0	0	0	0
Redbreast sunfish	59	14	0	0	21	0	5
Green sunfish	4	0	0	3	1	0	1
Pumpkinseed	13	2	4	5	2	4	1
Bluegill	49	4	7	1	8	18	3
Rock bass	125	22	4	2	10	11	2
Smallmouth bass	350	81	51	21	23	53	9
Largemouth bass	14	4	0	8	1	1	1
White crappie	0	1	0	2	0	0	0
Black crappie	0	2	0	0	0	1	0
Yellow perch	4	1	0	0	0	1	0
Walleye	1,188	560	83	82	81	235	17
Total	***14,598***	***19,714***	***12,035***	***18,132***	***14,960***	***14,697***	***11,712***

Table 1

Continued.

Date:	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*
Hours of Operation:	*8.4*	*10.3*	*11.8*	*7.2*	*7.5*	*8.5*	*8.8*
Start Time:	*9:20*	*7:15*	*7:50*	*8:35*	*9:00*	*7:43*	*8:15*
End Time:	*17:45*	*17:30*	*19:40*	*15:45*	*16:30*	*16:15*	*17:00*
Numbers of Lifts:	*16*	*19*	*20*	*15*	*12*	*20*	*14*
Water Temperature (F):	*69.0*	*68.5*	*68.0*	*67.0*	*68.0*	*68.0*	*68.0*
American shad	3,606	3,230	2,887	1,388	1,735	3,978	1,827
Blueback herring	12	8	12	18	0	5	6
Alewife	0	0	0	0	0	0	0
Gizzard shad	4,064	4,957	4,937	1,183	968	4,128	1,590
Rainbow trout	2	0	1	0	0	0	0
Brown trout	1	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0
Muskellunge	1	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0
Carp	15	6	14	3	1	4	1
Sea lamprey	0	0	1	2	1	1	2
Quillback	19	18	153	153	29	19	12
White sucker	1	0	0	0	0	0	0
Shorthead redhorse	26	11	41	18	6	21	17
Brown bullhead	0	0	0	0	0	0	0
Channel catfish	7	8	25	25	4	5	7
Yellow bullhead	0	0	0	0	0	0	0
Striped bass	0	0	1	0	0	0	1
Redbreast sunfish	14	1	10	0	1	0	0
Green sunfish	0	0	0	0	0	0	0
Pumpkinseed	0	0	2	0	0	0	0
Bluegill	9	13	4	6	0	5	4
Rock bass	6	7	6	9	3	9	4
Smallmouth bass	15	40	24	11	4	5	6
Largemouth bass	1	1	2	0	0	0	0
White crappie	2	0	0	1	0	0	0
Black crappie	1	0	1	0	0	0	0
Yellow perch	0	0	1	2	0	1	0
Walleye	131	167	304	180	121	190	195
Total	***7,933***	***8,467***	***8,426***	***2,999***	***2,873***	***8,371***	***3,672***

Table 1

Continued.

Date:	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours of Operation:	*8.8*	*8.6*	*9.0*	*9.0*	*6.0*	*7.3*	*8.1*
Start Time:	*7:15*	*8:00*	*7:30*	*8:00*	*10:30*	*8:55*	*8:00*
End Time:	*16:00*	*16:35*	*16:30*	*17:00*	*16:30*	*16:10*	*16:05*
Numbers of Lifts:	*15*	*18*	*20*	*17*	*17*	*17*	*20*
Water Temperature (F):	*64.0*	*64.0*	*64.0*	*65.0*	*66.0*	*65.0*	*67.0*
American shad	902	1,586	3,050	1,662	1,827	1,125	777
Blueback herring	11	4	3	4	8	5	343
Alewife	0	0	0	0	0	0	0
Gizzard shad	1,465	5,866	8,375	4,596	2,985	3,496	5,200
Rainbow trout	0	0	0	0	0	0	0
Brown trout	0	0	0	0	0	0	0
Splake	0	0	0	0	0	0	0
Muskellunge	0	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0
Carp	0	2	3	9	4	11	1
Sea lamprey	0	0	3	0	1	0	0
Quillback	35	95	35	19	27	340	18
White sucker	0	0	0	0	0	0	0
Shorthead redhorse	1	6	7	11	25	59	20
Brown bullhead	1	0	0	0	0	0	0
Channel catfish	17	3	5	21	5	29	3
Yellow bullhead	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0
Redbreast sunfish	0	0	3	2	0	0	0
Green sunfish	0	0	1	0	0	0	0
Pumpkinseed	1	0	0	0	0	0	0
Bluegill	0	5	0	1	7	5	0
Rock bass	1	1	0	1	3	10	0
Smallmouth bass	1	7	4	4	8	10	2
Largemouth bass	0	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0
Walleye	105	43	52	44	65	254	50
Total	***2,540***	***7,618***	***11,541***	***6,374***	***4,965***	***5,344***	***6,414***

Table 1

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*
Hours of Operation:	*7.4*	*7.0*	*6.4*	*6.8*	*6.6*		
Start Time:	*7:25*	*7:46*	*8:31*	*8:06*	*8:30*		
End Time:	*14:48*	*14:45*	*14:52*	*14:53*	*15:05*		
Numbers of Lifts:	*13*	*7*	*6*	*7*	*6*		
Water Temperature (F):	*66.0*	*67.0*	*67.0*	*67.0*	*67.0*		
American shad	533	596	292	354	114		
Blueback herring	15	15	5	1	0		
Alewife	0	0	0	0	0		
Gizzard shad	4,485	3,525	2,275	915	587		
Rainbow trout	1	0	0	0	0		
Brown trout	0	0	0	0	0		
Splake	0	0	0	0	0		
Muskellunge	0	0	0	0	0		
Tiger muskie	0	0	0	0	0		
Carp	3	4	1	0	5		
Sea lamprey	0	0	0	0	0		
Quillback	9	9	0	3	1		
White sucker	0	0	0	0	0		
Shorthead redhorse	14	4	4	7	12		
Brown bullhead	0	0	0	0	0		
Channel catfish	17	20	5	29	80		
Yellow bullhead	0	0	0	0	0		
Striped bass	0	0	0	0	0		
Redbreast sunfish	4	0	0	0	3		
Green sunfish	1	0	0	0	2		
Pumpkinseed	0	0	0	0	0		
Bluegill	1	8	4	4	1		
Rock bass	2	3	0	2	0		
Smallmouth bass	2	13	3	1	0		
Largemouth bass	0	1	0	0	0		
White crappie	0	0	0	1	2		
Black crappie	0	0	0	0	0		
Yellow perch	0	2	0	0	0		
Walleye	91	76	9	6	10		
Total	***5,178***	***4,276***	***2,598***	***1,323***	***817***	***0***	***0***

Table 1

Continued.

Date:	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*
Hours of Operation:	*6.8*	*6.3*		*7.8*	*6.2*		
Start Time:	*8:10*	*8:45*		*8:20*	*8:50*		
End Time:	*14:55*	*15:00*		*16:10*	*15:00*		
Numbers of Lifts:	*10*	*7*		*10*	*8*		
Water Temperature (F):	*65.0*	*68.0*		*70.0*	*70.9*		
American shad	599	350		308	101		
Blueback herring	16	5		0	3		
Alewife	0	0		0	0		
Gizzard shad	945	340		980	260		
Rainbow trout	0	0		0	1		
Brown trout	0	0		0	0		
Splake	0	0		0	0		
Muskellunge	0	0		0	0		
Tiger muskie	0	0		0	0		
Carp	0	2		5	7		
Sea lamprey	0	0		1	0		
Quillback	2	0		0	2		
White sucker	0	0		0	0		
Shorthead redhorse	5	0		2	2		
Brown bullhead	0	0		0	0		
Channel catfish	11	11		41	23		
Yellow bullhead	0	0		0	0		
Striped bass	0	0		0	0		
Redbreast sunfish	1	0		0	0		
Green sunfish	0	0		0	0		
Pumpkinseed	0	0		0	0		
Bluegill	0	4		7	4		
Rock bass	1	1		0	2		
Smallmouth bass	1	2		4	1		
Largemouth bass	0	0		0	0		
White crappie	0	0		0	1		
Black crappie	0	0		1	0		
Yellow perch	0	0		0	0		
Walleye	5	1		26	11		
Total	***1,586***	***716***	***0***	***1,375***	***418***	***0***	***0***

Table 1

Continued.

Date:	*11 Jun*	*12 Jun*	*Totals*
Hours of Operation:	*6.4*	*3.5*	***309.3***
Start Time:	*8:37*	*8:30*	
End Time:	*15:00*	*12:00*	
Numbers of Lifts:	*9*	*5*	***581***
Water Temperature (F):	*74.7*	*75.0*	
American shad	97	88	***89,816***
Blueback herring	10	5	***710***
Alewife	0	0	***13***
Gizzard shad	215	40	***151,873***
Rainbow trout	0	0	***9***
Brown trout	0	0	***1***
Splake	0	0	***2***
Muskellunge	0	0	***1***
Tiger muskie	0	0	***2***
Carp	1	1	***767***
Sea lamprey	0	0	***36***
Quillback	1	3	***4,608***
White sucker	0	0	***19***
Shorthead redhorse	2	0	***3,425***
Brown bullhead	0	0	***3***
Channel catfish	34	4	***726***
Yellow bullhead	0	0	***5***
Striped bass	0	0	***5***
Redbreast sunfish	0	0	***169***
Green sunfish	0	0	***13***
Pumpkinseed	0	0	***99***
Bluegill	12	0	***287***
Rock bass	1	0	***561***
Smallmouth bass	5	3	***3,379***
Largemouth bass	0	0	***68***
White crappie	0	0	***11***
Black crappie	0	0	***6***
Yellow perch	0	0	***23***
Walleye	38	7	***5,779***
Total	***416***	***151***	***262,416***

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 2001.

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)
30 Apr	34,900	58.0	30	9	1, 2 to 8, 10	A & C	500	171.20-172.5	225.5-226.58
1 May	32,500	61.0	28	10	1 to 8,10,12	A & C	500	170.8-172.0	226-226.52
2 May	29,200	62.0	24	5	4 to 7, 2	A & C	500	169.4-169.8	226.8-226.9
3 May	28,500	64.0	26	8	1 to 7, 9	A & C	500	169.2-172.9	225.8-226.7
4 May	24,800	67.0	24	8	1-3,5-7,9,10	A & C	500	168.4-172.2	225.9-226.7
5 May	21,300	68.5	26	8	3 to 10	A & C,B & C	500	165.5-172.0	225.7-226.3
6 May	19,200	70.2	28	5	3 to 7	A & C	500	167.8-169.9	226.3-226.6
7 May	20,900	70.0	24	9	1 to 9	A & C	500	168.4-170.6	226.1-226.9
8 May	18,800	69.0	21	10	1 to 10	A & C	500	169.93-171.20	225.75-226.65
9 May	17,500	69.0	26	10	1 to 10	A & C	500	168.71-169.61	225.39-226.41
10 May	17,700	68.0	36	10	1 to 10	A & C	500	169.1-170.1	225.6-226.9
11 May	16,600	68.0	28	8	1,2, 4 to 7,9,10	A & C	500	168.4-169.0	225.5-226.6
12 May	16,100	68.0	26	6	3 to 7, 9	A & C	500	168.0-169.4	225.0-226.3
13 May	15,000	68.0	24	3	3 to 5	A & C	500	169.2	226.0
14 May	13,700	69.0	24	1	2	A & C	500	170-170.2	226.0
15 May	13,300	68.5	26	3	1 to 2, 6	A & C	500	168.6-170.0	225.8-226.6
16 May	13,100	68.0	24	6	1,2, 4 to 7	A & C	500	168.4-170.1	225.7-226.8
17 May	12,700	67.0	20	5	1,2, 4 to 6	A & C	500	169.9	226.7
18 May	12,400	68.0	22	9	1 to 7 , 9, 10	A & C	500	170.6	226.2
19 May	11,400	68.0	18	4	4 to 7	A & C	500	168.3-169.2	225.8-226.4
20 May	11,400	68.0	22	2	5, 6	A & C	500	168.4-168.7	226.6
21 May	11,500	64.0	22	6	1,2, 4 to 7	A & B & C	500	168.9-170.2	226.2-226.8
22 May	12,500	64.0	22	6	1,2, 4 to 7	A & C	500	169-171.2	225.7-227.0
23 May	13,300	64.0	20	6	1,2, 3 to 5, 7	A & C	500	168.8-171.2	225.7-226.6

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)
24 May	14,700	65.0	22	10	1 to 10	A & C	500	170.0	227.1
25 May	13,900	66.0	22	6	2, 4 to 7, 12	A & C	500	169.3-170.5	225.4-226.3
26 May	14,600	65.0	24	4	4 to 7	A & C	500	168.52-170.0	226.2-226.63
27 May	19,900	67.0	24	5	3 to 7	A & C	500	169.7	226.5
28 May	21,200	66.0	18	5	2, 4 to 7	A & C	500	168.9-169.8	226.9
29 May	23,500	67.0	20	7	1,2, 4 to 7, 9	A & C	500	169.3-170.7	226.2-226.4
30 May	21,600	67.0	18	7	1,2, 4 to 7, 9	A & C	500	169.4-170.3	226.3-226.5
31 May	19,000	67.0	16	6	1,2, 4 to 7	A & C	500	169.1-169.4	225.9-226.1
1 Jun	18,100	67.0	16	5	1,2, 4 to 6	A & C	500	168.8-169.7	225.9-226.8
4 Jun	17,800	65.0	14	5	1,2, 4 to 6	A & C	500	169.1-169.5	226.2-227.0
5 Jun	18,900	68.0	14	3	1,2,6	A & C	500	169.2-170.0	226.3-226.5
7 Jun	17,100	70.0	16-18	6	1,2, 4 to 7	A & C	500	169.1-170.9	225.4-226.7
8 Jun	16,600	70.9	18	5	1,2, 4 to 6	A & C	500	169.5	226.6
11 Jun	14,100	74.7	18-20	6	1,2, 4 to 7	A & B & C	500	169.42-170.1	226.1-226.75
12 Jun	12,900	75.0	20-22	7	1,2,5,6 8 to 10	A & C	500	168.9-168.95	226.6-226.69

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2001.

Date:	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*
Observation Time (Start):	*10:45*	*9:45*	*12:25*	*10:30*	*8:10*	*8:00*	*9:00*	*8:30*	*9:15*	*7:30*
Observation Time (End):	*16:40*	*18:15*	*16:00*	*18:00*	*17:40*	*17:45*	*17:55*	*17:45*	*17:30*	*17:40*
Military time (hrs)										
0700 to 0759										74
0800 to 0859					440	291		147		222
0900 to 0959					1,230	326	178	932	222	498
1000 to 1059	20	134		88	523	304	216	586	1,102	422
1100 to 1159	117	217		251	368	321	332	498	1,425	405
1200 to 1259	191	242	30	416	221	188	365	351	1,326	862
1300 to 1359	128	189	285	270	190	285	502	448	957	672
1400 to 1459	353	208	475	143	155	229	551	1,077	813	337
1500 to 1559	231	210	457	109	198	139	485	667	485	486
1600 to 1659	152	91		85	182	327	261	334	454	363
1700 to 1759		193		115	41	265	248	501	323	185
1800 to 1859		11								
Total	***1,192***	***1,495***	***1,247***	***1,477***	***3,548***	***2,675***	***3,138***	***5,541***	***7,107***	***4,526***

Table 3

Continued.

Date:	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
Observation Time (Start):	*8:10*	*7:00*	*6:45*	*7:00*	*9:25*	*7:00*	*8:05*	*8:00*	*9:00*	*8:00*
Observation Time (End):	*18:10*	*17:55*	*17:40*	*16:40*	*17:45*	*17:40*	*19:50*	*16:00*	*16:55*	*16:45*
Military time (hrs)										
0700 to 0759		297	1,022	556		220				
0800 to 0859	611	1,273	1,754	1,333		224	274	172		408
0900 to 0959	732	1,154	991	634	46	265	491	106	57	817
1000 to 1059	412	639	640	503	169	313	449	208	91	415
1100 to 1159	661	478	389	459	216	273	310	192	701	392
1200 to 1259	571	603	483	303	264	458	464	159	284	465
1300 to 1359	467	589	417	385	703	450	322	122	395	354
1400 to 1459	764	565	297	474	814	454	226	146	207	472
1500 to 1559	720	564	312	360	693	276	119	283		393
1600 to 1659	509	347	394	248	527	175	232			262
1700 to 1759	399	292	143		174	122				
1800 to 1859	114									
Total	***5,960***	***6,801***	***6,842***	***5,255***	***3,606***	***3,230***	***2,887***	***1,388***	***1,735***	***3,978***

Table 3

Continued.

Date:	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Observation Time (Start):	*7:50*	*7:45*	*7:50*	*8:45*	*8:25*	*10:05*	*8:25*	*8:25*	*8:40*	*9:00*
Observation Time (End):	*17:15*	*16:11*	*16:55*	*16:45*	*17:15*	*16:40*	*16:25*	*16:46*	*15:25*	*15:00*
Military time (hrs)										
0700 to 0759	7	30	11							
0800 to 0859	129	134	48	328	163		85	70	54	
0900 to 0959	266	85	115	407	89		123	73	99	185
1000 to 1059	370	77	237	305	197	140	186	160	80	88
1100 to 1159	277	171	169	482	187	404	175	81	89	131
1200 to 1259	140	82	304	260	147	389	195	82	72	61
1300 to 1359	176	158	281	291	300	276	179	91	53	67
1400 to 1459	120	44	157	408	228	275	86	114	66	64
1500 to 1559	121	100	156	436	160	271	83	67	20	
1600 to 1659	163	21	108	133	191	72	13	39		
1700 to 1759	58									
1800 to 1859										
Total	***1,827***	***902***	***1,586***	***3,050***	***1,662***	***1,827***	***1,125***	***777***	***533***	***596***

Table 3

Continued.

Date:	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*
Observation Time (Start):	*9:00*	*9:00*	*9:00*			*8:50*	*8:45*		*8:42*	*8:50*
Observation Time (End):	*15:00*	*15:14*	*15:20*			*15:10*	*15:24*		*16:20*	*15:15*
Military time (hrs)										
0700 to 0759										
0800 to 0859						3	19		28	4
0900 to 0959	56	162	41			83	52		20	10
1000 to 1059	71	46	22			76	45		28	17
1100 to 1159	30	27	15			78	40		43	10
1200 to 1259	41	20	26			123	20		37	16
1300 to 1359	34	35	6			110	48		42	13
1400 to 1459	60	53	4			105	87		63	29
1500 to 1559		11				21	39		44	2
1600 to 1659									3	
1700 to 1759										
1800 to 1859										
Total	***292***	***354***	***114***	***0***	***0***	***599***	***350***	***0***	***308***	***101***

Table 3

Continued.

Date:	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*TOTAL*
Observation Time (Start):			*9:00*	*8:50*	
Observation Time (End):			*15:10*	*13:00*	
Military time (hrs)					
0700 to 0759					***2,217***
0800 to 0859				10	***8,224***
0900 to 0959			32	14	***10,591***
1000 to 1059			20	11	***9,410***
1100 to 1159			8	13	***10,435***
1200 to 1259			1	40	***10,302***
1300 to 1359			14		***10,304***
1400 to 1459			19		***10,742***
1500 to 1559			3		***8,721***
1600 to 1659					***5,686***
1700 to 1759					***3,059***
1800 to 1859					***125***
Total	***0***	***0***	***97***	***88***	***89,816***

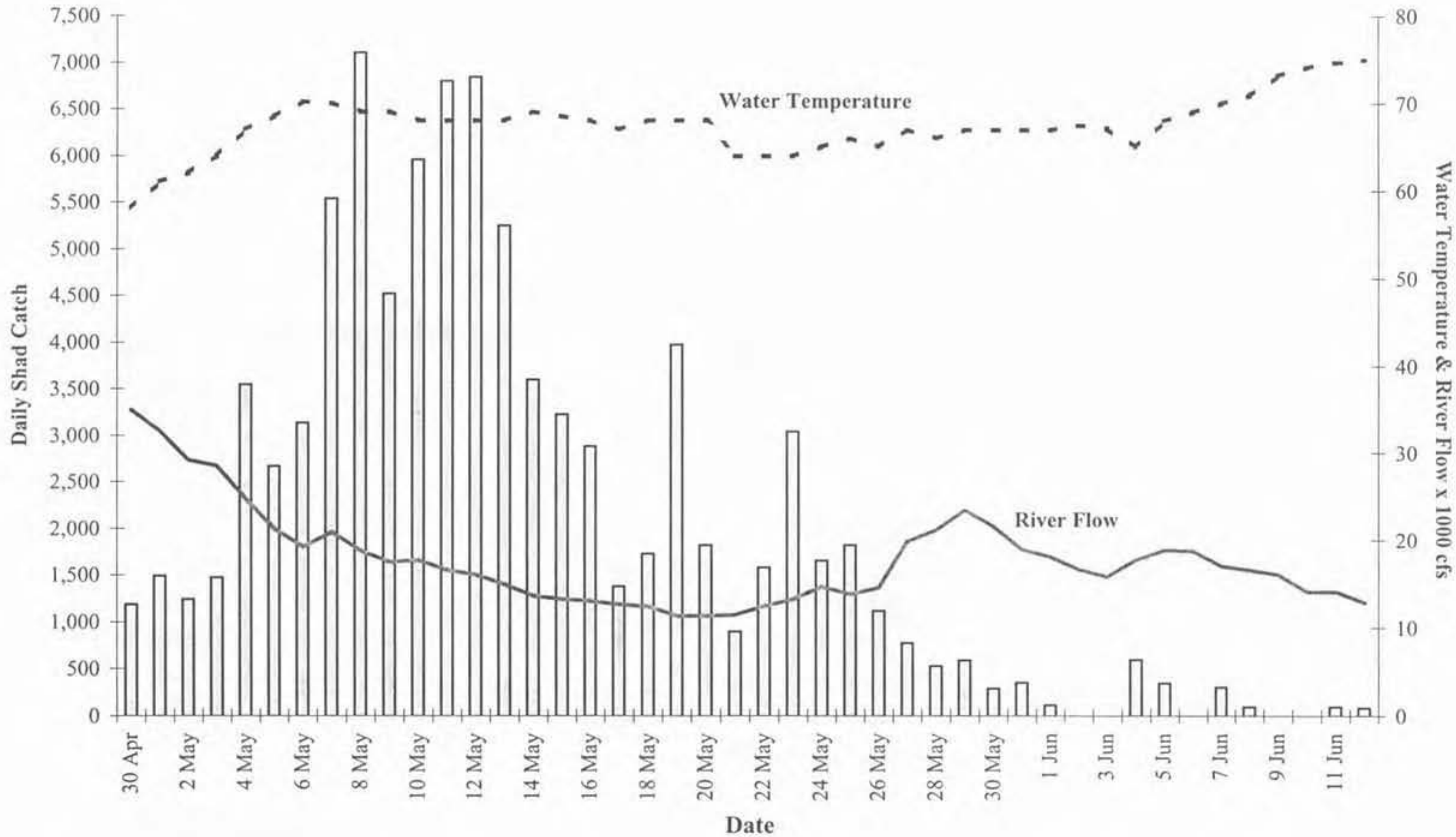

Figure 1

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 lift, spring 2001.

JOB I - Part 5

SUMMARY OF OPERATION AT THE YORK HAVEN FISHWAY IN 2001

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EXECUTIVE SUMMARY

Fishway operation at York Haven began on 3 May 2001. The fish ladder was operated continuously for a period of 37 days. Operation of the fishway was problem-free allowing upstream passage of fish at the project throughout the spring migration season. Based on a decline in the number of prespawned American shad observed passing through the ladder, fishway operation was canceled for the season on 8 June.

A total of 143,820 fish of 29 taxa were observed passing through the ladder. Gizzard shad was the dominant species observed using the ladder and comprised slightly more than 62% of the total number of fish that passed. Alosa species that passed included 16,200 American shad and 4 blueback herring.

Passage of shad varied daily with approximately 97% (15,577) of the shad passing between 4 and 29 May. Peak passage occurred on 10 May when 1,393 shad were passed. Some 97.4% and 2.6% of the shad passed in May and June, respectively. American shad were passed at water temperatures of 61.5°F to 73.5°F, river flows of 9,850 cfs to 23,117 cfs, and nominal East Channel flows of 2,000. Daily shad passage was generally highest early each day, then declined and leveled off mid-morning through mid-afternoon, followed by a slight decline during the last three hours of viewing. Total hourly shad passage was highest during the first two hours of viewing (0800 hrs to 0959 hrs). Peak hourly passage of shad (454) occurred on 12 May between 0800 hrs and 0859 hrs.

The normal 4,000 cfs Main Dam spill required during operation of fishway was maintained throughout the 37-day operating period except that, on a trial basis from 9 May to 8 June (31 days), spill over the Main Dam was reduced (low spill) at the end of fishway operation (1900 hrs) on alternate (fifteen) nights. The low spill varied from approximately 1,000 cfs up to 1,700 cfs (difference in operation of one additional turbine). The total number of shad that passed through the fishway during the entire day and/or during discrete time periods on the day following low spill were often greater than the number of shad that passed during the corresponding time periods following normal spill. Depending on the time period, the number of shad that passed through the fishway following low spill increased by 15.4% to 25.9%.

The second year of fishway operation was very successful. Passage and survival of fish that utilized the fishway was excellent. Operating experience coupled with implementation of recommendations from the 2001 season should enhance future operation of the fishway as well as increase the knowledge and understanding of American shad passage at the York Haven Project.

INTRODUCTION

In 1993, York Haven Power Company (YHPC), the licensees of the downstream Safe Harbor and Holtwood projects, various state and federal resource agencies, and two non-governmental organizations signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement required that migratory fish passage facilities be in service at the two downstream projects no later than April 1997, and at York Haven by April 2000. This agreement was reached based on numerous factors including, but not limited to, an increasing Susquehanna River American shad population and completion of a permanent fish passage facility at Conowingo Dam in 1991. 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.

YHPC placed into service the York Haven fishway at the East Channel Dam in April 2000. 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. Operation of the fishway has opened the river upstream to the Fabridam at Sunbury as well as most of the Juniata River, a major tributary of the Susquehanna.

On 2 April, prior to the start of fishway operation, a meeting of the York Haven Fish Passage Technical Advisory Committee (FPTAC) comprised of YHPC, USFWS, Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held at York Haven. The meeting included discussions and consensus on operation of the fishway during the 2001 spring migration season. As agreed upon, operation of the fishway commenced four days following the successful passage of 1,000 American shad through the Safe Harbor fish lift.

Objectives of 2001 operation were: (1) monitor passage of migratory and resident fishes through the York Haven fishway; (2) assess the effect that 4,000 cfs controlled spill over the Main Dam has on fishway effectiveness, and (3) continue to assess fishway operation, including improvements implemented based on the first year's operation.

YORK HAVEN OPERATIONS

Project Operation

The hydroelectric station located in York Haven, PA was built in 1904 and is situated at Susquehanna River mile 55 in Dauphin and York counties, Pennsylvania (Figure 1). It is the fourth upstream hydroelectric facility on the river and is located 12 miles south of Harrisburg, the state's capital. 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.

As part of the 1997 settlement agreement, YHPC agreed to maintain a minimum spill of 4,000 cfs over the Main Dam and a minimum release of 2,000 cfs in the East Channel through the open weir adjacent to the fishway during the spring migration. In 2001, with the consent of the FPTAC, the station reduced the 4,000 cfs spill over the Main Dam after the fishway was closed for the evening to a minimum of 1,000 cfs, on an alternate day basis, as described below.

Fishway Design and Operation

Fishway Design

Fishway design incorporated numerous criteria established by the USFWS and the other resource agencies. This included 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. The upper portion of the "weir cut" includes three independent groups of 25-ft diameter coffer cells between which two 20-ft fixed wheel gates are installed. The lower section of the "weir cut" includes a 67-ft adjustable weir with fixed crest at elevation 271.0 ft and a stop gate. The 250-ft long fish ladder has an entrance diffuser, serpentine baffles that form eight pools, and an exit flume. The design population of the fish ladder is 500,000 shad equivalents where ten river herring equal one shad. As in 2000, the fishway was operated this season with both layers of sill blocks installed on top the weir. Each sill block is one foot thick, which resulted in an effective weir crest at elevation of 273.0 ft.

The fish ladder pool volume is 700 cubic feet per pool with a nine-inch maximum rise per pool. Based on the Alden model study (White and Larsen, 1998), flow through the ladder including the pools varies from 33 cfs to 55 cfs, depending on flow in the East Channel. Flow through the "weir cut" in the existing East Channel Dam will range from a low of about 1,800 cfs to a maximum of 3,400 cfs depending on East Channel flow. Flow from the fish ladder entrance is augmented by flow through the diffuser and ranges from 108 cfs to 248 cfs.

Fishway Operation

All preseason preparations to the fishway were completed before 1 April. The fishway was opened on 3 May, four days after the Safe Harbor fish lift passed 1,000 American shad based on the operation plan developed and agreed to by the FPTAC. The fishway remained open for upstream passage until 1700 hrs on 8 June, a 37 consecutive day period. 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, elevated water temperatures, and the advanced spawning condition of shad that were passing through the fishway.

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. In addition, several reconnaissance surveys were made during periods of reduced flow below the Main Dam.

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 2001, 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 1900 hrs and opened each morning by 0800 hrs. Occasionally, it was closed for brief periods of time as needed each day to enable the person manning the fishway to conduct other activities. In an effort to improve viewing the adjustable crowder screen, installed prior to the start of operation, was set at 10-in. This setting was used throughout the season and enabled all fish that passed the ladder to be viewed.

As in 2000, 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 spreadsheet. Passage data and operational conditions were supplied electronically to YHPC's on-site coordinator/manager and other appropriate YHPC and GPU personnel on a daily basis. In addition, weekly passage information was supplied electronically to YHPC and GPU personnel and members of the FPTAC.

Each day a permanent record (video tape) of daily fish passage was made. The video system was the same system used in 2000 and it was set-up identical to that reported by 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 143,820 fish of 29 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (89,272) was the dominant species and comprised nearly 62% of the fish passed. Some 16,200 American shad were counted as they passed through the ladder. Other predominant fishes passed included quillback (12,940), walleye (10,260), channel catfish (4,513), shorthead redhorse (3,521) and smallmouth bass (3,414). Peak passage occurred on 10 May when some 8,225 fish were passed.

American Shad Passage

A total of 16,200 American shad passed upstream through the ladder in 2001 (Table 1). Passage of shad varied daily with approximately 97% (15,577) passing between 4 and 29 May. In May, over 500 American shad passed through the ladder on 13 days; on three of those days over 1,000 shad passed. Peak shad passage occurred on 10 May when 1,393 shad were passed. Some 97.4% and 2.6% of the shad passed in May and June, respectively.

American shad were passed at water temperatures of 61.5°F to 73.5°F, river flows of 9,850 cfs to 23,117 cfs, and East Channel flows of 2,000 cfs (Tables 2 and 3, Figures 3 and 4). Surface water elevations within the fishway varied daily throughout the season; however, due to relatively low river flows throughout the entire period of operation, surface water elevations within the fishway were generally very similar. Eighty-nine shad passed the ladder on 3 May, the day the ladder was opened, at a water temperature of 70.0°F. American shad passage through the ladder occurred in three waves or pulses. Peak passage occurred between 9 and 14 May. During this period 7,111 American shad passed the ladder at water temperatures that varied from 62.0°F to 72.0°F and at river flows that decreased from 15,700 cfs to 12,433 cfs. Some 4,150 shad passed the ladder from 15 to 20 May at water temperatures that varied from 63.5°F to 66.0°F and at river flows that decreased from 11,950 cfs to 9,867 cfs. Some 5,297 shad passed through the fishway between 21 and 29 May. During this period, water temperatures varied from 64.0°F to 69.8°F and river flows increased from 9,867 cfs to 19,133 cfs. During the last 10 days of fishway operation, from 30 May to 8 June, some 970 shad passed as river flows decreased from 18,350 cfs to 11,367 cfs and at water temperatures that increased from a low of 65.0°F to a season high of 73.5°F on 8 June.

The hourly passage of American shad in the fish ladder is given in Table 4. Generally, daily shad passage was highest early each day, then declined and leveled off mid-morning through mid-afternoon and then declined slightly during the last three hours of viewing. Peak hourly passage of shad (454) occurred 12 May between 0800 hrs and 0859 hrs. Total hourly passage was highest during the first two hours of viewing; some 4,230 shad passed during the first hour and 2,103 shad passed during the second hour. Total passage each hour from 1000 hrs to 1559 hrs, although similar, declined from that during the first two hours and varied from 1,514 to 1,055 shad per hour. Total hourly passage between 1600 hrs and 1900 hrs declined slightly from mid-day levels and varied from 862 to 814 shad per hour. Reduced afternoon passage of shad during the middle and later part of the season probably corresponded to a change in the behavior of shad brought about by spawning. It is generally understood that shad spawning is normally greatest around dusk.

Other Alosids

Just four alosids other than American shad were passed (Table 1). All were blueback herring with three passing in May and one in June. Passage occurred on 15, 25 and 30 May and 5 June. No alewife or hickory shad were observed passing through the ladder.

Passage During Modified Project Operation

During 2001, from 9 May to 8 June (31 days), the nightly volume of spill over the Main Dam was reduced from the normal spill (4,000 cfs) on a trial basis. Spill reductions were initiated at the end of fishway operation (1900 hrs) on fifteen alternate nights. Normal spill resumed each morning at approximately 0600 hours. The reduced spill (low spill) varied from approximately 1,000 cfs up to 1,700 cfs (difference in operation of one additional turbine). The total number of shad that passed through the fishway during the entire day and/or during discrete time periods on the day following low spill were often greater than the number of shad that passed during the corresponding time periods following normal spill. Depending on the time period, the number of shad that passed through the fishway following low spill increased by 15.4% to 25.9% (Table 5 and Figures 5 to 9).

Video Record

A review of the video record showed that fish passage was adequately captured on the tape record. Data in Table 6 lists by date and time the shad count, the tape count, and the difference between the two counts. The differences between visual counts and tape counts were minimal and varied from -2 to +4 shad. Viewing conditions as well as tape quality this season were very good. Lack of rain, resulted in relatively stable low river flows throughout the season which resulted in average visibility that ranged from 10.5-in to 24-in (Table 2).

Enhancements made prior to the start of operation this season improved the accuracy of fish passage counts. Average visibility during the season always exceeded the 10-in crowder screen setting. In addition, adding the electric hoist enabled the person counting fish to control the movement of fish that passed the window at any given time. As a result, the accuracy of fish passage numbers was greatly improved from that in 2000.

Observations

Once each day visual observations of fish activity were made on a random basis below the Main Dam. On several occasions several carp and quillback were observed trying to swim over the Main Dam. No shad or other alosids were observed below the Main Dam. It is also important to note that no stranded fish were observed below the Main Dam during several reconnaissance surveys conducted during modified Project operations between 0400 hrs and 0600 hrs. These surveys involved walking the dewatered habitat between the Main Dam and the East Channel.

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 2001 York Haven fishway operating season was very successful. Survival of fish that utilized the fishway was considered excellent as no mortalities were observed. Some 16,200 American shad used the fishway to pass upstream. This was almost 3.5 times the number counted in 2000 and amounted to 18.0% of the number of shad that passed Safe Harbor.

Over the next several seasons, YHPC plans to continue working 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. Results obtained this season indicate that shad passage following a nighttime reduction in spill to 1,000 cfs normally resulted in an increase in the total number of shad passing the fishway the following day. This suggests that total passage through the fishway may be improved by reducing spill over the Main Dam at all hours during the fish passage season. Combining proposed recommendations with operating experience gained during the first two seasons will enable all those involved with the Susquehanna River Shad Restoration partnership to gain a better understanding of fish passage at the York Haven Project.

RECOMMENDATIONS FOR 2002 OPERATION

- Reduce the nighttime controlled spill of 4,000 cfs over the Main Dam when flows are less than 23,000 cfs. Release a minimum flow of 1,000 cfs nightly between the end of daily fishway operation and the following morning (1900 hrs to 0600 hrs).

- On a trial basis, when river flow is less than 23,000 cfs, reduce the 4,000 cfs day time spill over the Main Dam on an alternate day basis to a nominal spill of 1,000 cfs during daily fishway operation (0600 hrs to 1900 hrs).

LITERATURE CITED

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

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

Table 1. Summary of the daily number of fish that passed by the York Haven Hydroelectric Project through the serpentine vertical notch ladder at the East Channel Dam in 2001.

Date	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May
Observation Time	10.0	10.5	11.0	11.0	10.7	11.0	10.8	11.0	11.0	11.0
Water Temperature (°F)	70.0	71.5	72.0	66.8	65.8	61.5	67.5	69.5	70.5	72.0
AMERICAN SHAD	89	337	423	407	289	573	981	1,393	1,128	1,273
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	3053	3139	2,696	2,674	2,152	2,327	3,706	3,914	3,118	4,546
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	1	0	0	2	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	1	1	2	0	1	0	1	0	0	2
BROWN TROUT	0	3	2	0	3	3	0	4	0	1
MUSKELLUNGE	0	0	1	0	1	2	0	0	0	0
CARP	91	36	48	32	27	22	28	80	28	95
QUILLBACK	211	1135	1,761	906	978	844	640	1,248	419	966
WHITE SUCKER	404	250	83	121	31	6	19	25	3	71
SHORTHEAD REDHORSE	212	413	131	314	258	281	171	249	158	129
WHITE CATFISH	0	0	0	0	0	0	0	0	0	0
YELLOW BULLHEAD	0	0	0	0	0	1	0	0	0	1
BROWN BULLHEAD	0	1	1	0	1	0	2	1	2	8
CHANNEL CATFISH	27	154	459	208	33	25	30	240	164	184
ROCK BASS	0	11	26	2	20	28	26	39	46	24
REDBREAST SUNFISH	0	0	0	0	0	1	1	0	3	3
GREEN SUNFISH	0	0	0	2	0	0	1	0	0	1
PUMKINSEED	0	0	0	52	0	1	3	2	1	1
BLUEGILL	0	0	0	0	0	0	0	0	1	4
SMALLMOUTH BASS	467	587	371	380	223	198	224	253	135	118
LARGEMOUTH BASS	0	1	0	2	0	4	4	1	2	1
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	67
YeLLOW PERCH	0	0	0	2	0	1	0	1	1	0
WALLEYE	108	292	518	757	461	366	358	650	576	550
NORTHERN HOG SUCKER	127	49	55	67	34	49	63	125	64	96
FALLFISH	0	50	31	0	8	0	0	0	0	0
TIGER MUSKELLUNGE	0	0	0	0	0	0	0	0	0	2
Total	4,791	6459	6,609	5,926	4,520	4,734	6,258	8,225	5,849	8,141

Table 1. Continued

Date	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May
Observation Time	11.0	10.3	11.0	11.0	8.7	11.0	10	9.3	9.5	10.7
Water Temperature (°F)	68.0	62.0	65.0	65.5	64.8	63.5	65	66.0	64.0	64.3
AMERICAN SHAD	748	794	485	715	767	500	641	942	224	250
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	1	0	0	0	0	0	0	0
GIZZARD SHAD	3,518	3,173	2,676	2,696	2,450	2,310	1372	1,626	1,506	1,261
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	1	0	2	0	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	1	0	1	0	0	0	0	0	0	0
BROWN TROUT	2	0	0	0	1	0	0	0	0	0
MUSKELLUNGE	0	0	0	0	0	0	2	0	0	0
CARP	19	7	7	21	5	4	9	27	3	6
QUILLBACK	313	139	247	122	32	31	59	459	150	704
WHITE SUCKER	21	0	10	3	0	1	9	5	4	1
SHORTHEAD REDHORSE	163	99	105	75	51	96	65	57	47	104
WHITE CATFISH	0	0	1	0	0	0	0	0	1	0
YELLOW BULLHEAD	1	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	3	0	1	1	0	0	0	0	0	0
CHANNEL CATFISH	112	42	39	67	23	35	97	201	43	444
ROCK BASS	2	9	6	6	1	0	1	5	3	2
REDBREAST SUNFISH	3	0	0	3	1	0	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0	0	0
PUMKINSEED	0	1	0	1	2	0	0	4	0	0
BLUEGILL	2	0	3	1	0	0	0	2	0	0
SMALLMOUTH BASS	37	35	35	39	13	7	8	21	13	11
LARGEMOUTH BASS	0	0	0	2	0	0	1	3	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	1	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	1	0	0	0
WALLEYE	458	379	392	365	331	219	303	416	232	203
NORTHERN HOG SUCKER	88	31	27	14	3	3	1	9	1	2
FALLFISH	1	0	0	0	0	0	0	0	0	0
TIGER MUSKELLUNGE	0	0	0	0	0	0	0	0	0	1
Total	5,492	4,709	4,037	4,131	3,682	3,206	2569	3,778	2,227	2,989

Table 1. Continued

Date	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun
Observation Time	9.5	10.0	10.7	9.7	9.3	9.8	9.3	8.6	8.4	8.7
Water Temperature (°F)	66.5	69.8	69.0	67.5	66.0	67.0	68.0	66.5	65.0	65.0
AMERICAN SHAD	407	689	346	376	464	294	131	69	44	86
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	1	0	0	0	0	1	0	0
GIZZARD SHAD	1,509	2,334	2,030	1,420	2,153	4,386	5,837	4,188	2,758	1,858
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	0	0	0	0	0	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	2	0	0	0	0	1	0	0	0
BROWN TROUT	0	0	0	0	2	0	0	1	2	0
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
CARP	23	33	17	6	8	12	6	2	2	6
QUILLBACK	253	156	246	159	152	102	79	114	70	23
WHITE SUCKER	32	35	5	11	7	0	12	0	0	0
SHORTHEAD REDHORSE	44	5	40	44	61	45	12	25	11	9
WHITE PERCH	0	0	0	0	0	0	0	0	0	1
YELLOW BULLHEAD	0	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	3	0	0	0	0	0	0	1	0
CHANNEL CATFISH	61	26	151	88	52	158	87	127	82	77
ROCK BASS	3	12	4	4	2	0	4	2	4	1
REDBREAST SUNFISH	1	0	1	0	0	0	0	1	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0	0	0
PUMKINSEED	0	0	2	0	1	2	0	2	1	0
BLUEGILL	0	13	2	4	0	1	5	0	0	1
SMALLMOUTH BASS	8	49	33	12	9	10	12	15	20	4
LARGEMOUTH BASS	0	3	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	1	0	0	0	0	0	0	0	0
WALLEYE	145	172	223	287	133	124	151	74	79	135
NORTHERN HOG SUCKER	3	8	9	5	0	4	4	1	0	1
FALLFISH	0	6	0	1	0	0	1	0	0	1
TIGER MUSKELLUNGE	0	0	0	0	0	0	0	0	0	0
Total	2,489	3,547	3,110	2,417	3,044	5,138	6,342	4,622	3,074	2,203

Table 1. Continued

Date	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	Total
Observation Time	7.9	8.2	7.9	8.0	8.0	7.9	7.3	359.7
Water Temperature (°F)	65.0	66.5	66.8	69.8	72.5	72.0	73.5	
AMERICAN SHAD	18	52	19	63	101	48	34	**16,200**
ALEWIFE	0	0	0	0	0	0	0	**0**
BLUEBACK HERRING	0	0	0	1	0	0	0	**4**
GIZZARD SHAD	1,358	1,707	790	445	1,062	991	533	**89,272**
HICKORY SHAD	0	0	0	0	0	0	0	**0**
STRIPED BASS	0	0	0	0	0	1	0	**8**
WHITE PERCH	0	0	0	0	0	0	0	**0**
AMERICAN EEL	0	0	0	0	0	0	0	**0**
RAINBOW TROUT	0	0	0	0	0	0	0	**13**
BROWN TROUT	0	0	0	0	0	0	0	**24**
MUSKELLUNGE	0	0	0	0	0	0	0	**6**
CARP	2	3	3	16	13	6	9	**762**
QUILLBACK	31	19	7	39	54	65	7	**12,940**
WHITE SUCKER	0	0	2	0	0	0	1	**1,172**
SHORTHEAD REDHORSE	5	9	5	14	2	5	7	**3,521**
WHITE CATFISH	0	0	0	0	0	0	0	**3**
YELLOW BULLHEAD	0	0	0	0	1	0	0	**4**
BROWN BULLHEAD	0	1	2	0	0	4	0	**32**
CHANNEL CATFISH	116	66	125	209	178	175	108	**4,513**
ROCK BASS	0	2	1	12	2	7	0	**317**
REDBREAST SUNFISH	0	1	0	4	0	0	4	**27**
GREEN SUNFISH	0	0	0	0	0	0	1	**5**
PUMKINSEED	0	2	0	1	5	0	8	**92**
BLUEGILL	1	0	3	1	2	8	5	**59**
SMALLMOUTH BASS	2	3	6	15	10	17	14	**3,414**
LARGEMOUTH BASS	0	0	0	0	0	0	1	**25**
WHITE CRAPPIE	0	0	0	0	0	0	1	**2**
BLACK CRAPPIE	0	0	0	0	0	0	1	**68**
YELLOW PERCH	0	0	0	0	0	0	0	**7**
WALLEYE	66	114	80	116	162	141	124	**10,260**
NORTHERN HOG SUCKER	0	2	2	2	3	5	9	**966**
FALLFISH	0	0	0	0	0	3	1	**103**
TIGER MUSKELLUNGE	0	0	0	0	0	0	0	**3**
Total	1,599	1,981	1,045	938	1,595	1,476	868	143,820

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 2001.

	River	East	Main Dam Flow (cfs)		Water				Stop	Elevation (ft)					
	Flow	Channel	0800 to	1900 to	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	1900 hrs	0800 hrs	(°F)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
3-May	23,117	2,000	4,000	4,000	70.0	13.3	10.0	14.0	closed	279.1	279.0	279.1	274.2	274.2	274.2
4-May	21,400	2,000	4,000	4,000	71.5	11.8	10.0	12.0	closed	279.0	278.9	279.1	274.0	273.9	274.1
5-May	18,567	2,000	4,000	4,000	72.0	10.5	8.0	12.0	closed	278.7	278.5	278.9	273.9	273.8	273.9
6-May	18,233	2,000	4,000	4,000	66.8	11.3	10.0	12.0	closed	278.9	278.9	278.9	273.9	273.9	274.0
7-May	17,600	2,000	4,000	4,000	65.8	14.4	13.0	18.0	closed	278.7	278.7	278.8	273.8	273.8	273.9
8-May	15,717	2,000	4,000	4,000	61.5	15.5	14.0	16.0	closed	278.6	278.6	278.7	273.8	273.8	273.9
9-May	15,700	2,000	4,000	1,000	67.5	22.7	20.0	24.0	closed	278.7	278.6	278.8	273.9	273.8	273.9
10-May	14,833	2,000	4,000	4,000	69.5	24.0	24.0	24.0	closed	278.7	278.6	278.7	273.9	273.8	273.9
11-May	14,200	2,000	4,000	1,000	70.5	18.9	16.0	24.0	closed	278.7	278.7	278.7	273.9	273.9	273.9
12-May	13,783	2,000	4,000	4,000	72.0	16.5	15.0	18.0	closed	278.6	278.6	278.6	273.8	273.8	273.8
13-May	13,017	2,000	4,000	1,000	68.0	13.0	12.0	14.0	closed	278.5	278.5	278.6	273.8	273.8	273.8
14-May	12,433	2,000	4,000	4,000	62.0	17.8	14.0	19.0	closed	278.5	278.4	278.6	273.8	273.7	273.9
15-May	11,950	2,000	4,000	1,000	65.0	15.0	15.0	15.0	closed	278.6	278.6	278.6	273.9	273.9	273.9
16-May	11,700	2,000	4,000	4,000	65.5	17.7	16.0	18.0	closed	278.6	278.5	278.6	273.9	273.8	273.9
17-May	11,183	2,000	4,000	1,000	64.8	15.5	13.0	18.0	closed	278.6	278.6	278.6	273.9	273.9	274.0
18-May	10,567	2,000	4,000	4,000	63.5	13.3	12.0	14.0	closed	278.4	278.3	278.5	273.8	273.8	273.9
19-May	10,083	2,000	4,000	1,000	65.0	17.5	16.0	18.0	closed	278.5	278.5	278.6	273.9	273.9	273.9
20-May	9,867	2,000	4,000	4,000	66.0	16.8	14.0	18.0	closed	278.5	278.3	278.6	273.9	273.8	273.9
21-May	9,867	2,000	4,000	1,000	64.0	12.5	12.0	13.0	closed	278.6	278.6	278.6	273.9	273.9	273.9
22-May	9,850	2,000	4,000	4,000	64.3	12.7	12.0	14.0	closed	278.5	278.5	278.6	273.9	273.9	273.9
23-May	10,650	2,000	4,000	1,000	66.5	15.7	14.0	16.0	closed	278.6	278.5	278.7	273.9	273.9	273.9
24-May	11,700	2,000	4,000	4,000	69.8	13.5	13.0	14.0	closed	278.6	278.6	278.6	273.9	273.9	273.9
25-May	11,633	2,000	4,000	1,000	69.0	12.0	10.0	14.0	closed	278.6	278.6	278.6	273.9	273.9	273.9
26-May	13,467	2,000	4,000	4,000	67.5	12.0	12.0	12.0	closed	278.6	278.5	278.6	273.9	273.9	273.9
27-May	18,700	2,000	4,000	1,000	66.0	16.2	16.0	18.0	closed	278.9	278.9	278.9	274.0	274.0	274.0
28-May	17,900	2,000	4,000	4,000	67.0	12.5	10.0	14.0	closed	278.7	278.7	278.7	273.8	274.0	274.0
29-May	19,133	2,000	4,000	1,000	68.0	12.0	12.0	12.0	closed	278.9	278.9	278.9	274.0	274.0	274.0
30-May	18,350	2,000	4,000	4,000	66.5	13.6	12.0	15.0	closed	278.8	278.8	278.8	274.0	274.0	274.1
31-May	16,567	2,000	4,000	1,000	65.0	17.1	16.0	18.0	closed	278.7	278.7	278.8	274.0	274.0	274.0
1-Jun	17,433	2,000	4,000	4,000	65.0	13.0	13.0	13.0	closed	278.6	278.5	278.6	273.9	273.9	274.0

Table 2. Continued

Date	River Flow (cfs)	East Channel Flow (cfs)	Main Dam Flow (cfs) 0800 to 1900 hrs	Main Dam Flow (cfs) 1900 to 0800 hrs	Water Temp. (°F)	Secchi (in) Avg.	Secchi (in) Min.	Secchi (in) Max.	Stop log Gate	Elevation (ft) Head Pond Avg.	Elevation (ft) Head Pond Min.	Elevation (ft) Head Pond Max.	Elevation (ft) Tailwater Avg	Elevation (ft) Tailwater Min.	Elevation (ft) Tailwater Max.
2-Jun	15,517	2,000	4,000	1,000	65.0	16.0	16.0	16.0	closed	278.6	278.6	278.7	274.0	274.0	274.0
3-Jun	14,500	2,000	4,000	4,000	66.5	14.0	14.0	14.0	closed	278.6	278.5	278.7	274.0	273.9	274.0
4-Jun	14,167	2,000	4,000	1,000	66.8	12.8	12.0	14.0	closed	278.7	278.7	278.8	274.0	274.0	274.0
5-Jun	14,600	2,000	4,000	4,000	69.8	13.9	13.0	14.0	closed	278.8	278.7	278.8	274.0	274.0	274.0
6-Jun	13,650	2,000	4,000	1,000	72.5	16.0	16.0	16.0	closed	278.7	278.7	278.8	274.0	274.0	274.0
7-Jun	12,300	2,000	4,000	4,000	72.0	13.4	13.0	14.0	closed	278.7	278.6	278.7	274.0	274.0	274.0
8-Jun	11,367	2,000	4,000	1,000	73.5	15.9	15.0	16.0	closed	278.7	278.7	278.7	274.0	274.0	274.1

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2001.

Date	River Flow (cfs)	East Channel Flow (cfs)	Elevation (ft) Head Pond Avg.	Head Pond Min.	Head Pond Max.	Tailwater Avg	Tailwater Min.	Tailwater Max.	Inside Fishway Avg	Inside Fishway Min.	Inside Fishway Max.	Inside Weir Avg	Inside Weir Min.	Inside Weir Max.	Above Counting Room Avg	Above Counting Room Min.	Above Counting Room Max.	Below Fixed Wheel Gate Avg	Below Fixed Wheel Gate Min.	Below Fixed Wheel Gate Max.	Counting Room Avg	Counting Room Min.	Counting Room Max.
3-May	23,117	2,000	279.1	279.0	279.1	274.2	274.2	274.2	274.9	274.9	275.0	277.4	277.3	277.5	278.9	278.9	279.0	277.3	277.3	277.4	278.9	278.9	279.0
4-May	21,400	2,000	279.0	278.9	279.1	274.0	273.9	274.1	274.7	274.7	274.8	277.4	277.3	277.6	278.7	278.7	278.8	277.1	277.1	277.2	278.7	278.7	278.8
5-May	18,567	2,000	278.7	278.5	278.9	273.9	273.8	273.9	274.6	274.5	274.7	277.2	277.1	277.4	278.5	278.3	278.7	276.9	276.9	277.0	278.4	278.3	278.7
6-May	18,233	2,000	278.9	278.9	278.9	273.9	273.9	274.0	274.7	274.6	274.8	277.4	277.3	277.4	278.6	278.6	278.6	277.1	277.0	277.2	278.6	278.5	278.6
7-May	17,600	2,000	278.7	278.7	278.8	273.8	273.8	273.9	274.7	274.7	274.7	277.2	277.2	277.3	278.5	278.5	278.6	277.0	277.0	277.1	278.5	278.5	278.5
8-May	15,717	2,000	278.6	278.6	278.7	273.8	273.8	273.9	274.6	274.6	274.7	277.2	277.2	277.2	278.4	278.4	278.5	277.0	277.0	277.1	278.4	278.3	278.5
9-May	15,700	2,000	278.7	278.6	278.8	273.9	273.8	273.9	274.6	274.6	274.7	277.2	277.1	277.3	278.5	278.5	278.5	277.1	277.0	277.1	278.5	278.4	278.5
10-May	14,833	2,000	278.7	278.6	278.7	273.9	273.8	273.9	274.6	274.6	274.7	277.1	277.1	277.2	278.4	278.4	278.5	277.0	276.9	277.0	278.4	278.3	278.4
11-May	14,200	2,000	278.7	278.7	278.7	273.9	273.9	273.9	274.6	274.6	274.7	277.2	277.2	277.2	278.5	278.5	278.5	277.0	277.0	277.1	278.3	278.3	278.4
12-May	13,783	2,000	278.6	278.6	278.6	273.8	273.8	273.8	274.5	274.5	274.5	277.1	277.1	277.2	278.4	278.4	278.4	277.9	277.9	277.9	278.3	278.3	278.3
13-May	13,017	2,000	278.5	278.5	278.6	273.8	273.8	273.8	274.5	274.5	274.5	277.1	277.1	277.2	278.4	278.4	278.4	276.9	276.9	277.0	278.3	278.3	278.3
14-May	12,433	2,000	278.5	278.4	278.6	273.8	273.7	273.9	274.5	274.5	274.5	277.1	277.0	277.2	278.3	278.2	278.4	276.9	276.9	277.0	278.2	278.2	278.3
15-May	11,950	2,000	278.6	278.6	278.6	273.9	273.9	273.9	274.5	274.5	274.5	277.2	277.1	277.2	278.4	278.4	278.4	277.0	277.0	277.0	278.3	278.3	278.4
16-May	11,700	2,000	278.6	278.5	278.6	273.9	273.8	273.9	274.5	274.4	274.5	277.1	277.1	277.2	278.4	278.2	278.4	277.0	276.9	277.0	278.3	278.2	278.4
17-May	11,183	2,000	278.6	278.6	278.6	273.9	273.9	274.0	274.6	274.5	274.7	277.1	277.1	277.2	278.4	278.3	278.4	276.9	276.9	277.0	278.3	278.2	278.3
18-May	10,567	2,000	278.4	278.3	278.5	273.8	273.8	273.9	274.6	274.5	274.6	277.0	276.9	277.1	278.2	278.0	278.3	276.9	276.8	276.9	278.2	278.1	278.2
19-May	10,083	2,000	278.5	278.5	278.6	273.9	273.9	273.9	274.6	274.6	274.7	277.1	277.1	277.1	278.3	278.3	278.4	276.7	275.9	276.9	278.3	278.3	278.3
20-May	9,867	2,000	278.5	278.3	278.6	273.9	273.8	273.9	274.6	274.6	274.6	277.1	277.0	277.2	278.3	278.0	278.4	276.9	276.8	277.0	278.2	278.1	278.3
21-May	9,867	2,000	278.6	278.6	278.6	273.9	273.9	273.9	274.6	274.6	274.7	277.1	277.1	277.1	278.4	278.4	278.4	277.0	277.0	277.0	278.3	278.3	278.4
22-May	9,850	2,000	278.5	278.5	278.6	273.9	273.9	273.9	274.6	274.6	274.7	277.1	277.0	277.2	278.3	278.2	278.4	276.9	276.9	277.0	278.2	278.2	278.3
23-May	10,650	2,000	278.6	278.5	278.7	273.9	273.9	273.9	274.7	274.6	274.7	277.2	277.1	277.2	278.4	278.4	278.5	277.0	277.0	277.0	278.3	278.3	278.4
24-May	11,700	2,000	278.6	278.6	278.6	273.9	273.9	273.9	274.6	274.6	274.6	277.1	277.1	277.1	278.4	278.4	278.4	276.9	276.9	277.0	278.3	278.3	278.3
25-May	11,633	2,000	278.6	278.6	278.6	273.9	273.9	273.9	274.6	274.6	274.6	277.1	277.1	277.2	278.3	278.3	278.4	277.0	277.0	277.0	278.2	278.2	278.3
26-May	13,467	2,000	278.6	278.5	278.6	273.9	273.9	273.9	274.6	274.6	274.6	277.0	277.0	277.1	278.3	278.2	278.4	276.9	276.9	277.0	278.2	278.2	278.3
27-May	18,700	2,000	278.9	278.9	278.9	274.0	274.0	274.0	274.7	274.7	274.7	277.3	277.3	277.4	278.7	278.6	278.7	277.1	277.1	277.1	278.6	278.6	278.7
28-May	17,900	2,000	278.7	278.7	278.7	273.8	274.0	274.0	274.5	274.5	274.6	277.2	277.2	277.3	278.5	278.5	278.5	277.0	277.0	277.1	278.3	278.3	278.4
29-May	19,133	2,000	278.9	278.9	278.9	274.0	274.0	274.0	274.6	274.6	274.6	277.3	277.3	277.3	278.7	278.7	278.7	277.1	277.0	277.1	278.6	278.6	278.6
30-May	18,350	2,000	278.8	278.8	278.8	274.0	274.0	274.1	274.5	274.5	274.6	277.2	277.2	277.3	278.6	278.6	278.6	277.1	277.1	277.1	278.4	278.4	278.5
31-May	16,567	2,000	278.7	278.7	278.8	274.0	274.0	274.0	274.5	274.4	274.6	277.2	277.2	277.3	278.5	278.4	278.5	277.0	277.0	277.0	278.4	278.4	278.4
1-Jun	17,433	2,000	278.6	278.5	278.6	273.9	273.9	274.0	274.5	274.5	274.6	277.1	277.0	277.1	278.4	278.3	278.4	276.9	276.9	277.0	278.2	278.2	278.3

Table 3. Continued

Date	River Flow (cfs)	East Channel Flow (cfs)	Elevation (ft)																				
			Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
			Avg.	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.
2-Jun	15,517	2,000	278.6	278.6	278.7	274.0	274.0	274.0	274.5	274.5	274.6	277.2	277.2	277.2	278.4	278.4	278.4	277.0	277.0	277.0	278.3	278.3	278.4
3-Jun	14,500	2,000	278.6	278.5	278.7	274.0	273.9	274.0	274.5	274.5	274.6	277.1	277.1	277.2	278.4	278.3	278.4	277.0	276.9	277.1	278.3	278.2	278.4
4-Jun	14,167	2,000	278.7	278.7	278.8	274.0	274.0	274.0	274.6	274.6	274.6	277.1	277.1	277.2	278.5	278.5	278.6	277.0	277.0	277.1	278.4	278.4	278.4
5-Jun	14,600	2,000	278.8	278.7	278.8	274.0	274.0	274.0	274.6	274.6	274.6	277.2	277.2	277.3	278.5	278.5	278.6	277.1	277.1	277.1	278.4	278.4	278.4
6-Jun	13,650	2,000	278.7	278.7	278.8	274.0	274.0	274.0	274.6	274.6	274.6	277.2	277.2	277.3	278.5	278.5	278.5	277.1	277.1	277.1	278.4	278.3	278.5
7-Jun	12,300	2,000	278.7	278.6	278.7	274.0	274.0	274.0	274.6	274.6	274.6	277.1	277.1	277.1	278.4	278.4	278.5	277.0	277.0	277.0	278.3	278.3	278.3
8-Jun	11,367	2,000	278.7	278.7	278.7	274.0	274.0	274.1	274.6	274.6	274.6	277.2	277.2	277.2	278.4	278.4	278.4	277.0	277.0	277.1	278.3	278.3	278.3

Table 4. Hourly summary of American shad passage through the sepentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2001.

Date	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May
Observation Time (Start)	1000	0800	0800	0800	0800	0800	0800	0800	0800	0800
Observation Time (End)	1730	1900	1900	1900	1900	1900	1900	1900	1900	1900
Military Time (HRS)										
0800 - 0859	-	162	173	116	42	128	309	425	362	454
0900 - 0959	-	63	53	56	43	53	119	200	175	207
1000 - 1059	17	24	44	51	22	68	100	102	84	130
1100 - 1159	6	23	29	31	25	-	77	59	122	108
1200 - 1259	12	10	15	24	35	65	66	118	73	90
1300 - 1359	0	21	15	12	16	46	68	108	96	38
1400 - 1459	20	13	16	17	21	57	36	135	87	85
1500 - 1559	3	12	34	27	24	50	50	72	32	81
1600 - 1659	9	4	17	28	17	30	39	53	33	25
1700 - 1759	12	3	9	33	14	42	47	55	40	30
1800 - 1900	10	2	18	12	30	34	70	66	24	25
Total Catch	89	337	423	407	289	573	981	1393	1128	1273

Date	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0900	0800	0800
Observation Time (End)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Military Time (HRS)										
0800 - 0859	194	133	93	146	179	82	99	346	55	26
0900 - 0959	95	69	30	101	88	49	39	175	34	25
1000 - 1059	104	73	41	46	29	59	52	90	31	18
1100 - 1159	52	67	38	58	-	57	54	66	15	10
1200 - 1259	52	45	51	54	52	58	75	53	30	6
1300 - 1359	25	59	16	38	159	33	58	24	14	21
1400 - 1459	21	0	73	16	76	23	48	61	13	15
1500 - 1559	27	140	43	128	80	34	29	36	9	30
1600 - 1659	32	106	30	39	49	39	50	41	8	14
1700 - 1759	53	60	26	54	37	30	73	20	11	35
1800 - 1900	93	42	44	35	18	36	64	30	4	50
Total Catch	748	794	485	715	767	500	641	942	224	250

Table 4. Continued

Date	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun
Observation Time (Start)	0800	0800	0800	0800	0900	0800	0800	0800	0800	0800
Observation Time (End)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Military Time (HRS)										
0800 - 0859	89	208	66	61	106	51	0	20	11	17
0900 - 0959	-	71	68	58	57	51	39	14	7	12
1000 - 1059	19	66	35	45	53	19	25	5	6	7
1100 - 1159	43	55	32	33	34	20	19	7	2	15
1200 - 1259	29	80	15	35	59	23	9	7	2	6
1300 - 1359	39	58	17	29	49	24	6	4	7	15
1400 - 1459	31	37	24	39	28	18	3	7	2	10
1500 - 1559	32	37	18	23	29	31	8	1	3	0
1600 - 1659	38	26	26	20	23	23	12	2	4	2
1700 - 1759	28	17	27	15	12	19	8	2	-	2
1800 - 1900	59	34	18	18	14	15	2	-	-	-
Total Catch	**407**	**689**	**346**	**376**	**464**	**294**	**131**	**69**	**44**	**86**

Date	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	Total
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	
Observation Time (End)	1900	1900	1900	1900	1900	1900	1700	
Military Time (HRS)								
0800 - 0859	1	11	2	16	25	14	8	4,230
0900 - 0959	2	12	1	7	19	7	4	2,103
1000 - 1059	2	10	2	6	9	10	10	1,514
1100 - 1159	1	5	3	5	11	1	3	1,186
1200 - 1259	1	5	1	3	6	5	4	1,274
1300 - 1359	2	1	1	9	13	3	1	1,145
1400 - 1459	2	4	1	5	4	4	3	1,055
1500 - 1559	4	2	2	5	10	3	1	1,150
1600 - 1659	3	2	6	7	4	1	-	862
1700 - 1759	-	-	-	-	-	-	-	814
1800 - 1900	-	-	-	-	-	-	-	867
Total Catch	**18**	**52**	**19**	**63**	**101**	**48**	**34**	**16,200**

Table 5. Summary of American shad passage at York Haven Fishway during various time periods over a thirty-one day period when the nightly volume of spill over the main dam was varied on a trial basis, 9 May to 8 June, 2001. Scheduled spill reductio were initiated at the end of fishway operation (1900 hrs) on alternate days. High spill equaled 4,000 cfs and low spill varied from a minimum of 1,000 cfs up to 1,700 cfs (difference in operation of one additional turbine).

	Time Periods				
	Entire day	0800 - 1200 hrs	0800 - 1100 hrs	0800 - 1000 hrs	0800 - 0900 hrs
Low Spill (1,000 to 1,700 cfs)	7,544 (53.6%)	4,320 (55.4%)	3,754 (55.8%)	3,068 (56.4%)	2,010 (55.7%)
High Spill (4,000 cfs)	6,538 (46.4%)	3,484 (44.6%)	2,978 (44.2%)	2,376 (43.6)	1,599 (44.3)
Total	14,082	7,804	6,732	5,444	3,609
# increase (Low spill vs High spill)	1,006	836	766	692	411
% Increase (Low spill vs High spill)	15.4%	24.0%	25.7%	25.9%	25.7%

( ) Percentage of shad passage during time period

Table 6. Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 2001 York Haven fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
5-May	12	0800 to 0859	173	175	-2 -(1%)
10-May	24+	0800 to 0859	425	421	4 (1%)
13-May	12	1000 to 1059	104	103	1 (1%)
20-May	18	1400 to 1459	61	61	0 (0%)
27-May	16	0800 to 0859	106	106	0 (0%)
6-Jun	16	0800 to 0859	25	25	0 (0%)

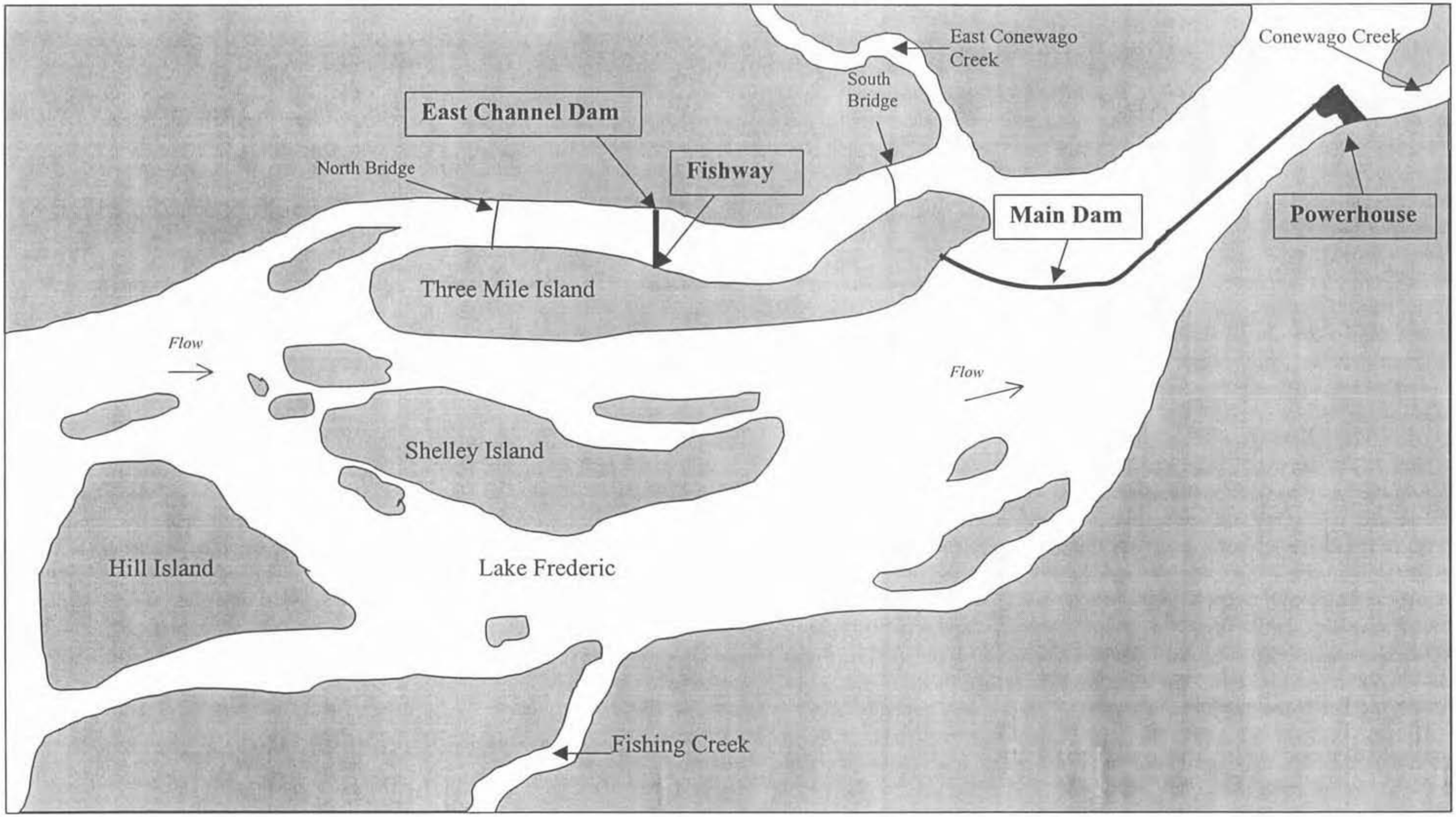
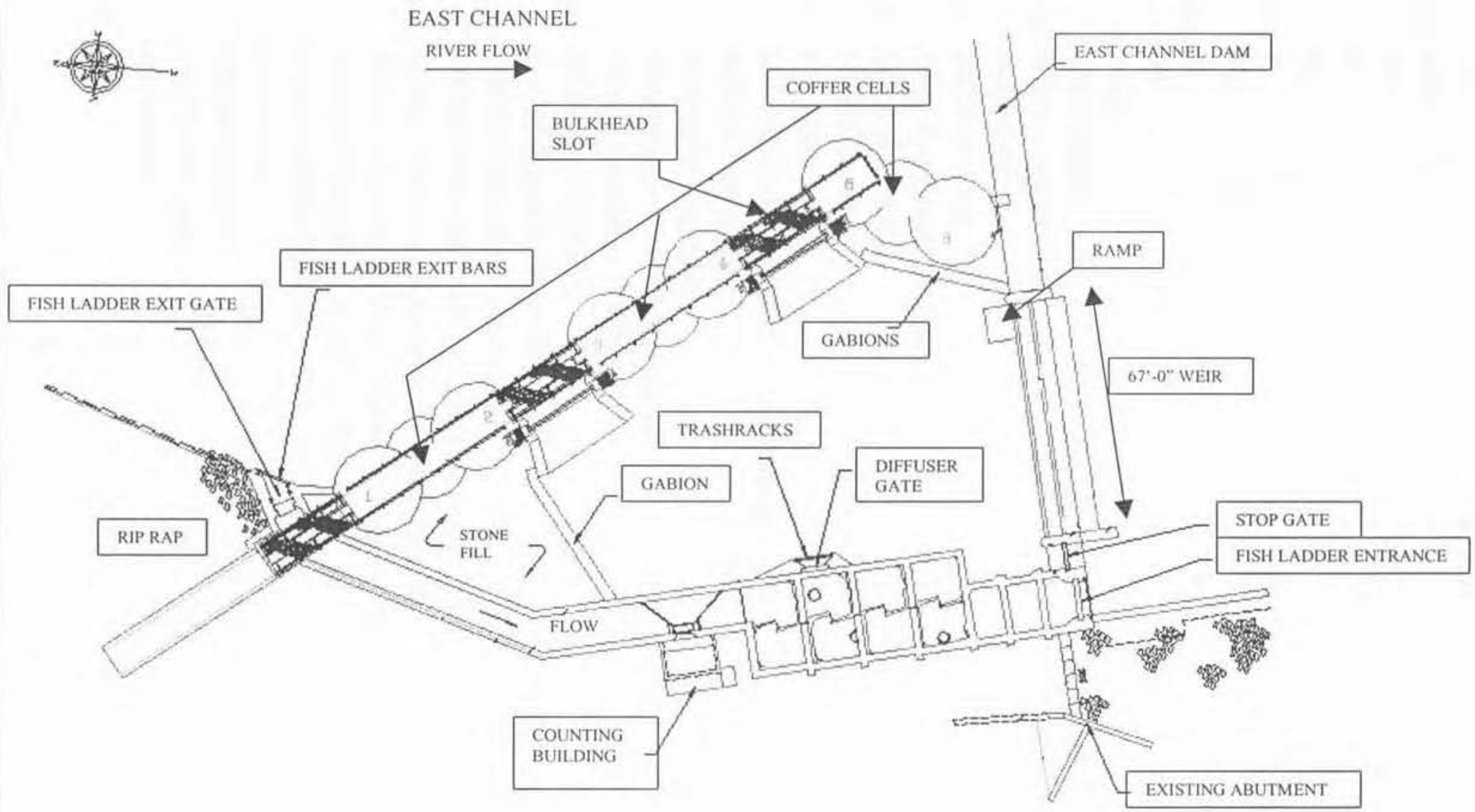


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



GENERAL ARRANGEMENT
YORK HAVEN FISHWAY
FIGURE 2

Figure 3. Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2001

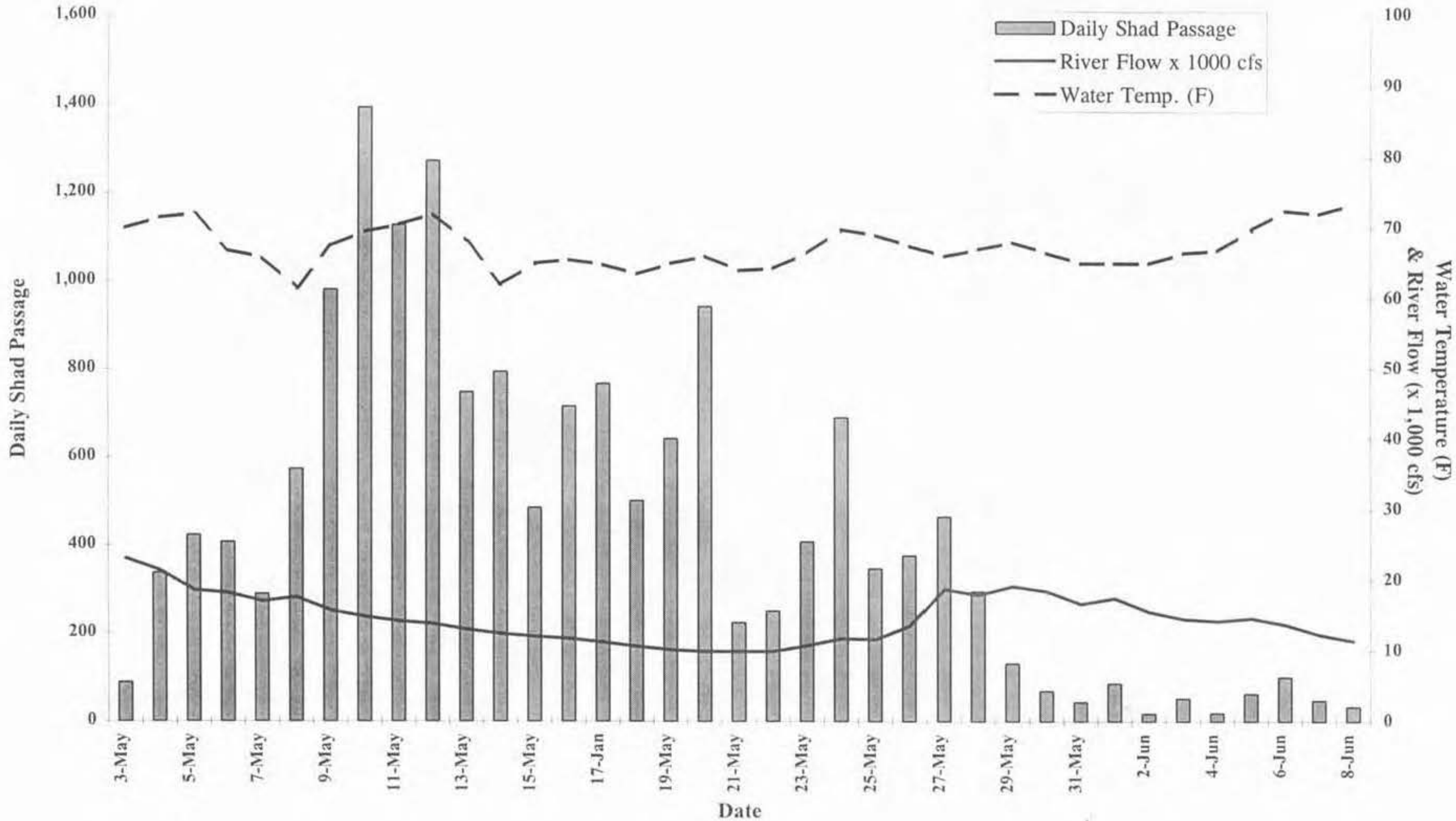


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2001

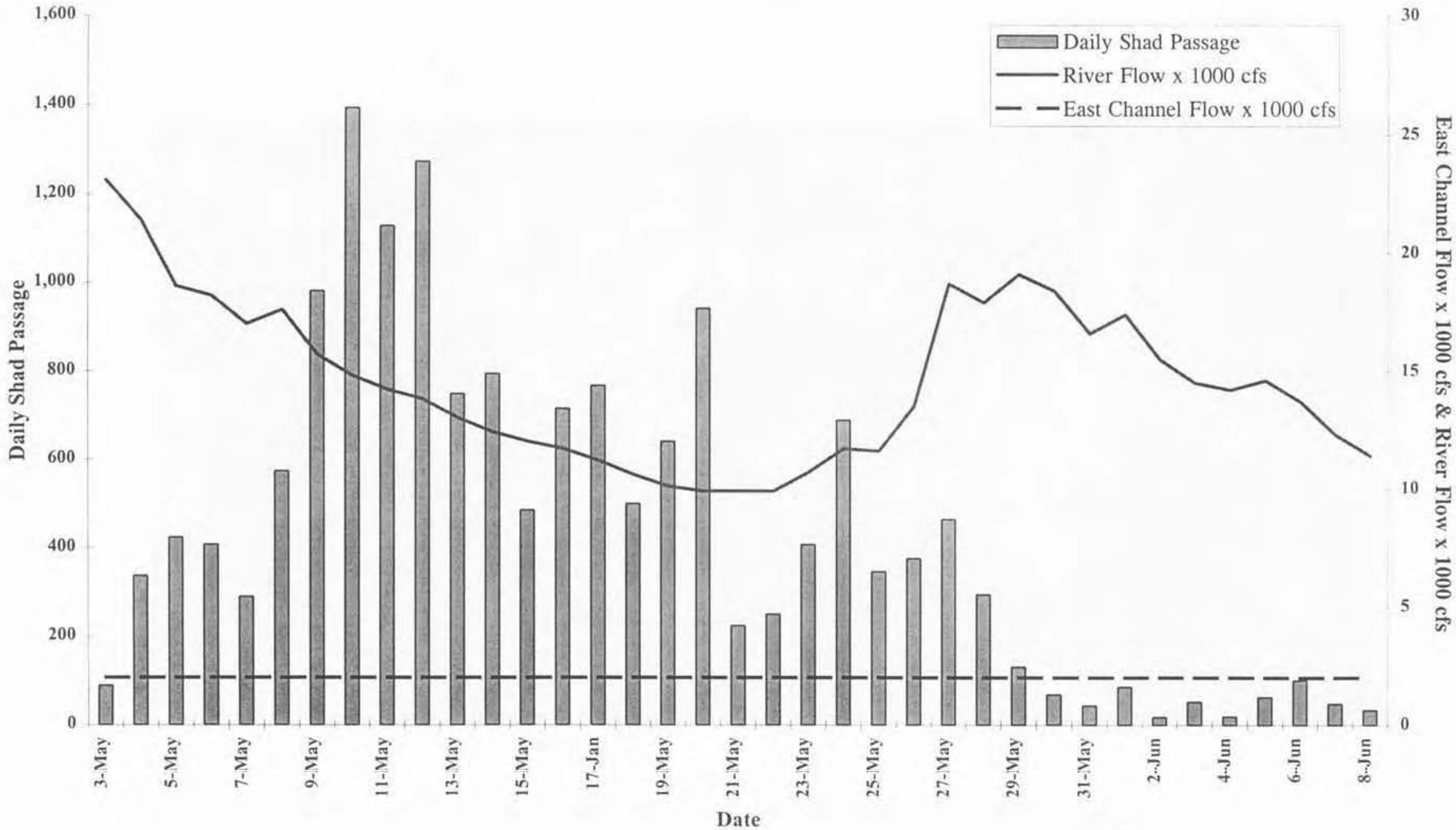


Figure 5. American Shad Passage At York Haven Fishway During Project Operation Changes, Spring 2001

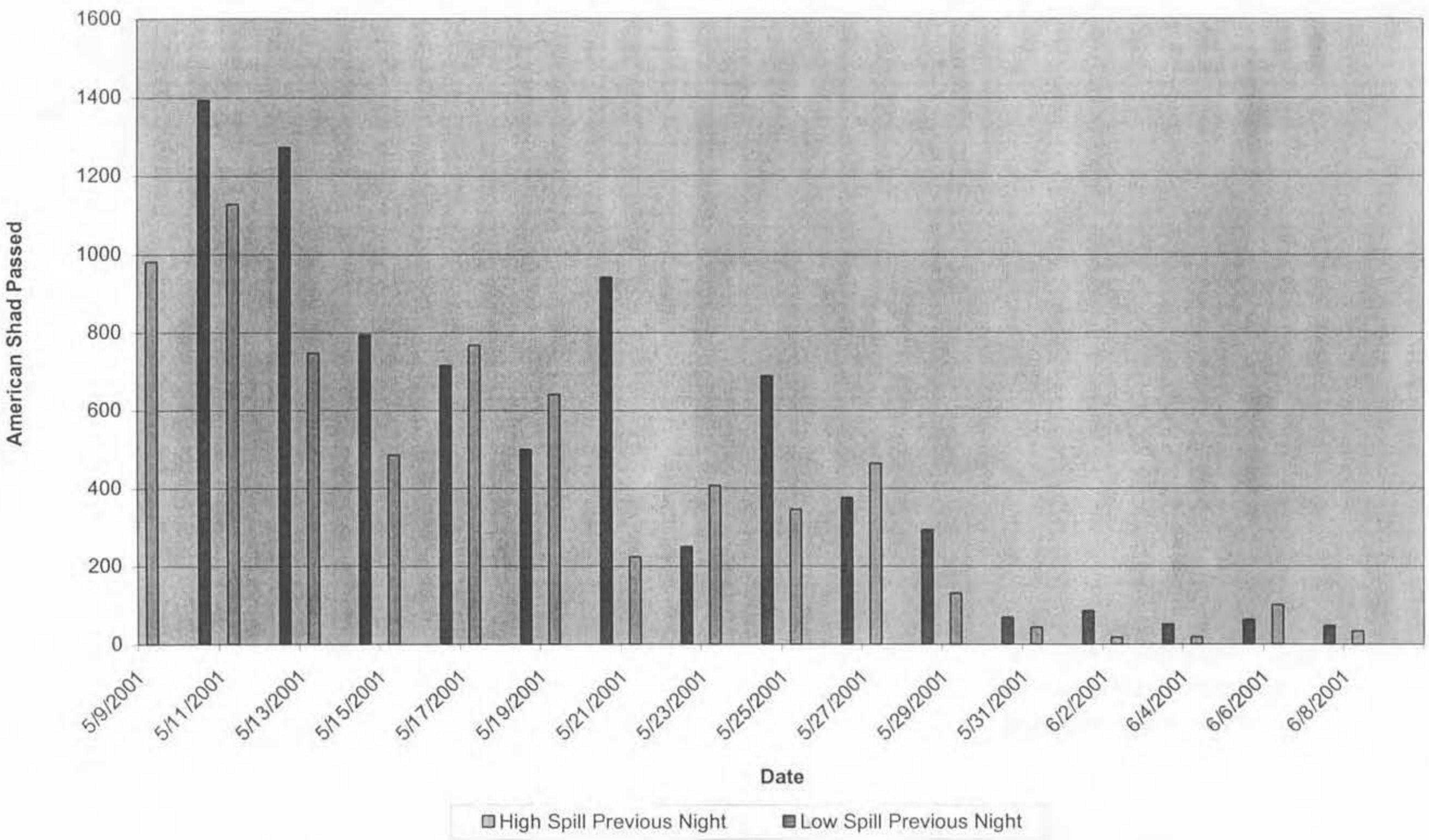


Figure 6. American Shad Passage At York Haven Fishway During Project Operation Changes, 0800 - 1200 hrs, Spring 2001

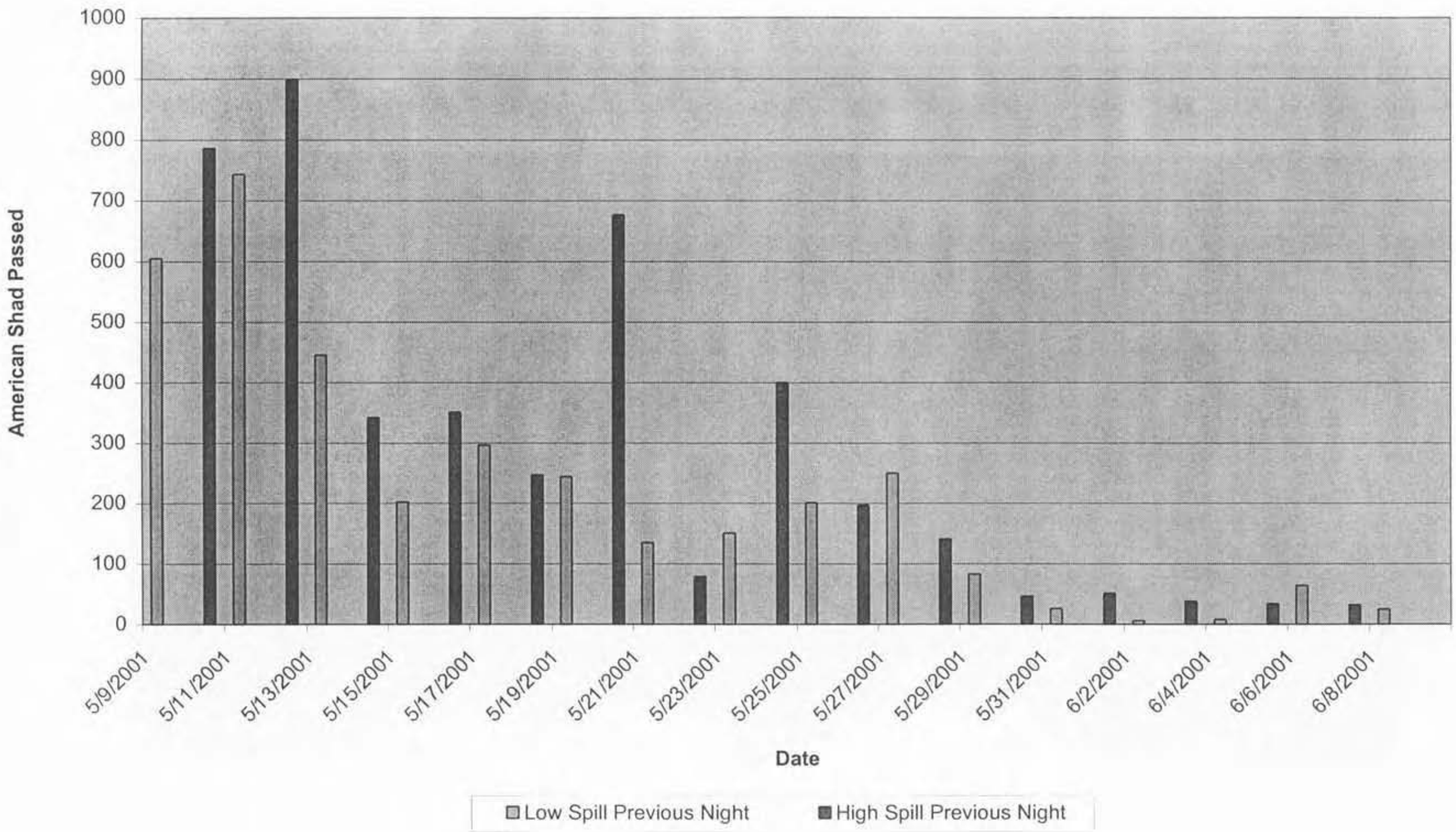


Figure 7. American Shad Passage At York Haven Fishway During Project Operation Changes, 0800 1100 Hrs, Spring 2001

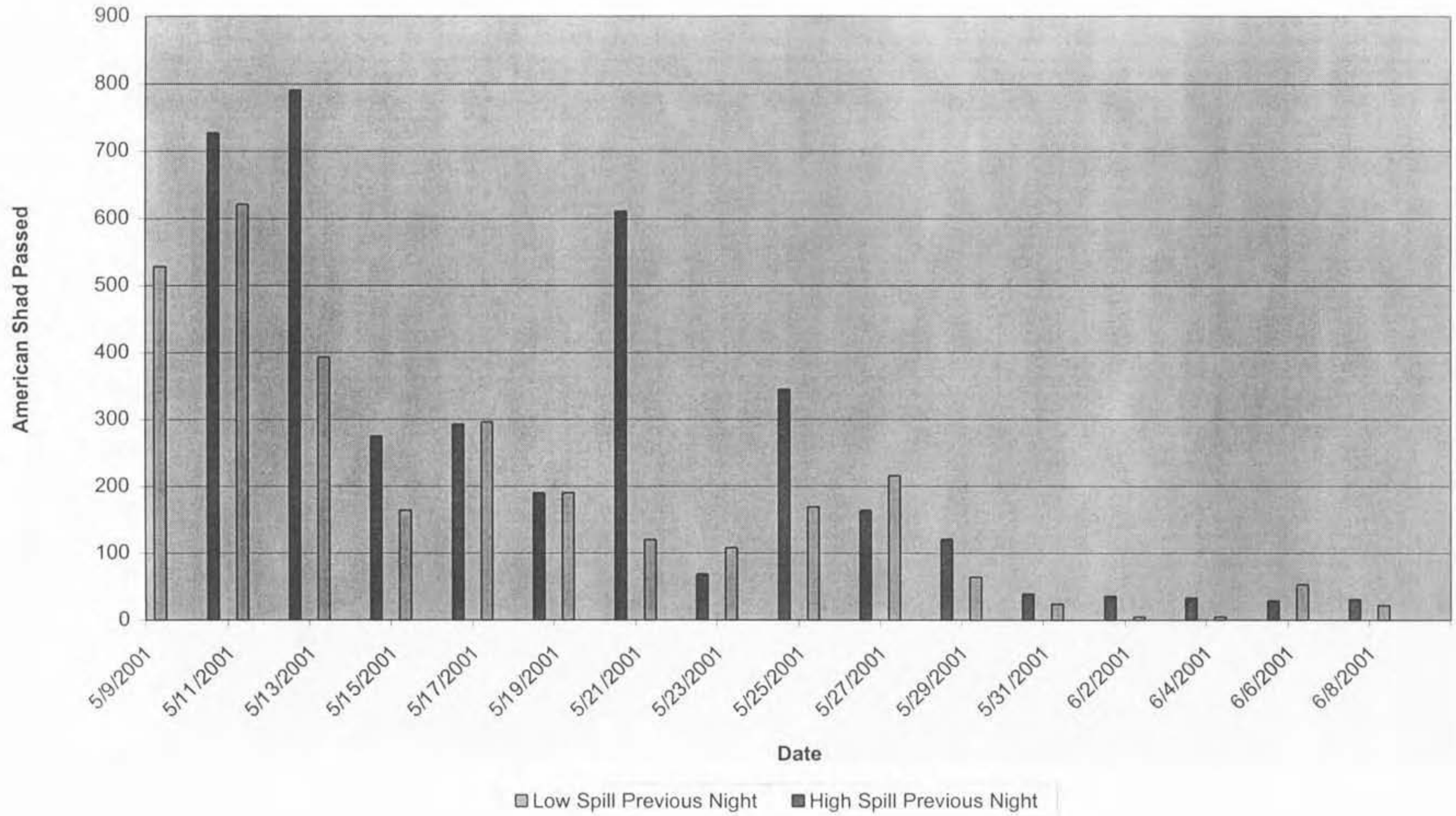


Figure 8. American Shad Passage at York Haven Fishway During Project Operation Changes, 0800 - 1000 hrs, Spring 2001

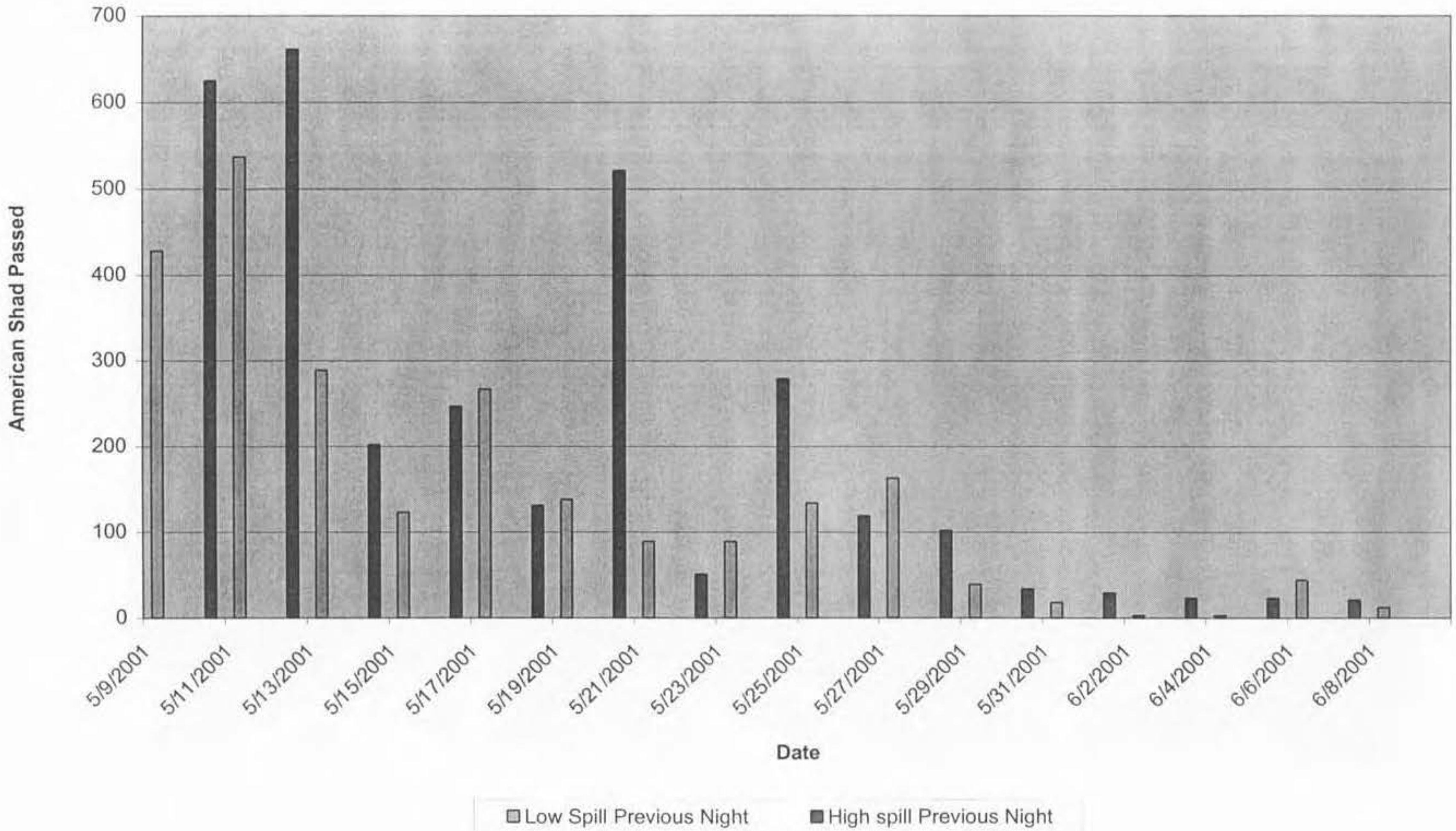
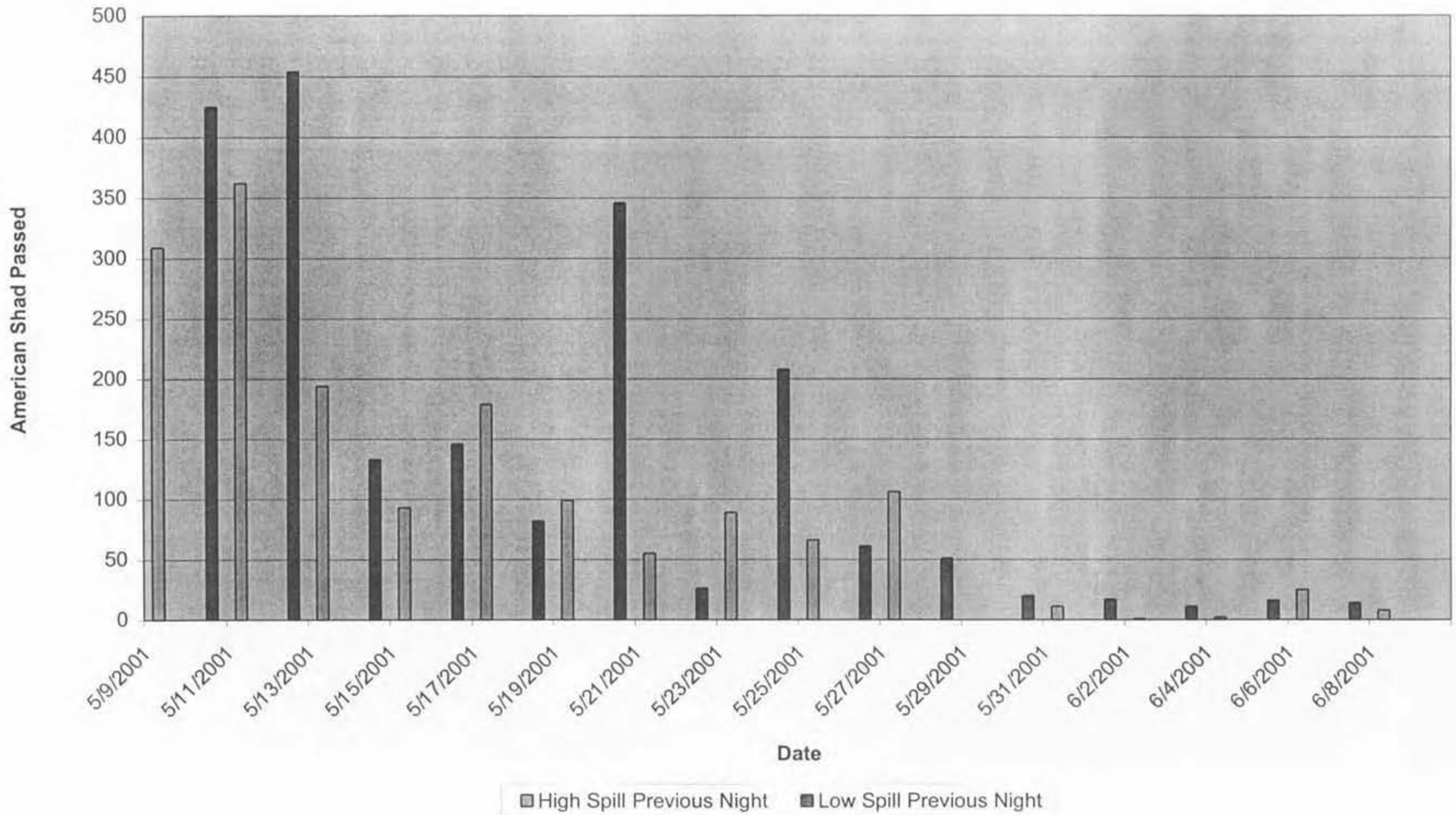


Figure 9. American Shad Passage At York Haven Fishway During Project Operation Changes, 0800 0900 Hrs, Spring 2001



JOB II - Part 1

THE AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2001

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ABSTRACT

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 for stocking in the Susquehanna River. Fertilized American shad eggs obtained from several rivers initiate hatchery activities. The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. (Lancaster, Pennsylvania) was contracted to capture ripe adult shad, on the spawning grounds, during spawning activity, artificially fertilize the eggs and deliver them to the hatchery. The objective was to deliver up to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Egg collection began on 12 May and ended on 28 May. Sampling occurred on 15 dates and included 31 boat-days of gill netting. No boat-days were expended in haul seining. Egg collection in 2001 was not hampered by weather conditions. A total of 3.9 million eggs was

obtained. The Van Dyke Hatchery received all eggs for culture. Egg viability averaged 77.2%, exceeding the 60-70% goal of the PFBC. All eggs came from the Coxsackie site. All eggs were collected by gill net.

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 2001 was to deliver 10 to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

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

COLLECTING METHODS AND 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. Gill netting was not conducted from Friday at 6:00 PM to Saturday at 6:00 PM, in observance of a NYDEC designated lift day.

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 2001 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

Both crews began sampling on May 12. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on May 28 due to lack of spawners when water temperature reached 63°F. Sampling occurred on 15 dates during this period including 31 boat-days of gill netting. Haul seines were not used in 2001.

A total of 3.92 million eggs were shipped to the Van Dyke Hatchery (Table 2). Hudson River shad egg collection in 2001 was the lowest since 1992-1993, principally because of the late start of operations due to contracting problems. Compared to other years, the first 2 weeks of the collection season were missed entirely. All of the eggs in 2001 came from the Coxsackie site. The Castleton and Cheviot sites were fished at the end of the season without eggs being taken. The goal of 60-70% viability was exceeded with an average of 77.2% and a range from 69.4% to 86.8% for individual shipments.

The egg collection period extended for 17 days from May 12 to May 28 but no deliveries were made after May 22. Both boats were used during the entire collecting period, and a third boat was added on May 26 in an unsuccessful effort to locate other productive sites. Weather conditions did not hamper egg collection in 2001.

SUMMARY

A total of 3.92 million American shad eggs (120 L) were collected from the Coxsackie site on the Hudson River and delivered to PFBC's Van Dyke Hatchery in nine shipments between May 12-22. While favorable weather and water temperature conditions persisted, this number was considerably less than that taken in each of the past 7 years. This was caused by the late start of operations related to Pennsylvania contracting problems. Overall egg viability of 77.2% exceeded the goal established for Hudson collections.

Table 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson rivers and delivered to the Van Dyke Hatchery, 1983-2001.

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	21.10	26.59
2000	3.83	14.88	18.71
2001	6.35	3.92	10.27
	140.83	141.04	281.87

TABLE 2. Collection data for American shad eggs, Hudson River, 2001.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability
12-May	Coxsackie	4.5	148,246	17	63	79.0
13-May	Coxsackie	31.2	931,211	18	63	73.0
14-May	Coxsackie	20.2	630,196	21	62	74.0
16-May	Coxsackie	29.3	1,018,271	26	62	81.0
17-May	Coxsackie	14.5	482,856	28	61	78.0
19-May	Coxsackie	5.7	217,601	32	61	80.0
20-May	Coxsackie	4.8	170,378	33	62	87.0
21-May	Coxsackie	4.7	159,902	37	63	84.0
22-May	Coxsackie	5.2	160,453	40	62	69.0
Total		120.1	3,919,114	9	62	77.2

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2001

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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 2001, 141 million American shad eggs have been collected from the Delaware River. From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 13.3 million in the

Lehigh River and 2.8 million in the Schuylkill River. The goal of this activity in 2001, 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, 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 and 2001, however, the Ecology III contract was not re-newed and the PFBC Area Fisheries Manager and his staff did the work without the assistance of Ecology III. Sixteen 200-foot gill nets with mesh sizes ranging from 4.5 to 6.0 inches 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, which 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 5 liters of eggs and 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 driven 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

After spawning the shad, representative samples of each night's catch of both sexes were measured and weighed and scale and otolith samples were removed for analysis. Ovaries from green females were also removed and weighed. Most adult shad did not survive the rigors of netting and artificial spawning and it was necessary to properly dispose of the carcasses. The National Park Service provided a disposal pit on park property and shad carcasses were delivered there each night and covered with hydrated line.

Results and Discussion

Table 1 summarizes daily Delaware River shad egg collections during May and June 2001. American shad spawning operations commenced on May 6, when river flow was 1177 cfs, and river temperature was 17.0° C (62.6° F). Egg take ended on June 4, when river flow was 7,590 cfs and temperature was 16.0° C (60.8° F). The 2001 egg-take operation was conducted during relatively stable flow and temperature conditions (Figure 1, Table 1).

Nets were set on twenty nights with 16 nets set each night. The number of nets set per mesh size (stretch, inch) each night was: 4.50- 3 each; 4.75- 2 each; 5.00- 5 each; 5.25- 2 each; 5.50- 2 each; 5.75- 1 each;and 6.00- 1 each.

A total of 925 adult American shad were caught (Table 1). Nightly catches ranged from a low of 11 to a high of 157 shad. Sex ratio (male to female) was 0.35:1. The egg-take was terminated on June 4, 2001, due to low numbers of shad and eggs being collected and low viability of the collected eggs.

Summary

Shad eggs were collected and shipped on 16 of the 20 nights that were fished from 6 May through 4 June 2001. During this time, 925 adult shad were captured and 142 liters of eggs were shipped for a hatchery count of 6.3 million eggs. This compares to 541 shad and 3.8 million eggs in

2000, 714 shad and 5.5 million eggs in 1999 and 1,237 shad and 10.4 million eggs in 1998 (Figure 2). Overall, the percent viability of eggs was 20.5%.

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, 2001.							
Date	No. of nets	Water Temp C	No. of shad captured	No. of eggs shipped (liters)	No. of eggs shipped	No. of viable eggs shipped	Percent Viability
5/6/01	16	17.0	157	24.1	1,177,149	66,650	5.7%
5/7/01	16	17.0	61	11.8	606,116	115,028	19.0%
5/8/01	16	18.0	72	13.5	519,140	230,841	44.5%
5/9/01	16	18.0	54	13.0	511,736	63,766	12.5%
5/10/01	16	19.1	55	9.6	357,510	94,161	26.3%
5/13/01	16	20.0	77	13.3	702,170	105,504	15.0%
5/14/01	16	19.0	44	4.9	243,896	72,224	29.6%
5/15/01	16	19.0	35	9.5	518,738	180,061	34.7%
5/16/01	16	19.0	42	3.9	230,915	17,250	7.5%
5/17/01	16	17.0	21	No shipment			
5/20/01	16	18.5	37	4.6	184,784	300	0.2%
5/22/01	16	17.0	23	No shipment			
5/23/01	16	16.5	13	No shipment			
5/24/01	16	18.0	37	6.3	221,275	0	0.0%
5/28/01	16	16.0	16	1.1	41,993	12,875	30.7%
5/29/01	16	16.0	68	8.6	389,055	50,890	13.1%
5/30/01	16	16.0	53	11.0	407,120	155,333	38.2%
5/31/01	16	16.0	30	4.2	139,862	81,566	58.3%
6/3/01	16	17.0	19	2.7	96,850	53,560	55.3%
6/4/01	16	16.0	11	No shipment			
Totals	320		925	142.1	6,348,308	1,300,009	20.5%

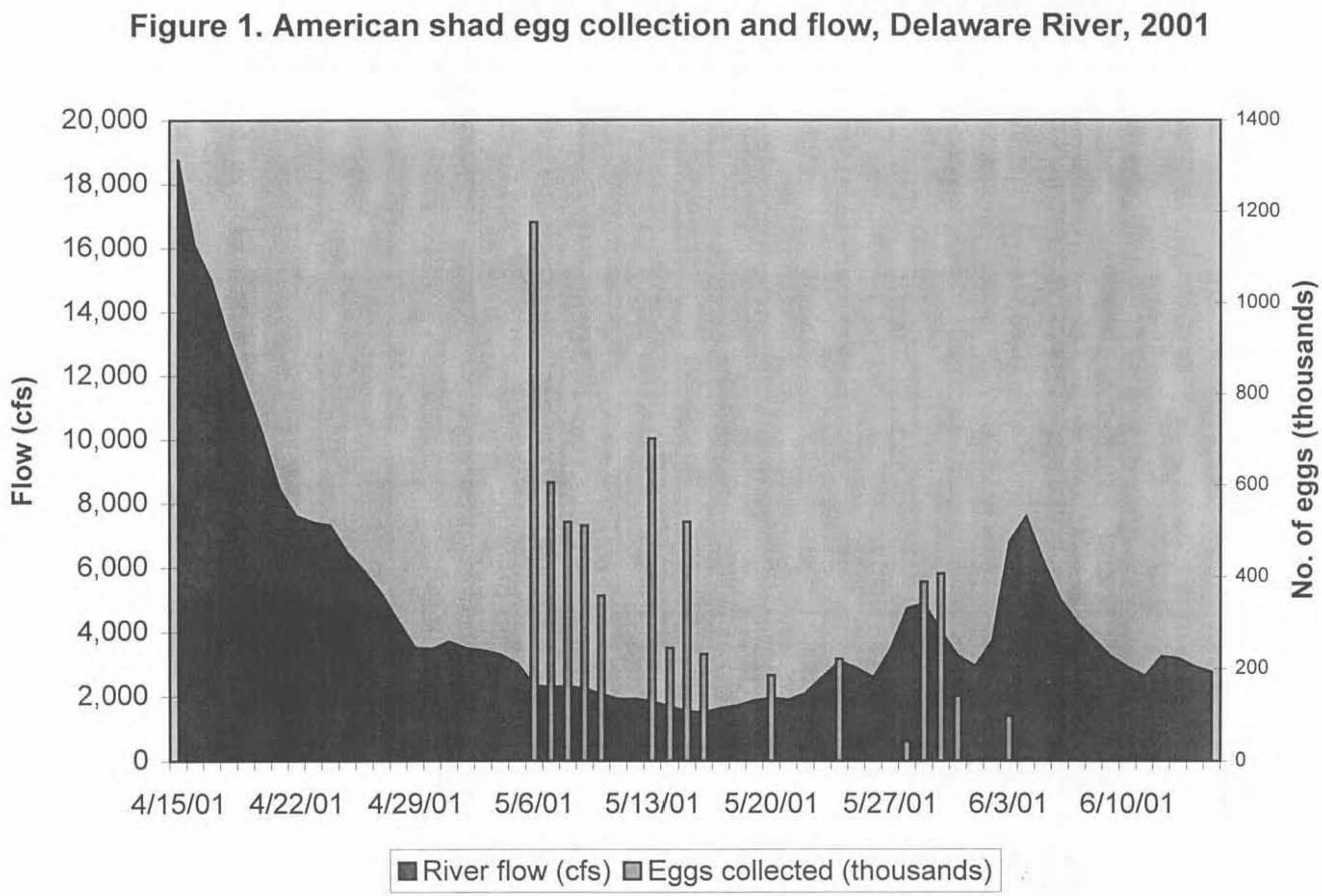
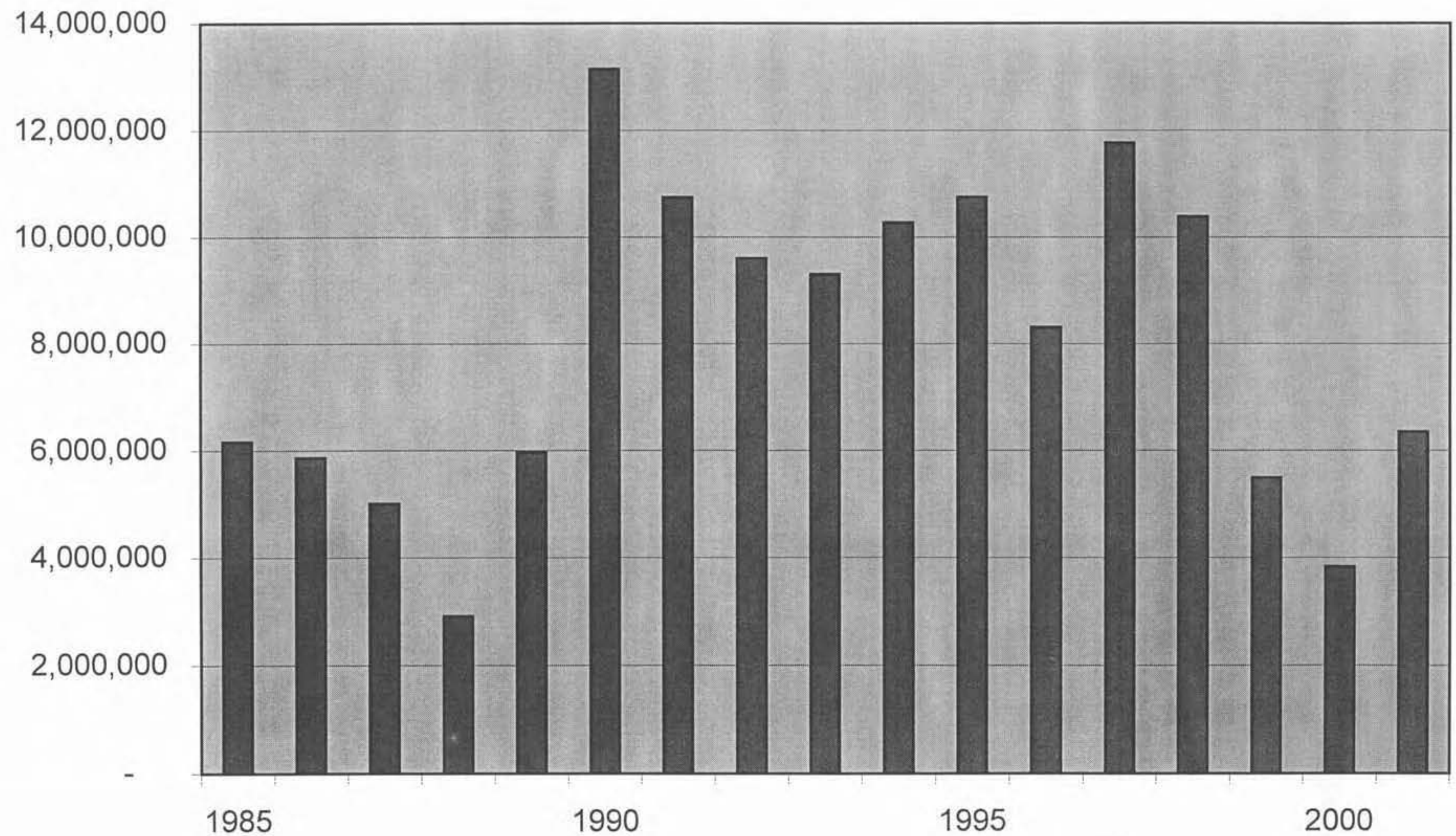


Figure 1. American shad egg collection and flow, Delaware River, 2001
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Flow (cfs)
1400
1200
1000
800
600
400
200
0
No. of eggs (thousands)
4/15/01
4/22/01
4/29/01
5/6/01
5/13/01
5/20/01
5/27/01
6/3/01
6/10/01
River flow (cfs)
Eggs collected (thousands)

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 2001

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Background

For over a decade the Pennsylvania Fish and Boat Commission (PFBC) 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 60%.

The removal of up to 10 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 and others. In an effort to reduce the costs and controversy of out of basin egg shipments, to take advantage of the growing Susquehanna shad population, and to enhance the genetic integrity of the hatchery product, hormone-induced tank spawning of shad broodfish was initiated at Conowingo Dam.

Introduction

The Conowingo Dam West fish lift was built in 1972 and has been operated annually during the months of April, May, and early June. Initially it was an integral part of the anadromous fish restoration effort, which combined the operation of the West fish lift, hand sorting of target species, and a fleet of transport trucks to carry American shad and other alosids to upriver release sites. Since the completion of permanent fish lifts at Conowingo Dam (1991), Holtwood Dam (1997) and Safe Harbor Dam (1997), plus a fish ladder at York Haven Dam (2000), the Conowingo West fish lift is now operated under contract to: (1) collect shad broodfish for egg production and culture at the U. S. Fish and Wildlife Service (USFWS) Northeast Fishery Center at Lamar and Maryland DNR's Joseph Manning Hatchery at Cedarville; (2) collect shad for biological information, otoliths for mark analysis, and to record Maryland DNR tag returns; and (3) provide up to 10,000 adult herring annually for the PFBC's tributary stocking program.

In recent years the West fish lift has operated daily from 11 am 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 trials 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

The American shad tank-spawning trials conducted at the Conowingo West fish lift in 2001 were patterned after similar trials conducted by USFWS at Lamar in previous years. Most of the equipment and supplies needed to conduct the spawning trials was provided by the Lamar Hatchery using SRAFRC funds. Lamar personnel also conducted a field training session for Normandeau personnel at Conowingo Dam at the beginning of the first spawning trial.

Each trial included 60 shad (if available) with a sex ratio of 3:2, favoring males. Thus, most trials were conducted with 36 males and 24 females. Each shad was injected with a Luteinizing Hormone-Releasing Hormone (LHRH) implant in the thick muscles of the shoulder area. Males received a 75 ug implant and females received a 150 ug implant. Both pre-spawn and post-spawn blood samples (1.0 ml) were taken from 10 female shad in three trials (early, mid, and late season). Females from which blood was to be drawn were anesthetized with MS-222 prior to the collection of blood samples - and they were fin clipped. These clipped fish were avoided when post-spawn blood samples were collected. Needles used for drawing blood were coated with a liquid heparin solution to prevent coagulation of the blood. Blood samples were centrifuged within an hour after collection to separate the plasma from the packed cells. Each plasma sample was divided into two 300 ul samples (if enough plasma was available) and frozen. The frozen plasma samples were shipped to the USFWS facility at Lamar at the end of the season.

Implanted shad were placed in a covered 3,400 gallon 12-ft. diameter fiberglass flow-through tank (Figure 1) that was supplied with 25 to 40 gpm of river water through a wall-mounted 2-in. fitting. A screened 4-in. PVC drain pipe in the bottom of the tank provided the only exit for the demersal shad eggs and water from the large tank. The water level in the spawning tank was maintained by the height of the external standpipe that also provided a source of water for the rectangular 72-in. by 36-in. by 16-in. raised egg collection tank. 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.

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 3 liter measuring cup. The eggs collected at the beginning of a pulse would often be held overnight in the frame net and shipped the following day with the next day's production but in separate boxes. The packaging of eggs for shipment followed well-established techniques. Five liters of water hardened eggs were mixed with 5 liters of river water in double plastic bags. Pure oxygen was introduced into the inner bag before being sealed with tape. The bags were placed into marked insulated shipping containers and driven to the PFBC Van Dyke facility by PFBC or Normandeau personnel. When less than 5 liters of eggs were collected in a two-day period, they were measured for volume and released in the river below Conowingo Dam.

An attempt to hand-strip eggs from adult shad was made during several trials. Hand stripping was not done prior to the hormone induced egg pulse but 0 to 3 days following the pulse. At the completion of each trial, all carcasses were buried at an off-site location.

Results

Hormone induced spawning trials with American shad at Conowingo Dam began on 30 April and concluded on 4 June 2001. During this interval, ten spawning trials were conducted with 599 adult shad. Each trial ran from 2 to 5 days. The largest pulse of eggs in Trials 1 and 2 was observed 48 to 72 hours after hormone injection, but, beginning with Trial 3 and continuing to Trial 10, the largest pulse of eggs was observed between 24 and 48 hours following hormone injection. A total of 101.7 liters of eggs was collected from the hormone induced egg releases (Table 1). Of this total, 92.4 liters (5.81 million eggs) were shipped to the Van Dyke Hatchery and 9.3 liters were released into the river below Conowingo Dam. The overall viability of the shad eggs sent to the Van Dyke Hatchery was 33.2% (Job III). In addition to the hormone induced egg releases, hand stripping of adults in 6 of the 10 trials produced another 1.3 liters of eggs, all of which were released below Conowingo Dam. The eggs collected by stripping appeared lower in quality than those produced in the spawning tank.

The spawning tank was not aerated but dissolved oxygen was supplied with the continuous inflow of river water and an unknown amount from surface exchange. Dissolved oxygen levels in river water and the spawning tank were monitored during the trials (Table 2). Daily river oxygen levels ranged from 13.3 to 7.05 ppm during the spawning trials. Spawning tank oxygen levels averaged 1.88 ppm lower than river levels, with a range of 0.25 to 3.45 ppm below river values. Spawning tank water temperature was effected by ambient air temperature and averaged 0.68°F higher than river temperature.

Preliminary results of early, mid- and late season pre- and post-spawn blood chemistry conducted for shad spawned in tanks at Conowingo indicated that post spawning potassium levels were elevated; glucose and lactate results mixed; and sodium and chloride levels were depressed. Dead shad were removed from the spawning tank when they floated to the surface or at the end of each trial. Mortalities ranged from 0 to 17 fish per trial with the higher numbers associated with trials that included collection of blood samples.

Summary

The results of the hormone-induced spawning trials conducted at Conowingo Dam in 2001 show that tank spawning at the West lift site may be a good source of fertilized shad eggs for the PFBC hatchery at Van Dyke. The hand-stripping efforts produced only a small volume of low quality eggs and could be eliminated in future trials.

Recommendations for 2002

- Set-up and use the 12-ft. spawning tank and associated equipment as in 2001.
- Replace one of the large holding tanks inside the West lift fenced area with a second spawning tank system (8 or 10-ft. diameter).
- Supply both tank spawning systems with bottled oxygen.
- Experiment with different sex ratios (e.g., 2 males to 1 female).
- Eliminate blood extraction from female shad to improve survival and egg production.
- Conduct spawning trials simultaneously or staggered dependant upon availability of shad.
- Run as many trials as possible particularly when temperature and fish maturation appear optimal.

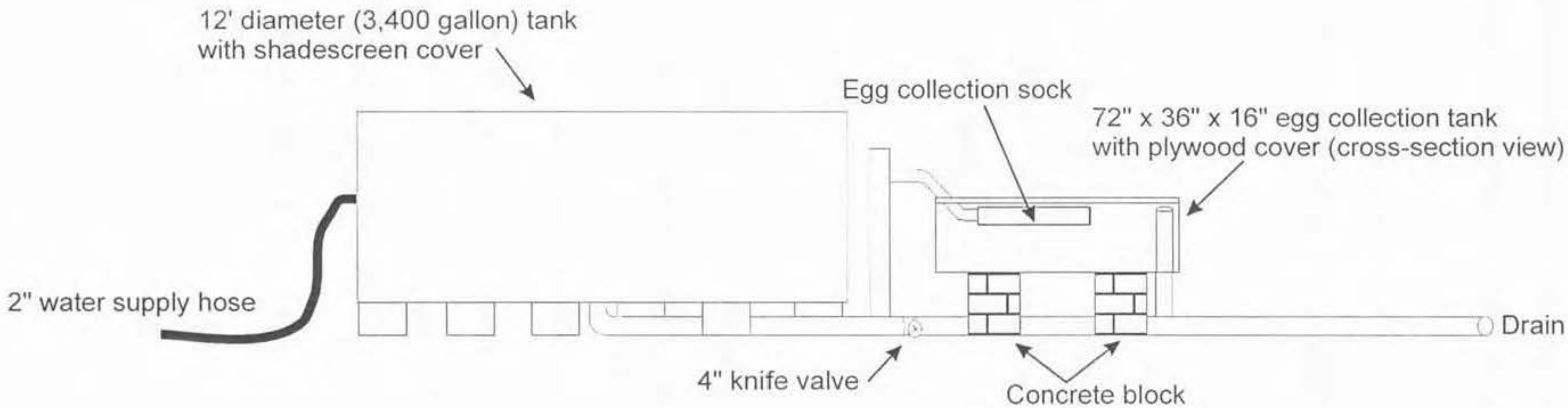

Figure 1

Schematic of tank spawning system used at Conowingo Dam West Fish Lift in 2001.

Table 1

Summary of egg production data for hormone-induced spawning trials conducted at Conowingo Dam in the spring of 2001.

Trial Number	Start Date	Sex Ratio Male/Female	Eggs Taken (24 h intervals)					Total Liters of Eggs	Male/Female Mortalities	Clean Out Date
			24 h	48 h	72 h	96 h	120 h			
1 *	30 Apr	36/24		7.5 V	4.0 R	0.2 S		11.7	5/12	4 May
2	6 May	36/24		10.2 V	0.3 R, 0.2 S			10.7	0/0	9 May
3	9 May	36/24	6.4 V	6.2 V	0.6 R	0.4 R	0.4 R, 0.4 S	14.4	0/0	14 May
4 *	14 May	36/24	4.4 V	5.3 V	0.8 R			10.5	0/6	17 May
5	17 May	36/24	2.8 V	7.3 V	0.2 R			10.3	0/0	20 May
6	21 May	36/24	3.8 V	4.3 V, 0.1 S				8.2	0/0	23 May
7	24 May	35/25	6.5 V	0.2 R, 0.1 S				6.8	0/2	26 May
8	27 May	36/24	5.5 V	6.1 V, 0.3 S				11.9	0/0	29 May
9 *	30 May	36/24	1.6 V	7.4 V				9	0/2	1 Jun
10	1 Jun	34/24		7.1 V	2.4 R			9.5	0/9	4 Jun
Totals		358/241	31.0 V	61.4 V 0.2 R 0.5 S	8.3 R 0.2 S	0.4 R 0.2 S	0.4 R 0.4 S	103	5/31	

Key * = Blood Samples Taken
V = Liters of eggs shipped to Van Dyke Hatchery
R = Liters of eggs released in river below Conowingo Dam
S = Liters of eggs stripped from shad and released in river below dam.

Table 2

Temperature and dissolved oxygen data collected during the 2001 hormone-induced spawning trials with American shad at Conowingo Dam.

Trial Number	Date	Temperature (°F)			Dissolved Oxygen (ppm)		
		River	Tank	Difference	River	Tank	Difference
1	30 Apr	60.8			13.30		
1	1 May	62.2			11.25		
1	2 May	64.4	65.5	1.1	12.80	9.40	-3.40
1	3 May	65.8	67.1	1.3	12.50	9.40	-3.10
1	4 May	65.0	64.3	-0.7	10.90	8.20	-2.70
2	6 May	67.3			9.40		
2	7 May	68.4	69.1	0.7	10.25	7.80	-2.45
2	8 May	68.7	70.0	1.3	9.60	7.50	-2.10
2	9 May	69.8	70.0	0.2	9.15	7.30	-1.85
3	9 May	69.8	70.0	0.2	9.15	7.30	-1.85
3	10 May	72.0	72.0	0.0	8.65	6.10	-2.55
3	11 May	73.6	74.5	0.9	8.65	5.70	-2.95
3	12 May	72.5	73.4	0.9	7.65	5.20	-2.45
3	13 May	73.6	73.8	0.2	8.20	6.45	-1.75
3	14 May	71.3	72.2	0.9	8.20	6.50	-1.70
4	15 May	71.2	71.8	0.6	8.35	7.20	-1.15
4	16 May		71.8			8.10	
4	17 May	69.6	70.0	0.4	8.25	7.20	-1.05
5	18 May	68.9	69.5	0.6	5.35	6.70	1.35
5	19 May	69.4	69.7	0.3	8.00	6.30	-1.70
5	20 May	68.2			7.55		
6	21 May	68.1	68.4	0.3	7.20	6.30	-0.90
6	22 May	69.4	69.9	0.5	7.70	5.00	-2.70
6	23 May	70.6	70.4	-0.2	8.80	8.20	-0.60
7	24 May	70.0	71.6	1.6	7.35	7.10	-0.25
7	25 May	69.8	70.4	0.6	6.65	5.40	-1.25
7	26 May	69.0	69.9	0.9	6.75	6.50	-0.25
8	27 May	70.3	70.2	-0.1	7.45	7.00	-0.45
8	28 May	70.9	72.5	1.6	7.05	5.80	-1.25
8	29 May	71.7	72.5	0.8	7.95	5.20	-2.75
9	30 May	71.5	71.6	0.1	7.55	5.20	-2.35
9	31 May	70.1	71.6	1.5	7.80	4.35	-3.45
9	1 Jun	69.8	69.9	0.1	7.90		
10	1 Jun	69.8	69.9	0.1	7.90	6.10	-1.80
10	2 Jun	69.7	70.7	1.0	8.45	6.30	-2.15
10	3 Jun	69.9	70.7	0.8	7.30	5.70	-1.60
10	4 Jun	70.3			7.90	5.70	-2.20

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2001

M. L. Hendricks

Pennsylvania Fish and Boat Commission

Benner Spring Fish Research Station

State College, PA

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 2001 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 21.1 million eggs (423 L) were received in 54 shipments in 2001 (Table 1). This was the third fewest eggs since 1992 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 35.0%, the lowest ever recorded. 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 12 to May 22, 2001. Hudson River eggs were collected only from the site at Coxsackie, where water depths permit gill netting at all stages of the tide. Nine shipments (3.9 million eggs) were delivered with an overall viability of 77.2%. Delays in the signing of our contract with The Wyatt Group resulted in missing the first week of spawning on the Hudson River and reduced the total egg-take substantially.

Delaware River shipments were received from May 6 to June 3. A total of 16 shipments of eggs were received from the Delaware River (6.3 million eggs) with a viability of 20.5%. As in 1999 and 2000, Delaware River shipments exhibited lower egg viability, compared to pre-1999, due to changes in methods of enumerating dead eggs (Hendricks 2001).

The U. S. Fish and Wildlife Service, Northeast Fishery Center, in Lamar, PA continued tank-spawning operations in 2001. 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 5 million eggs, in 13 shipments, were delivered to the Van Dyke Hatchery. Viability of Lamar tank-spawned eggs at Van Dyke was 22.4%.

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 5.8 million eggs, in 16 shipments, were delivered to the Van Dyke Hatchery. Viability of Lamar tank-spawned eggs at Van Dyke was 33.2%.

Research was conducted in 2001 to attempt to improve viability of American shad eggs collected on the Delaware River by water hardening and shipping them in 200 mg/L $CaCl_2$. That experiment is discussed in Appendix 2.

SURVIVAL

Overall survival of larvae was 88% compared to a range of 41% to 94% for the period 1984 through 2000. The high survival was due to extending the egg incubation period from 7 to 8 days (when possible) and extreme vigilance in preventing mortality due to larvae laying on top of each other and smothering each other in the first few days after hatch.

Survival of individual tanks followed three patterns (Figure 1). Eight tanks, stocked at 5-10 days of age, exhibited 8d survival averaging 97.6%. Eleven tanks, stocked at 10-12 days of age, exhibited 12-day survival averaging 94%. Twenty-one tanks, stocked at 14-30 days of age, exhibited 24-day survival averaging 81%. These tanks exhibited the prototypical pattern of higher mortality beginning at 9 days of age, presumably due to death of non-feeding larvae after exhaustion of yolk-sac nutrition.

Survival of larvae from tank-spawned eggs vs. those from strip-spawned eggs is plotted in Figure 2. For larvae stocked at 10-12 days of age, 10-day survival of strip-spawned eggs (97.6%, 3 tanks) was slightly higher than tank-spawned eggs (94.0%, 8 tanks). This difference was not statistically significant (t-test, p=0.08, Ott 1977). For larvae stocked at 15 days of age or more, 15-day survival of tank-spawned eggs (89.9%, 7 tanks) was slightly higher than strip-spawned eggs (86.4%, 13 tanks). This difference was also not statistically significant (t-test, p= 0.06, Ott 1977). Thus, hatchery survival of larvae from strip-spawned eggs was no different than hatchery survival of tank-spawned eggs. Larvae resulting from tank-spawn operations appeared to be smaller than larvae resulting from strip-spawn operations, however, no measurements were taken. This was probably a result of smaller eggs in tank-spawn operations.

For the first time ever, no tanks exhibited high mortality within the first three days after hatch due to larvae laying on top of each other. This had been an ongoing problem (Hendricks, 1996, 1997, 1998. 1999). All the mortality problems noted in 1995- 1999 were also associated with larvae laying on the bottom of the tank, beginning the morning after hatch. In 1996, we attempted to feed the larvae earlier, beginning at 3 days of age. We continued this practice in the last four years, and, when possible, attempted to maintain water temperatures at 65 or 66F. The newly installed furnace allowed us to maintain these temperatures for all of the 2001 culture season. In addition, we routinely installed the double-down influent pipes prior to hatching, re-established circular flow on day two, and removed the double-down pipes on day three. These strategies appeared to reduce but not eliminate the problem of larvae laying on the bottom. In 2000, we extended the egg incubation period from 7 to 8 days to give the larvae more time to develop, prior to hatching. We did this by moving the incubation jar to the tank on day 7 without sunning the eggs. In this way, the larvae which hatched on day 7 were not lost in the egg battery effluent, yet most larvae did not hatch until day 8, when the eggs were sunned for the first time. This fish culture procedural change, coupled with the practices initiated in prior years, has eliminated the problem of smothering of shad larvae.

LARVAL PRODUCTION

Production and stocking of American shad larvae, summarized in Tables 2, 3 and 4, totaled 6.5 million. A total of 1.0 million was released in the Juniata River, 2.8 million in the Susquehanna River at Clemson Island, Montgomery Ferry, Liverpool and Millersburg, 677 thousand in the North Branch Susquehanna River and 22 thousand in the West Branch Susquehanna River. American shad larvae were also stocked in tributaries: 141 thousand in Conodoguinet Creek, 211 thousand in the Conestoga River, 182 thousand in Swatara Creek, and 170 thousand in West Conewago Creek. In addition, 676 thousand larvae were stocked in the Lehigh River and 491 thousand stocked in the Schuylkill River to support restoration efforts there. Larvae were also provided to Delaware Division of Wildlife (Nanticoke River, 49 thousand) and New Jersey Division of Fish, Game and Wildlife (Raritan River, 105 thousand). Some 6,500 fingerlings, left over from mark retention studies, were stocked in the Juniata River at Warrior Ridge Dam.

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 or middle Susquehanna River were given a triple mark at 3,6, and 9 days of age. This mark was duplicated by a small number (22,450) of larvae stocked in the West Branch Susquehanna River, from Van Dyke. Larvae from the Susquehanna River egg source, reared at Lamar, and stocked in the West Branch Susquehanna River, were given a quadruple mark at 3,6,9, and 15 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 quintuple mark at 3, 6, 9, 12 and 18 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 West Conewago Creek were given a triple mark at 9, 12, and 15 days of age. Larvae stocked in the North Branch Susquehanna River were given a quintuple mark at 3, 6, 12, 15, and 18 days of age. Larvae stocked in the Lehigh River were given a quintuple mark at 3, 6, 9, 12 and 18 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 stocking groups of marked fry in raceways and examining otolith samples collected later. Retention of tetracycline marks for American shad was 100% for all groups analyzed. One of forty specimens marked at days 3,6 and 9 exhibited little otolith growth between the marks at day 6 and 9, resulting in the two marks being very close together. Fingerling shad left over from the mark retention analysis were consolidated into 2 raceways, fed 40gOTC/kg food for three consecutive days and stocked 17 days later, on October 16, 2001. Mark retention on these feed marks was 100% but marks were faint and difficult to detect due to auto-fluorescence near the otolith edge. Analysis of survival of each uniquely marked group is discussed in Appendix 1.

SUMMARY

A total of 54 shipments (21.1million eggs) was received at Van Dyke in 2001. Total egg viability was 35% and survival of viable eggs to stocking was 88%, resulting in production of 6.5 million larvae. The majority of the larvae were stocked in the Juniata River (1.0 million) and the middle Susquehanna River near Montgomery Ferry (2.8 million). Larvae were also released in Conodoguinet Cr. (141 thousand), Conestoga River (201 thousand), Swatara Creek (182 thousand), West Conewago Creek (169 thousand), the North Branch Susquehanna River (676 thousand), the West Branch Susquehanna River (22 thousand), the Lehigh River (676 thousand), the Schuylkill River (491 thousand), the Nanticoke River (49 thousand), and the Raritan River (105 thousand).

Overall survival of larvae was 88%. The high survival was largely due to preventing smothering of larvae when they lay on the bottom in the first few days after hatch.

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 2001

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 egg shells 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. Construct new foam bottom screens for Van Dyke jars each year.
9. Do not disinfect foam bottom screens prior to use.
10. Continue to hold Delaware River eggs until 8:00AM before processing.
11. Conduct controlled experiments to determine the relative survival of larvae from strip-spawn vs. tank-spawn egg sources.

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Figure 1. Survival of American shad larvae, Van Dyke, 2001.

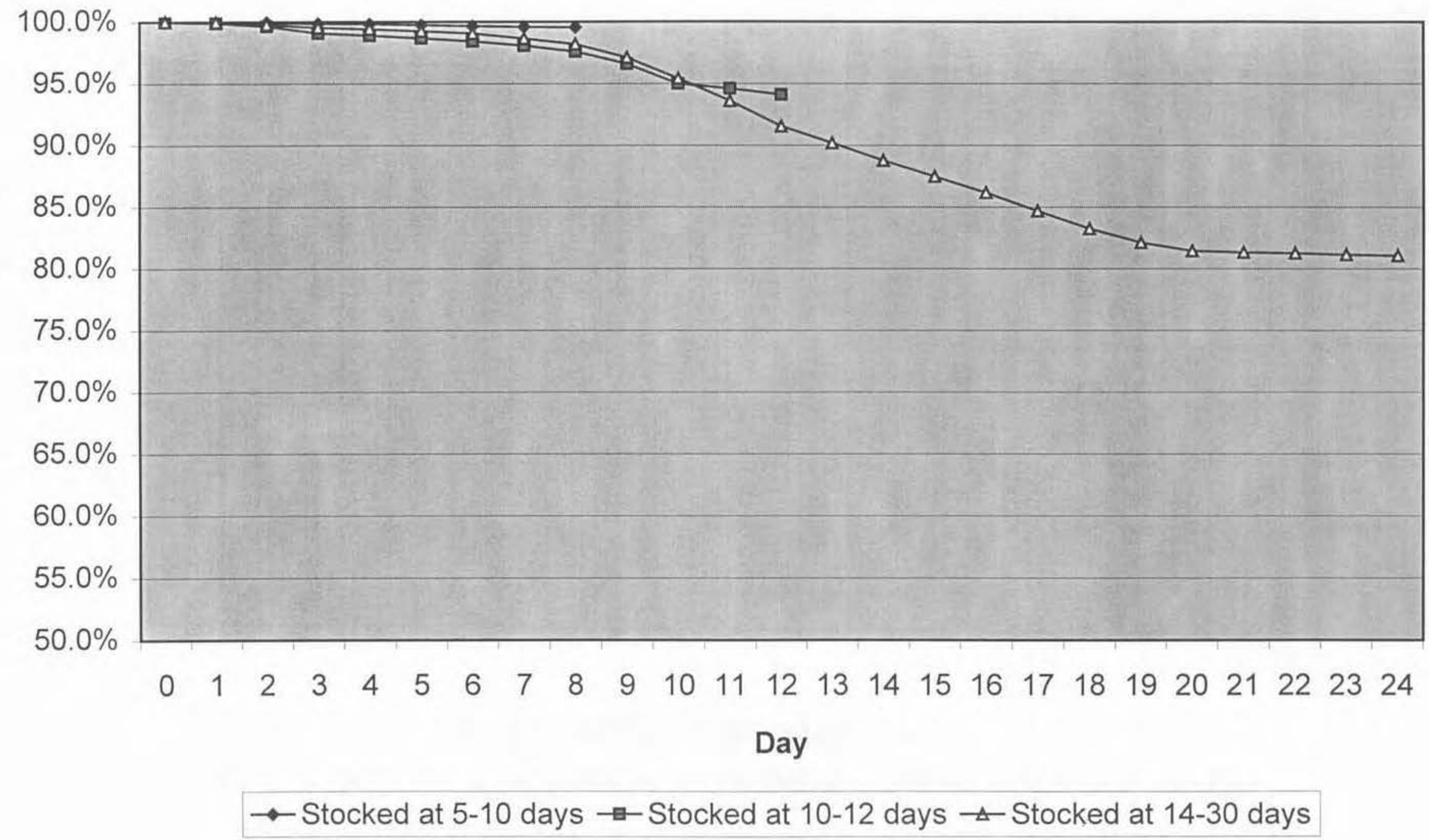

Figure 2. Survival of larvae from tank-spawn eggs vs. strip-spawn eggs, Van Dyke, 2001.

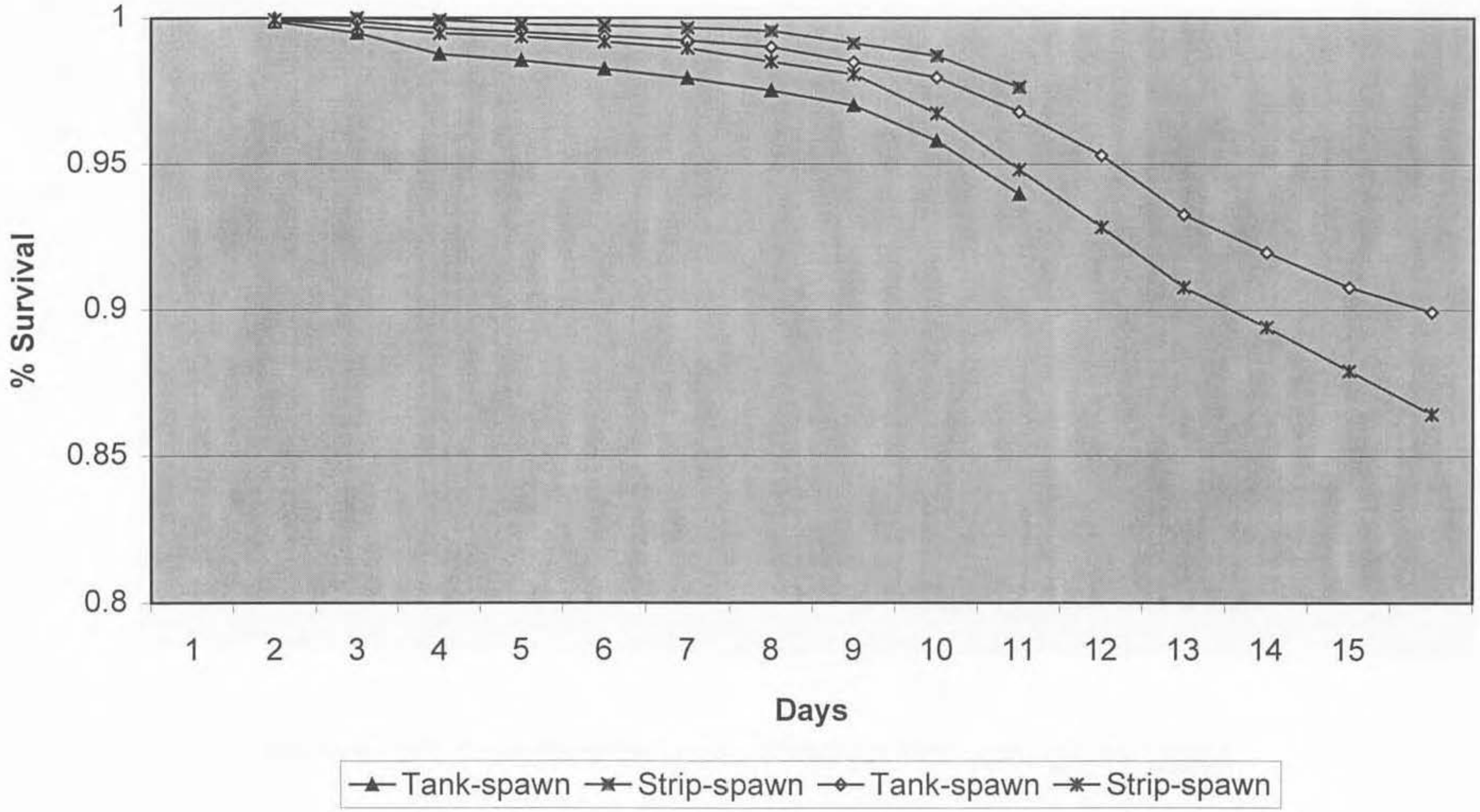

Table 1. American shad egg shipments received at Van Dyke, 2001.

No.	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	Susq.-Conowingo	5/2/01	5/3/01	7.5	420,835	100,000	23.8%
2	Susq.-Lamar	5/4/01	5/5/01	8.6	620,378	241,728	39.0%
3	Susq.-Lamar	5/5/01	5/6/01	6.3	421,313	163,710	38.9%
4	Delaware	5/6/01	5/7/01	24.1	1,177,149	66,650	5.7%
5	Susq.-Lamar	5/6/01	5/7/01	6.1	414,931	100,490	24.2%
6	Delaware	5/07/01	5/08/01	11.8	606,116	115,028	19.0%
7	Susq.-Lamar	5/07/01	5/08/01	5.6	339,647	72,654	21.4%
8	Susq.-Conowingo	5/07/01	5/08/01	10.2	609,307	211,535	34.7%
9	Delaware	5/08/01	5/09/01	13.5	519,140	230,841	44.5%
10	Susq-Lamar	5/08/01	5/09/01	3.8	263,014	38,174	14.5%
11	Delaware	5/09/01	5/10/01	13.0	511,736	63,766	12.5%
12	Susq.-Lamar	5/09/01	5/10/01	9.4	706,655	78,424	11.1%
13	Delaware	5/10/01	5/11/01	9.6	357,510	94,161	26.3%
14	Susq.-Lamar	5/10/01	5/11/01	10.3	642,908	159,302	24.8%
15	Susq.-Conowingo	5/10/01	5/11/01	6.4	481,127	173,881	36.1%
16	Susq.-Conowingo	5/11/01	5/11/01	6.2	400,651	198,111	49.4%
17	Hudson-Coxsackie	5/12/01	5/13/01	4.5	148,246	117,709	79.4%
18	Hudson-Coxsackie	5/13/01	5/14/01	31.2	931,211	677,168	72.7%
19	Delaware	5/13/01	5/14/01	13.3	702,170	105,504	15.0%
20	Delaware	5/14/01	5/15/01	4.9	243,896	72,224	29.6%
21	Hudson-Coxsackie	5/14/01	5/15/01	20.2	630,196	468,145	74.3%
22	Delaware	5/15/01	5/16/01	9.5	518,738	180,061	34.7%
23	Susq.-Conowingo	5/15/01	5/16/01	4.4	317,403	105,619	33.3%
24	Susq.-Conowingo	5/16/01	5/16/01	5.3	268,799	51,853	19.3%
25	Delaware	5/16/01	5/17/01	3.9	230,915	17,250	7.5%
26	Hudson-Coxsackie	5/16/01	5/17/01	29.3	1,018,271	821,390	80.7%
27	Susq-Lamar	5/16/01	5/17/01	4.1	381,591	6,103	1.6%
28	Hudson-Coxsackie	5/17/01	5/18/01	14.5	482,856	375,519	77.8%
29	Susq-Lamar	5/17/01	5/18/01	6.3	690,433	179,934	26.1%
30	Susq-Conowingo	5/18/01	5/19/01	2.8	167,261	93,583	56.0%
31	Susq-Conowingo	5/19/01	5/19/01	7.3	417,060	242,242	58.1%
32	Hudson-Coxsackie	5/19/01	5/20/01	5.7	217,601	174,024	80.0%
33	Hudson-Coxsackie	5/20/01	5/21/01	4.8	170,378	147,986	86.9%
34	Delaware	5/20/01	5/21/01	4.6	184,784	300	0.2%
35	Susq.-Lamar	5/21/01	5/21/01	0.8	42,109	0	0.0%
36	Susq.-Lamar	5/21/01	5/21/01	3.3	262,589	61,824	23.5%
37	Hudson-Coxsackie	5/21/01	5/22/01	4.7	159,902	133,570	83.5%
38	Susq-Lamar	5/21/01	5/22/01	1.2	124,051	14,003	11.3%
39	Susq-Lamar	5/21/01	5/22/01	2.9	142,993	15,013	10.5%
40	Hudson-Coxsackie	5/22/01	5/23/01	5.2	160,453	111,413	69.4%
41	Susq-Conowingo	5/22/01	5/23/01	3.8	271,849	112,203	41.3%
42	Susq-Conowingo	5/23/01	5/23/01	4.3	275,482	56,351	20.5%
43	Delaware	5/24/01	5/25/01	6.3	221,275	0	0.0%
44	Susq-Conowingo	5/25/01	5/26/01	6.5	409,267	148,790	36.4%
45	Delaware	5/28/01	5/29/01	1.1	41,993	12,875	30.7%
46	Susq-Conowingo	5/28/01	5/29/01	5.5	314,224	92,728	29.5%
47	Susq-Conowingo	5/29/01	5/29/01	6.1	380,752	9,057	2.4%
48	Delaware	5/29/01	5/30/01	8.6	389,055	50,890	13.1%
49	Delaware	5/30/01	5/31/01	11.0	407,120	155,333	38.2%
50	Delaware	5/31/01	6/01/01	4.2	139,862	81,566	58.3%
51	Susq.-Conowingo	5/31/01	6/1/01	1.6	108,834	36,814	33.8%
52	Susq.-Conowingo	6/1/01	6/1/01	7.4	453,886	158,027	34.8%
53	Susq.-Conowingo	6/3/01	6/3/01	7.1	512,173	135,692	26.5%
54	Delaware	6/3/01	6/4/01	2.7	96,850	53,560	55.3%
Totals		No. of shipments					
	Hudson-Coxsackie	9		120	3,919,113	3,026,925	77.2%
	Delaware	16		142	6,348,308	1,300,009	20.5%
	Susq.-Conowingo	16		92	5,808,909	1,926,486	33.2%
	Susq.-Lamar	13		69	5,052,614	1,131,358	22.4%
	Grand total	54		423	21,128,944	7,384,777	35.0%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976-2001.

					No. of shad stocked (all rivers)				
Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	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
						Total	207,713		
					Total since 1985 (OTC marked)		182,847		

*Includes fry reared at Manning.

Table 3. American shad stocking and fish transfer activities, 2001.

Date	Tank	Number	OTC mark (days)	Location	Origin	Age	Size
5/21/01	A1 1	92,908	3,6,9	Millerstown (Greenwood)	Susq.- Conowingo	11	Fry
5/24/01	A2 1	368,463	3,6,9	Millerstown (Rt. 17 bridge)	Susq.-Lamar	12	Fry
6/4/01	A3 1	151,460	3,6,9,12	Schuylkill River	Delaware	19	Fry
5/25/01	A4 1	168,817	3,6,9	Millers Canoe Rental	Susq.-Lamar	10	Fry
6/5/01	B1 1	182,490	3,6,9,15,18	Swatara Creek	Susq.-Conowingo	20	Fry
6/4/01	B2 1	203,161	3,6,9,12	Schuylkill River	Delaware	18	Fry
6/5/01	B3 1	210,831	3,9,12,15	Conestoga River	Susq.-Lamar	18	Fry
6/4/01	B4 1	136,280	3,6,9,12	Schuylkill River	Delaware	16	Fry
5/29/01	C1 1	366,345	3,6,9	Thompsontown	Susq.- Conowingo	10	Fry
5/29/01	C2 1	116,291	3	Thompsontown	Hudson-Coxsackie	8	Fry
6/11/01	C3 1	172,206	3,6,12,15,18	North Branch Susquehanna River	Hudson-Coxsackie	20	Fry
6/11/01	C4 1	179,209	3,6,12,15,18	North Branch Susquehanna River	Hudson-Coxsackie	20	Fry
6/11/01	D1 1	157,704	3,6,12,15,18	North Branch Susquehanna River	Hudson-Coxsackie	20	Fry
6/8/01	D2 1	154,090	3,9,12	Lehigh	Delaware	17	Fry
6/11/01	D3 1	167,863	3,6,12,15,18	North Branch Susquehanna River	Hudson-Coxsackie	19	Fry
5/30/01	D4 1	248,108	3	Liverpool	Hudson-Coxsackie	7	Fry
6/8/01	E1 1	161,857	3,9,12	Lehigh	Delaware	15	Fry
6/12/01	E2 1	140,821	3,6,9,12,18	Conodoguinet Creek	Susq.- Conowingo	19	Fry
5/30/01	E3 1	281,509	3	Liverpool	Hudson-Coxsackie	5	Fry
5/31/01	E4 1	266,935	3	Millersburg	Hudson-Coxsackie	6	Fry
5/31/01	F1 1	270,645	3	Millersburg	Hudson-Coxsackie	6	Fry
6/12/01	F2 1	169,545	9,12,15	West Conewago Creek	Susq.-Lamar	17	Fry
6/1/01	F3 1	181,171	3	Clemson Island	Hudson-Coxsackie	6	Fry
6/1/01	F4 1	192,922	3	Clemson Island	Hudson-Coxsackie	6	Fry
6/6/01	G1 1	326,916	3,6,9	Montgomery Ferry	Susq.-Conowingo	10	Fry
6/27/01	G2 1	105,410	3,9,12,15,18,21	Raritan River	Hudson-Coxsackie	30	Fry
6/6/01	G3 1	147,257	3	Montgomery Ferry	Hudson-Coxsackie	8	Fry
6/18/01	H1 1	49,376	3,6,9,12,15,18	Nanticoke River	Susq.-Lamar	20	Fry
6/9/01	H2 1	127,723	3	Clemson Island	Hudson-Coxsackie	10	Fry
6/20/01	H3 1	22,450	3,6,9	West Branch Susquehanna River	Susq.-Lamar	21	Fry
6/10/01	H4 1	108,300	3	Liverpool	Hudson-Coxsackie	10	Fry
6/14/01	I1 1	100,000	3,6,9	Mifflin	Susq.-Conowingo	15	Fry
6/26/01	I2 1	53,853	3,9,12	Lehigh	Delaware	24	Fry
6/14/01	I3 1	50,000	3,6,9	Mifflin	Susq.- Conowingo	11	Fry
6/26/01	I4 1	44,223	3,9,12	Lehigh	Delaware	19	Fry
6/16/01	A1 2	88,820	3,6,9	Mexico	Susq.- Conowingo	10	Fry
6/26/01	A2 2	218,502	3,9,12	Lehigh	Delaware	18	Fry
6/18/01	A3 2	184,451	3,6,9	Liverpool	Susq.- Conowingo	10	Fry
6/21/01	A4 2	112,625	3,6,9	Mexico	Susq.- Conowingo	10	Fry
6/26/01	B1 2	43,101	3,9,12	Lehigh	Delaware	14	Fry
10/16/01	BS raceways	6,500	various + single feed mark	Warrior Ridge Dam	various	126-153	Fing.

Table 4. Production and utilization of juvenile American shad, 2001.

	Site	Fry	Fingerling
Releases	Millerstown (Greenwood)	92,908	
	Millerstown (Rt. 17 Bridge)	368,463	
	Miller's Canoe Rental	168,817	
	Mexico	201,445	
	Mifflin	150,000	
	Warrior Ridge Dam		6,500
	Juniata River Subtotal	981,633	6,500
	Clemson Island	501,816	
	Montgomery Ferry	956,809	
	Millersburg	537,580	
	Liverpool	822,367	
	Conodoguinet Creek	140,821	
	Conestoga River	210,831	
	Swatara Creek	182,490	
	West Conewago Creek	169,545	
	North Branch Susquehanna River	676,982	
	West Br. Susq. R. (Van Dyke)	22,450	
	West Br. Susq. R. (Lamar)	306,860	
	Susquehanna River Basin Subtotal	5,510,184	6,500
	Schuylkill River	490,901	
	Lehigh River	675,625	
	Nanticoke River	49,376	
	Raritan River	105,410	
	Total	6,831,496	6,500

Table 5. Tetracycline marking regime for Alosids stocked in North America, 2001.

Year	Number	Size	Mark Immersion (days)	Mark Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers.	Mark Retention (%) Feed
2001- American shad												
	313,560	Fry	single*	-	Waldoboro	-	Saco R.	Saco R.	307ppm OTC	-	68	-
	308,596	Fry	single*	-	Waldoboro	-	Androscoggin R.	Merrimac R.	307ppm OTC	-	-	-
	1,489,913	Fry	single*	-	Waldoboro	-	Kennebec R.	mixed	307ppm OTC	-	80-95	-
	618,879	Fry	single*	-	Waldoboro	-	Sebastocook R.	mixed	307ppm OTC	-	85-87	-
	2,730,948	Fry	Subtotal									
	6,671	Fing.	possibly	single	Waldoboro	Waldoboro	Kennebec R.	mixed	307ppm OTC?	88g OTC/kg food	-	-
	1,940,860	Fry	3	-	Van Dyke	-	Juniata & Susq. R.	Hudson	256ppm OTC	-	100	-
	1,859,345	Fry	3,6,9	-	Van Dyke	-	Juniata & Susq. R.	Susq.	256ppm OTC	-	100	-
	22,450	Fry	3,6,9	-	Van Dyke	-	W. Br. Susq. R.	Susq.	256ppm OTC	-	100	-
	306,860	Fry	3,6,9,15	-	Lamar	-	W. Br. Susq. R.	Susq.	256ppm OTC	-	100	-
	140,821	Fry	3,6,9,12,18	-	Van Dyke	-	Conodoguinet Cr.	Susq.	256ppm OTC	-	100	-
	169,545	Fry	9,12,15	-	Van Dyke	-	W. Conewago Cr.	Susq.	256ppm OTC	-	100	-
	490,901	Fry	3,6,9,12	-	Van Dyke	-	Schuylkill R.	Delaware	256ppm OTC	-	100	-
	210,831	Fry	3,9,12,15	-	Van Dyke	-	Conestoga R.	Susq.	256ppm OTC	-	100	-
	675,625	Fry	3,9,12	-	Van Dyke	-	Lehigh R.	Delaware	256ppm OTC	-	100	-
	182,490	Fry	3,6,9,15,18	-	Van Dyke	-	Swatara Cr.	Susq.	256ppm OTC	-	100	-
	676,982	Fry	3,6,12,15,18	-	Van Dyke	-	N. Br. Susq. R.	Hudson	256ppm OTC	-	100	-
	6,676,710	Fry	Subtotal									
	105,410	Fry	3,9,12,15,18,21	-	Van Dyke	-	Raritan R.	Hudson	256ppm OTC	-	100	-
	49,376	Fry	3,6,9,12,15,18	-	Van Dyke	-	Nanticoke R. (DE)	Susq.	256ppm OTC	-	100	-
	40,000	Fry	Egg,6,12	-	Manning	-	Nanticoke R. (DE)	Potomac	200ppm OTC	-	-	-
	6,500	Fing.	various	single	Van Dyke	Ben. Spr.	Juniata R.	various	256ppm OTC	40g OTC/# food	100	100
	221,478	Fry	9,12	-	Manning	-	Patuxent R.	Susq.	200ppm OTC	-		-
	142,710	Fry	3,12	-	Manning	-	Patuxent R.	Potomac	200ppm OTC	-		-
	77,500	Early juv.	3,6	-	Cedarville	Mirant Ponds	Patuxent R.	Susq./Pot.	200ppm OTC	-		-
	15,000	Early juv.	egg,3,6	-	Cedarville	Mirant Ponds	Patuxent R.	Susq./Pot.	1000/200ppm OTC	-		-
	21,903	Fing.	-	single**	Manning	Mirant Ponds	Patuxent R.	Susq./Pot.	-	500mg/kg live wt.		-
	32,483	Fing.	-	single**	Manning	Mirant Ponds	Choptank R.	Susq./Pot.	-	500mg/kg live wt.		-
	3,335,773	Fry	3,9	-	Harrison L.	-	Potomac R.	Potomac R.	200ppm OTC	-		-
	2,137,211	Fry	3,6,9,12,15	-	Harrison L.	-	James R.	York R.	200ppm OTC	-	100	-
	476,032	Fry	3,6,12,15	-	Harrison L.	-	York R.	York R.	200ppm OTC	-	100	-
	7,129,257	Fry	9	-	King & Queen	-	James R.	York R.	271ppm OTC	-	100	-
	998,666	Fry	3,6,12,15	-	King & Queen	-	York R.	York R.	271ppm OTC	-	100	-
	3,000,000	Fry	15	-	PTG	-	Pamunkey R	Pamunkey R	200ppm OTC	-		-
	6,000,000	Fry	6, 15	-	MTG	-	Mattaponni R.	Mattaponni R.	200ppm OTC	-		-
	130,000	Fry	3,6,12	-	Edenton	-	Roanoke R.	Meherrin R.	200ppm OTC	-	-	-
	570,000	Fry	3,6,12	-	Edenton	-	Roanoke R.	Tar R.	200ppm OTC	-	-	-
	1,369,000	Fry	3,6,12	-	Watha	-	Roanoke R.	Tar R.	233ppm OTC	-	-	-

Table 5. (continued)

Year	Number	Size	Mark Immersion (days)	Mark Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers.	Mark Retention (%) Feed
Hickory Shad												
	1,111,363	Fry	Egg,3	-	Manning	-	Choptank R.	Susq.	1000/200ppm OTC	-		-
	47,404	Fry	1,3	-	Manning	-	Choptank R.	Susq.	200ppm OTC	-		-
	1,230,068	Fry	Egg,3	-	Manning	-	Marshyhope Cr.	Susq.	1000/200ppm OTC	-		-
	1,230,000	Fry	Egg,3	-	Manning	-	Nanticoke R.	Susq.	1000/200ppm OTC	-		-
	1,380,776	Fry	Egg,3	-	Manning	-	Patuxent R.	Susq.	1000/200ppm OTC	-		-
	4,999,611	Fry	Subtotal									
	53,500	Early juv.	Egg	-	Manning	Mirant ponds	Patuxent R.	Susq.	1000ppm OTC	-		-
	19,907	Fing.	-	single**	Manning	Mirant ponds	Choptank R.	Susq.	-	500mg/kg live wt.	-	-
	20,238	Fing.	-	single**	Manning	Mirant ponds	Patuxent R.	Susq.	-	500mg/kg live wt.	-	-

* Revieved a single immersion mark, but not necessarily on day 3

**Also recieved coded wire tags

Appendix 1

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2001.

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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 2001 and summarizes results from 1995 to 2001.

Materials and Methods

Production larvae, stocked in 2001, included 1.94 million Hudson River source (strip-spawn) larvae marked at three days of age; and 1.86 million Susquehanna River source (tank-spawn) larvae marked at 3,6, and 9 days of age. These groups were stocked at various sites in the Juniata River and the middle Susquehanna River near Montgomery Ferry. Susquehanna River sites were stocked when high, turbid water prevented stocking 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 North and West Branches of the Susquehanna River and Conestoga, Conewago, Conodoguinet, and Swatara Creeks. Approximately 6,500 feed-marked fingerlings were stocked in the Juniata River below Warrior Ridge Dam.

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 2000 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

Marking and recovery data for 1995 to 2001 are tabulated in tables 1-1 through 1-7, respectively. In 2001, Hudson River source larvae stocked in the Juniata River and middle Susquehanna River near Montgomery Ferry exhibited the best survival (relative survival set to 1.00, Table A1-7). Susquehanna River egg source larvae stocked at the same sites exhibited relative survival of 0.64, much lower than that for Hudson River source larvae. Susquehanna River source larvae stocked in Swatara Cr. and the North Branch Susquehanna River were recovered at about the same rate as those stocked in the Juniata River and middle Susquehanna River near Montgomery Ferry (relative survival 0.56 and 0.51, respectively). Susquehanna River larvae stocked in Conestoga River, Conewago Cr., the West Branch Susquehanna River and Conodoguinet Cr. exhibited very low relative survival (0.11, 0.09, 0.05, and 0.03 respectively).

A summary of the results of seven years of uniquely marking larvae according to stocking site is provided in Table A1-8. Recovery rates for 2001 varied from 0.07 to 2.07. The overall recovery rate for 2001 (1.37) was second only to 1997 (1.77).

Larvae stocked in the North Branch did extremely well in previous years, but only average in 2001. These fish were stocked well upstream, at Tunkhannock. The highest catch of shad from the lift net occurred on Dec. 7, the last day of sampling. The catch of North Branch shad as a proportion of the daily total was also the highest on Dec. 7, suggesting that low Autumn river flows may have delayed out-migration, beyond the last sampling date.

Larvae stocked in the West Branch have not done well, exhibiting relative survival of 0.00 to 0.41 during the period 1996 to 2001.

Overall survival of American shad larvae, stocked in smaller tributaries, was relatively poor in 2001, perhaps due to the fact that all small tributaries were stocked with Susquehanna River egg source larvae. In the past, larvae stocked in smaller tributaries did well in some years and poorly in others, for example, Conestoga R. larvae exhibited the best survival in 1995 and 1999, poor relative survival in 1997 (0.12) and 2000 (0.18) and were not detected in 1996 and 1998. The high survival releases in 1995 and 1999 were at the Rt. 322 bridge near Ephrata (river mile 38), as was the low survival release in 2000. The other low survival releases were at Conestoga Pines Park in Lancaster (river mile 22).

Larvae stocked in Conodoguinet Creek larvae exhibited good relative survival in 1995 and 2000 (0.77 and 0.74) fair relative survival in 1999 (0.59), but poor relative survival in other years (0.03 to 0.37; 1996, 1997, 1998, and 2001). Water quality in Conodoguinet Creek is good at the larval stocking site, but low dissolved oxygen may be problematic in the lower reaches of the stream.

Larvae stocked in Swatara Cr. did well in 1998 and 1999(relative survival 0.96 and 0.80, respectively), average relative survival in 2001 (0.56), and were not detected in 2000, probably due to the low number stocked (33,000).

In Conewago Cr., larvae did well in 1998 and 2000 (0.89 and 0.84), and poorly in 1999 and 2001 (0.20 and 0.09), despite release at the same site. Thus, recovery rate of shad larvae at each stocking site fluctuates from year to year with no one site consistently better than the others. The exception is that the West Branch Susquehanna River exhibits consistently low recovery rates, possibly due low fertility.

Crecco and Savoy (1985) found that survival of 5-day cohorts of American shad larvae in the Connecticut River was highest at low river flow, high water temperature and high zooplankton density. This dependence on environmental conditions may explain the varying survival of larvae stocked in tributaries of the Susquehanna River, particularly since each tributary receives only one stocking per year. If environmental conditions are ideal at the time of stocking, survival may be good for that release group. If environmental conditions are poor, survival may be poor or zero. Based on the above considerations, I make the following recommendations.

1. We should continue spreading larvae out by stocking a number of sites in the Juniata River. Due to logistical considerations, the majority of production larvae must be stocked in close proximity to the Van Dyke Hatchery.
2. The stocking site for Conestoga River should remain at Rt. 322, near Ephrata.
3. Continue marking fish stocked in different tributaries with unique marks.

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Table 1-1. 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, 1995. (Corrected for the total of number of shad collected.)

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	%	Juveniles Recovered N	%	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	7-9	5/19-6/16	9,070,000	91%	1,923.9	90	2.12	0.65
Conodoguinet Cr.	19	6/6	220,000	2%	55.4	3	2.52	0.77
mouth of Conodoguinet Cr.	19	6/6	230,000	2%	68.0	3	2.96	0.90
Conestoga R.	22	6/15	198,000	2%	65.0	3	3.28	1.00
mouth of Conestoga R.	22	6/15	190,000	2%	22.5	1	1.18	0.36
Muddy Cr.	22	6/19	93,000	1%	0.0	0	0.00	0.00
		Total	10,001,000		2,135		2.13	

*Note: Fry released in Muddy Cr. could only have been recaptured at Peach bottom.

Table 1-2. 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, 1996. (Corrected for the total number of shad collected.)

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	%	Juveniles Recovered N	%	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	6-8	5/24-6/24	5,730,200	77%	59.3	66	0.10	0.31
Conodoguinet Cr.	16	6/14	171,700	2%	2.1	2	0.12	0.37
Conestoga R.	17	6/17	277,100	4%	0.0	0	0.00	0.00
Standing Stone Cr.	21	7/2	42,900	1%	0.0	0	0.00	0.00
W. Br. Susq. R.	17	6/15	561,100	8%	5.2	6	0.09	0.28
N. Br. Susq. R.	13	6/19	682,500	9%	22.9	26	0.34	1.00
		Total	7,465,500		90		0.12	

Table1-3. 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, 1997. (Corrected for the total number of shad collected.)

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	8-14	6/2-6/25	3,037,000	41%	563.2	40	1.85	0.89
Juniata R./ various sites	18-20	6/9-7/1	2,270,000	30%	474.7	33	2.09	1.00
Conodoguinet Cr.	18	6/24	174,000	2%	5.0	0	0.29	0.14
Conestoga R.	25	7/1	231,000	3%	6.0	0	0.26	0.12
Huntingdon	10	5/31	486,000	7%	73.7	5	1.52	0.72
W. Br. Susq. R.	23	6/30	622,000	8%	53.6	4	0.86	0.41
N. Br. Susq. R.	17-19	6/23	1,199,000	16%	242.3	17	2.02	0.97
		Total	8,019,000		1,419		1.77	

Table 1-4. 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, 1998. (Corrected for the total number of shad collected.)

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	9-20	5/19-6/9	8,925,000	76%	135.3	76	0.15	0.72
Juniata R./ Susq. egg source	11-12	6/11-6/15	565,000	5%	5.9	3	0.10	0.49
Conodoguinet Cr.	16	5/29	305,000	3%	1.6	1	0.05	0.25
Conestoga R.	20	6/1	229,000	2%	0.0	0	0.00	0.00
Conewago Cr.	16	5/29	321000	3%	6.0	3	0.19	0.89
Swatara Cr.	20	6/1	230000	2%	4.7	3	0.20	0.96
W. Br. Susq. R.	15	6/19-6/25	56,000	0%	0.0	0	0.00	0.00
N. Br. Susq. R.	17-20	5/27	1,126,000	10%	23.8	13	0.21	1.00
Standing Stone Cr.	fing.	9/9	2,200	0%	0.0	0	0.00	0.00
		Total	11,759,200		177		0.15	

Table 1-5. 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, 1999. (Corrected for the total number of shad collected.)

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./	5-10	5/17- 6/1	10,229,000	87%	648.4	89	0.63	0.73
Juniata R./ Susq. egg source	-	-	0	0%		0	0.00	0.00
Conodoguinet Cr.	14	6/11	373,000	3%	19.1	3	0.51	0.59
Conestoga R.	20	6/10	236,000	2%	20.5	3	0.87	1.00
Conewago Cr.	19	6/8	219000	2%	3.8	1	0.18	0.20
Swatara Cr.	20	6/10	249000	2%	17.2	2	0.69	0.80
W. Br. Susq. R.	17-22	6/21	984,000	8%	0.0	0	0.00	0.00
N. Br. Susq. R.	19	6/4	1,211,000	10%	22.6	3	0.19	0.21
		Total	13,501,000		732		0.54	

Table 1-6. 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, 2000. (Corrected for the total number of shad collected.)

Stocking Site	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	7-15	5/19- 6/1	7,368,860	63%	533.9	88	0.72	1.00
Conodoguinet Cr.	15	6/5	111,017	1%	6.0	0	0.54	0.74
Conestoga R.	23	6/12	231,178	2%	3.0	0	0.13	0.18
Conewago Cr.	18	6/5	109,352	1%	6.7	0	0.61	0.84
Swatara Cr.	25	6/12	33,321	0%	0.0	0	0.00	0.00
W. Br. Susq. R.	21	6/26	960,982	8%	16.3	1	0.17	0.23
N. Br. Susq. R.	16-19	6/2-6/29	974,614	8%	39.2	3	0.40	0.56
		Total	9,789,324		605		0.62	

Table A1-7. 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, 2001.

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	5-10	5/29-6/10	1,940,860	35%	402.4	53	2.07	1.00
Juniata R./ middle Susq. R. near Mont. Ferry	Susq.-both	10-15	5/21-6/21	1,859,345	34%	245.6	33	1.32	0.64
Conodoguinet Cr.	Susq.-Conowingo	19	6/12	140,821	3%	1.0	0	0.07	0.03
Conestoga R.	Susq.-Lamar	18	6/5	210,831	4%	4.6	1	0.22	0.11
Conewago Cr.	Susq.-Lamar	17	6/12	169,545	3%	3.0	0	0.18	0.09
Swatara Cr.	Susq.-Conowingo	20	6/5	182,490	3%	21.1	3	1.15	0.56
W. Br. Susq. R.	Susq.-Lamar			306,860	6%	2.9	0	0.09	0.05
N. Br. Susq. R.	Hudson	19-20	6/11	676,982	12%	71.9	10	1.06	0.51
			Total	5,487,734		753		1.37	

Table A1-8. 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, 1995-2001.

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

Appendix 2

Evaluation of methods to improve the viability of Delaware River American shad eggs, 2001; with analysis of historical trends in Delaware River egg collections.

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Introduction

The Pennsylvania Fish and Boat Commission is restoring American shad to the Susquehanna River under the auspices of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). 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 60% 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 Kobayashi (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%. Increasing water hardness at Van Dyke would be very difficult to achieve, however, we could easily add $CaCl_2$ to the water hardening bath at the egg collection site and to the egg transport water, resulting in increased hardness for the first 8 to 10 hours of incubation.

In 2000, Hendricks (2001) investigated the potential for improving viability of Delaware River American shad eggs by holding adult male shad in chilled salt water until stripping, use of chilled whole sperm, use of isotonic salt solutions during sperm activation, and use of calcium chloride during water hardening and transport. 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 shows promise. This report follows up on the work of Hendricks (2001) by replicating trials of water hardening and transport of shad eggs in 200 mg/L $CaCl_2$.

Materials and Methods

The study consisted of 12 treatments and 12 controls (3 replicates per night for 4 nights). American shad were collected by gill net using standard methods. Eggs from one to five ripe female shad were stripped into a dry plastic dishpan. Feces were removed immediately with a dry spoon. The eggs were fertilized with semen from several males and thoroughly mixed. The semen was activated by addition of river water.

After a few minutes for fertilization, the eggs were washed with river water to remove remaining sperm. At this point, eggs were divided and approximately one liter poured into each of two labeled 5 gallon buckets for water hardening. One lot was water hardened in river water (control) and the other in 200 mg/L $CaCl_2$ (treatment). Eggs were aerated using a pump and airstone. After at least one hour of water hardening, egg lots were put in labeled plastic bags in a 1:1 mixture of water to eggs. Eggs from the control lot were shipped in river water, while the treatment lot was shipped in 200 mg/L $CaCl_2$. Pure oxygen was added and the bags sealed for shipping to the Van Dyke Hatchery. At the Van Dyke Hatchery, eggs were processed at approximately 9:00AM. Egg lots were tempered to ambient water temperatures (60F), disinfected in 50ppm free iodine for 10 min, rinsed and incubated separately in labeled May-Sloan hatching jars.

Egg viability was assessed at the tail-free stage by taking three random samples (at least 100 eggs each) of each egg lot, viewing the sample with a microscope and counting the number of live and dead eggs. The three samples were pooled and the percent live was tested for statistical significance using the Sign Test and Wilcoxin's Signed-Rank Test (Ott, 1977).

Results and Discussion

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. Viability for control lots exceeded that of test lots for 3 replicates, and one replicate had 0.0 percent viability for both test and controls. 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.

Viability of eggs collected concurrently with this study but used for production (not a part of this controlled experiment) is also presented in Table 1. There was a high degree of variability, with no trend, between the production lots and experimental lots. For shipment 9, viability of production eggs was 13 percent higher than any of the experimental lots, but for shipment 6, 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 (Shipment 6, test, replicates B and C) 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.

In addition to low egg viability, Delaware River eggs include large numbers of small, non-water hardened eggs. American shad eggs, like other fish eggs, should water harden even if they are not fertilized. Occasionally, we have experienced a shipment of Hudson River eggs where good males were not available. These shipments rarely contain small, non-water hardened eggs. This suggests that there may be problems with females (egg quality) on the Delaware River, resulting in expulsion of poor eggs, which will not water harden.

Variability in quality of eggs or sperm is not apparent on the Hudson River where egg viabilities are typically over 70 percent for each shipment. The "secret" to high egg viability on the Hudson River is thought to be the use of good quality, live males (Mark Plummer, The Wyatt Group, personal communication). Egg collection procedures on the Hudson River are different from those on the Delaware River due to the difference in habitat type. On the Hudson River, drift gill nets are used to collect spawners from the tidal spawning grounds. Eggs are stripped from the females as soon as they are brought aboard the boat. The eggs are held in a bowl until a good male is collected. The male is stripped immediately or held in a circular tank, to ensure that all males are alive when stripped. This is in contrast to the egg collection procedure on the Delaware River, where males and females are collected from an anchored gill net. The fish are marked according to mesh size by twisting a color-coded pipe cleaner through the mouth and gills, and held in a washtub. When all nets have been checked, the fish are bought to shore and strip-spawned. The extra handling and delay in spawning may be impairing the quality of eggs, sperm or both, and may be the source of the low egg viability for the Delaware River.

It should be noted that Delaware River egg collections are conducted at rkm 351, 129 km up river from the freshwater tidal zone at Trenton (rkm222). Furthermore, Trenton is approximately 133 km up river from the salt line. In contrast, Hudson River egg collections are conducted in the freshwater tidal portion of the river, approximately rkm 95 to 151. Thus, the Delaware shad have migrated a longer distance and are under greater stress at the time of spawning than Hudson River fish. This may help explain the lower egg viability.

Historical egg shipment data for the Delaware River from 1985 to 2001 is presented in Table 2-2 and Figures 2-1 and 2-2. Since 1985, number of liters of eggs per nights fishing (shipment) has declined and number of shipments has increased (Figure 2-1). This reflects increasing difficulty in obtaining eggs and increased effort to attempt to fill the quota of 10 million eggs. At the same time egg viability has decreased and the number of eggs per liter has increased. Linear regression (Figure 2-2) demonstrates the correlation between number of eggs per liter and egg viability (r-square= 0.58, F=0.0004, df=16).

The full extent of the problems with Delaware River American shad egg collections can be summarized by a single statistic: the number of shipments required to obtain one million viable eggs (Table 2-2, Figure 2-3). Between 1985 and 1993, one million viable eggs could be obtained in 1 to 3 shipments. Since 1999, 7 to 9 shipments were required.

In summary, use of 200 mg/L $CaCl_2$ in water hardening and shipping results in a small, but statistically significant improvement in egg viability. Inspection of the data suggests that there is high variability in quality of eggs and/or sperm, not evident on the Hudson River. Historical trends indicate that increasing effort is required to collect eggs from the Delaware River, and that egg viability has decreased over time. With these considerations in mind, I recommend that we re-think methodologies and collection sites and consider a fresh approach to collection of American shad eggs on the Delaware River.

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Table 2-1. Viability of Delaware River American shad eggs water hardened and shipped in 200 mg/L $CaCl_2$ vs untreated controls, 2001.

		Test			Control			Production		
Shipment	Replicate	Vol (L)	Number	% Live	Vol (L)	Number	% Live	Vol (L)	Number	% Live
6	A	0.80	40,954	38.3%	0.80	40,954	38.9%	6.90	353,227	12.8%
	B	0.84	43,001	43.1%	0.80	40,954	28.5%			
	C	0.98	50,168	12.0%	0.72	36,858	5.7%			
9	A	0.86	33,169	39.4%	0.84	32,398	31.3%	8.70	335,551	52.3%
	B	0.70	26,998	18.5%	0.72	27,770	24.3%			
	C	0.82	31,627	37.0%	0.82	31,627	27.7%			
11	A	0.90	35,428	11.9%	0.90	35,428	12.8%	8.70	342,469	14.9%
	B	0.42	16,533	12.3%	0.36	14,171	10.0%			
	C	0.92	36,215	1.1%	0.80	31,491	0.6%			
13	A	0.86	32,161	27.3%	0.86	32,161	22.5%	5.50	205,681	31.6%
	B	0.88	32,909	25.1%	0.86	32,161	15.0%			
	C	0.38	14,211	0.0%	0.22	8,227	0.0%			
			Average	22.2%			18.1%			

Table 2-2. American shad egg shipment data, Delaware River, 1985-2001.

Year	Number of Egg Shipments	Volume of eggs (L)	Number of Eggs	Viability (%)	Eggs/L	L/shipment	Shipments per million viable eggs
1985	9	169	6,163,300	51	36,534	19	2.9
1986	6	171	5,864,600	58	34,276	29	1.8
1987	6	139	5,006,500	55	35,938	23	2.2
1988	4	105	2,906,800	63	27,605	26	2.2
1989	5	141	5,963,600	62	42,400	28	1.4
1990	9	374	13,146,900	52	35,133	42	1.3
1991	10	303	10,745,000	59	35,462	30	1.6
1992	9	272	9,601,000	60	35,259	30	1.6
1993	14	245	9,303,194	57	37,972	18	2.6
1994	15	231	10,273,763	22	44,437	15	6.6
1995	11*	295	10,752,738	45	36,512	27	2.3
1996	13	254	8,308,940	62	32,777	20	2.5
1997	17	270	11,764,260	39	43,652	16	3.7
1998	11	188	10,384,059	33	55,382	17	3.2
1999	14	124	5,489,339	27	44,448	9	9.4
2000	11	78	3,827,250	40	49,067	7	7.3
2001	16	142	6,348,308	33	44,706	9	7.6

* Two additional shipments delivered to Manning Hatchery

Figure 2-1. Trends in Delaware River American shad egg collections, 1985-2001.

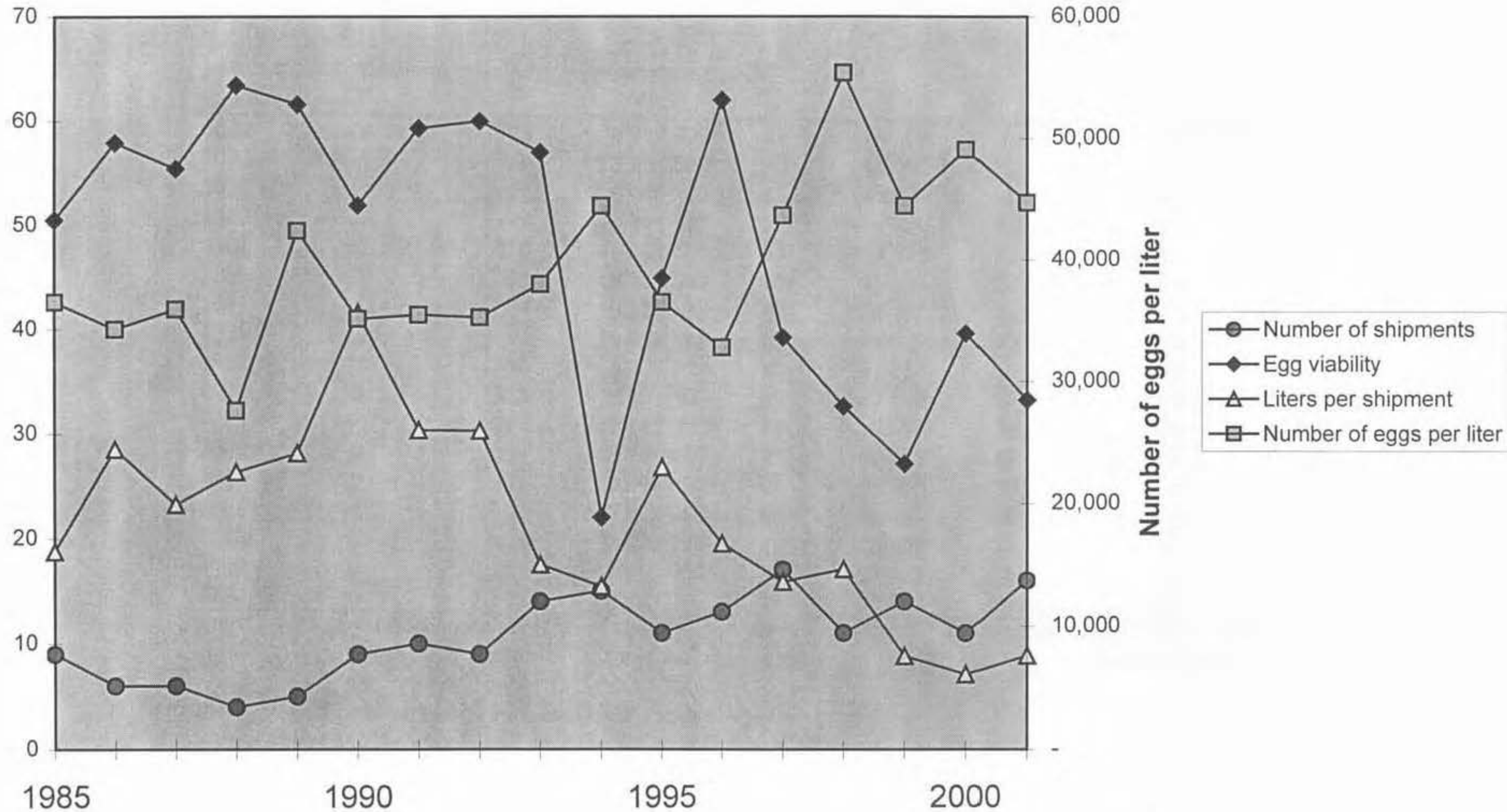


Figure 2-2. Relationship between number of eggs per liter and egg viability, Delaware River American shad eggs, 1985-2001.

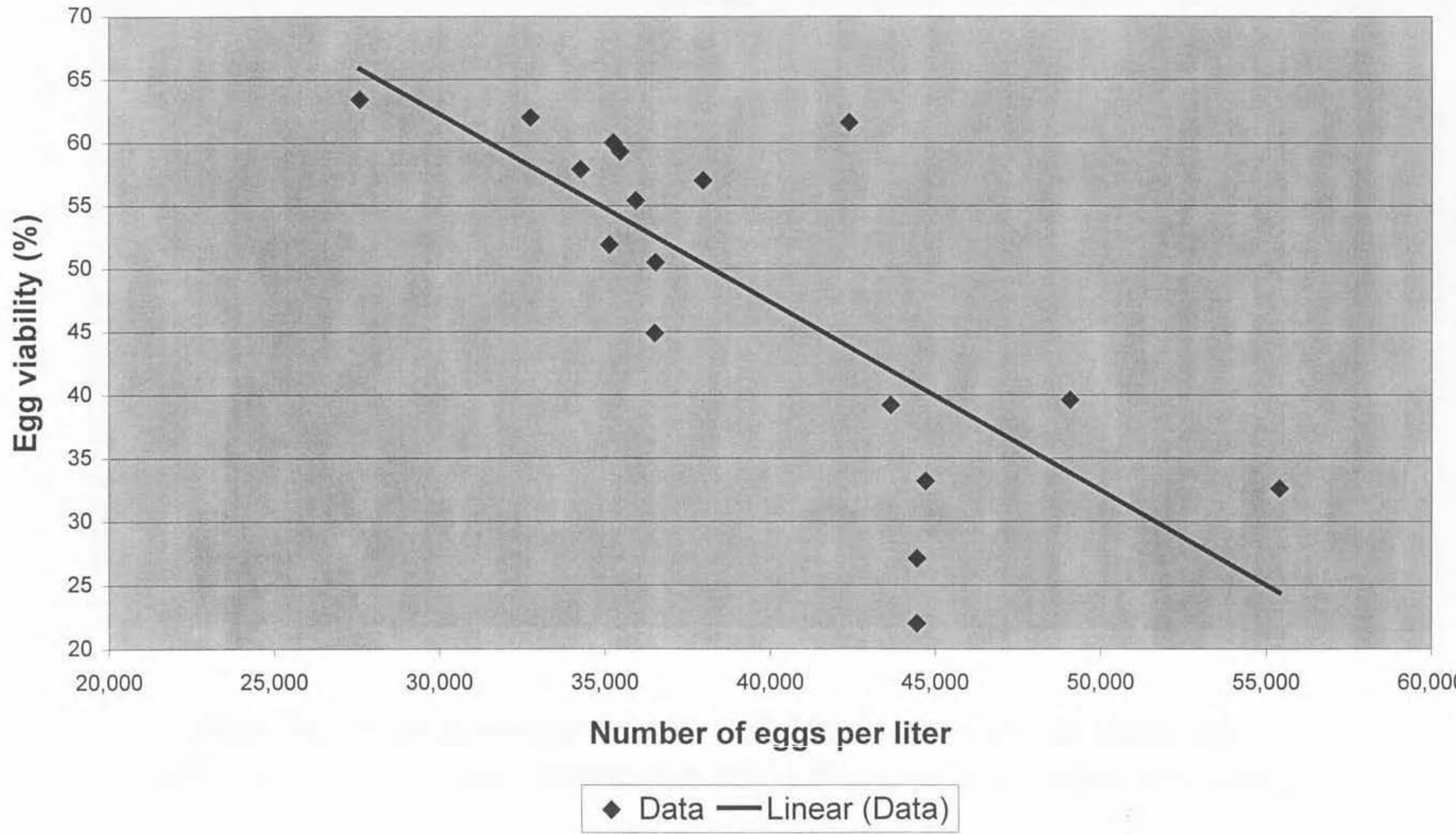
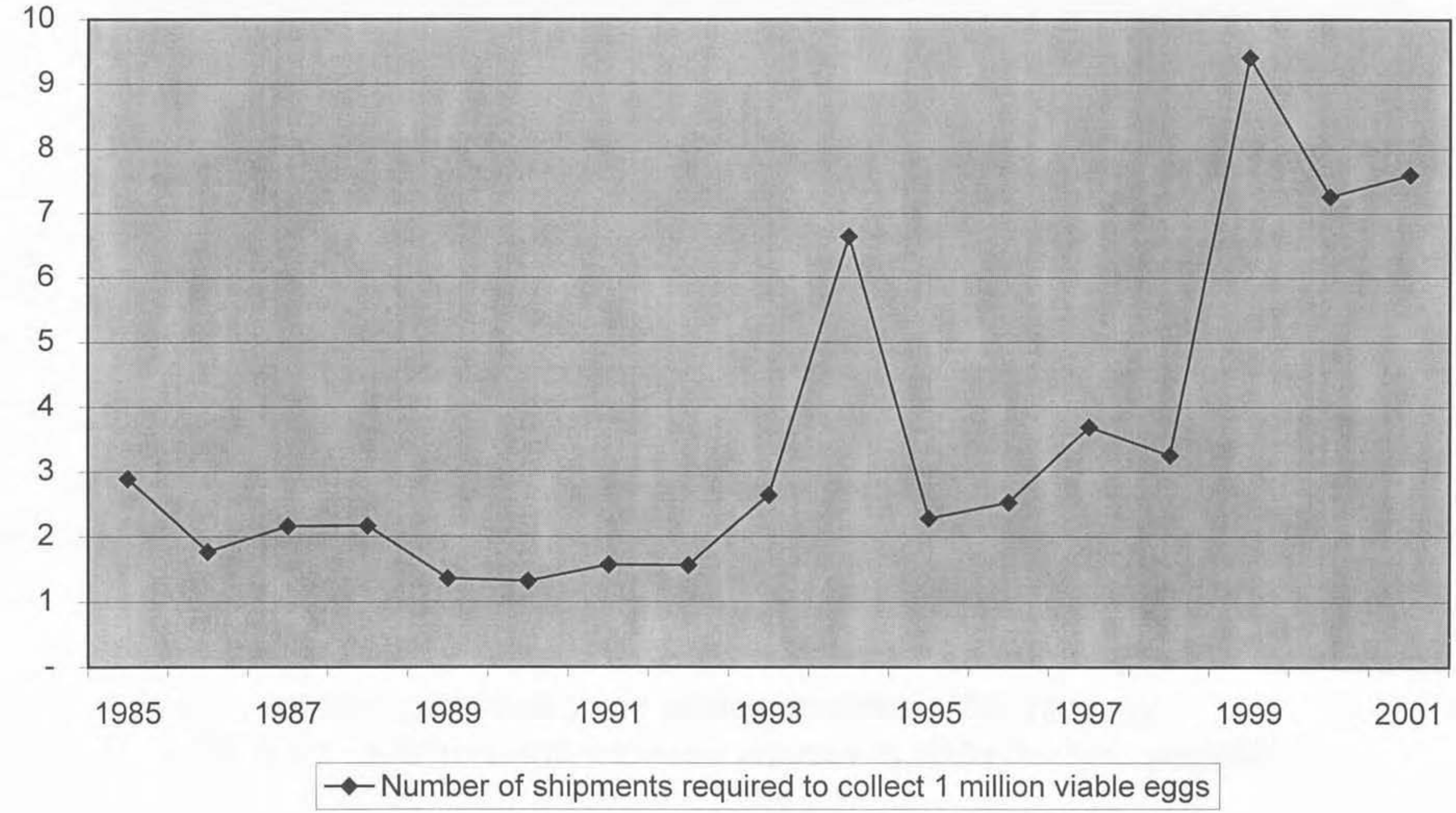


Figure 2-3. Number of shipments (nights fishing) required to collect 1 million viable American shad eggs, Delaware River, 1985-2001.



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 adult spawners, and hatchery stocking of 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.

Since the completion of fish passage facilities at Holtwood and Safe Harbor in 1997, the Conowingo East Lift has operated in fish passage mode. The Conowingo West Lift continues to be used as a source of adult American shad and river herring to support special studies or transport to spawning sites above dams. During the 2001 spring migration, Conowingo East Lift passed a record 194,574 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 109,976, 89,816, and 16,200 American shad, respectively. American shad had access from the mouth of the Susquehanna to the Fabri Dam on the Susquehanna main stem, and Warrior Ridge or Raystown on the Juniata. Several large tributaries including Muddy Creek and West Conewago Creek, York County; Conestoga River and Little Conestoga Creek, Lancaster

County; Conodoguinet Creek, Cumberland County; and Swatara Creek, Dauphin/Lebanon County are also accessible to American shad.

Of the 10,940 adult shad collected by the Conowingo West Lift during 2001, 970 and 823 were transported to Lamar and Manning hatcheries, respectively. Observed transport and delayed mortalities of shad amounted to less than 1%. Overall sex ratio (SR) in these transfers was about 0.7 to 1 favoring females. Of the river herring collected, 1,520 and 300 alewives were stocked in the Little Conestoga, and Conestoga, respectively. Blueback transports included 5,049 adults stocked in the Conestoga (2,690), Little Conestoga (1,510), and Conodoguinet (849). Mortality for river herring transports was less than 1%.

During the 2001 production season, the PFBC Van Dyke Research Station for Anadromous Fish released 5.51 million shad larvae in the Susquehanna Basin, Pennsylvania. Most larvae were released between 21 May to 21 June in the following locations, numbers, and days(d) of age (tetracycline marks by days of age in parentheses):

Juniata River (various sites)	981,633 age 6-13d (3; 3,6,9)
Juniata River (Warrior Ridge)	6,500 age 126-153(feed tag)
Susquehanna R.(various sites)	2,818,572 age 9-13d (3; 3,6,9)
W. Branch Susquehanna R.	306,860 age 21d (3,6,9,15)
W. Branch Susquehanna R.	24,450 age 21d (3,6,9)
N. Branch Susquehanna R	676,982 age 19d (3,6,12,15,18)
Conodoguinet Creek	140,821 age 15d (3,6,9,12,18)
Conestoga River	210,831 age 23d (3,9,12,15)
W. Conewago Creek	169,545 age 18d (9,12,15)
Swatara Creek	182,490 age 25d (3,6,9,15,18)

METHODS

Juvenile American shad were collected at several locations in the Susquehanna River Basin during the summer and fall in an effort to document in-stream movement, outmigration, 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 verses wild composition of the samples.

Haul Seining - Main Stem

RMC/Normandeau Associates, Incorporated (RMC) conducted haul seining in the lower Susquehanna River once each week on 15 dates beginning 16 July and continuing through 24 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 23 July through 22 August. A total of 7 consecutive hauls were conducted at 30 stations in five tributaries (six stations per tributary; Table 1) using a seine measuring 30-ft X 6-ft with 3/8 in stretch mesh. All tributaries were sampled on five dates.

Push-netting

Push-netting for juvenile alosids was conducted by RMC at various sites in the upper portion of

Conowingo pool beginning 4 June and continuing through 9 July for a total of 13 sampling dates. A total of 10 stations were sampled during 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 water 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 by RMC 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 pulsator electrofisher with anode mounted on 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. Total number of shad captured and observed, but avoided capture, was enumerated.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Sampling at Holtwood Dam inner forebay was conducted by RMC using a fixed 8-ft square lift-net beginning 12 September and continuing every three days through 7 December (30 total). Sampling began at sunset and consisted of 10 lifts with 10 minute intervals between lift cycles.

The lift-net was placed on the north side of the coffer cell in the inner forebay. A lighting system was used to illuminate the water directly over the lift-net similar to that employed in 2000.

RMC conducted intake screen sampling for impinged alosids at Peach Bottom Atomic Power Station three times per week from 3 October to 7 December for a total of 28 samples. Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosids twice weekly from 8 October to 7 December for a total of 16 samples.

Susquehanna River Mouth and Flats

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

Disposition of Samples

Subsamples of up to 30 juveniles per day were used for otolith analysis. Samples of shad from most collections were returned to PFBC's Benner Spring Fish Research Station for analysis of tetracycline marks on otoliths. Otoliths were surgically removed from the fish, cleaned and mounted on slides, ground to the focus on the sagittal plane on both sides, and viewed under ultraviolet light to detect fluorescent rings indicating tetracycline immersion treatments.

RESULTS

Haul Seining - Main Stem

The first juvenile American shad captured by haul seine occurred on 16 July at a water temperature of 27.0°C and a river flow of 8,000 cfs (Table 2). The last juvenile was captured on

9 October at a water temperature of 15.0°C and a river flow of 5,990 cfs. For the season, a total of 377 juvenile American shad were collected in 90 hauls (Table 2). Shad were captured on 13 of 15 sampling dates. Daily Catch-Per-Unit-Effort (D CPUE) ranged from zero on two sampling dates to 11.67 shad per haul on 7 August (Table 3). Geometric Mean Catch-Per-Unit-Effort (individual hauls) was 1.52; Geometric Mean Catch-Per-Unit-Effort (daily combined hauls) was 3.04 (Table 4). Of the total 377 juveniles captured, 88 (23.3%), 179 (47.5%), 103 (27.3%), 7 (1.9%) were taken during July, August, September, and October, respectively (Table 3). The length of juvenile shad ranged from 46 mm on 16 July to 136 mm on 25 September (Table 5). A total of 19 taxa was collected by seine.

Haul Seining - Tributaries

A total of 13 American shad were collected by seine in selected tributaries. American shad were captured in the Conestoga River (7) at stations 2 and 5, and Swatara Creek (6) at station 2 (Table 1 and 6); no shad were captured in W. Conewago Creek, Conodoguinet Creek, and Little Conestoga Creek. Juveniles ranged in size from 39 to 91 mm total length. Shad from the Conestoga average 74 mm TL while those from Swatara were much smaller averaging 49 mm TL (Table 6). No river herring were collected in any of the tributaries sampled. A total of 34 taxa was collected by seine in tributaries.

Push-netting

Two juvenile American shad and 134 blueback herring were collected in approximately 650 minutes of push-netting (Table 7). Total CPUE for American shad and blueback herring was

0.003/50 min and 0.206/50 min, respectively (Table 7). A total of 12 taxa was collected during push-netting.

Electrofishing

River reaches on the Susquehanna and Juniata rivers were sampled for a combined total of 1004 minutes of shock time resulting in the capture of 11 juvenile American shad. Six juveniles were captured in Susquehanna River in 506 minutes of shock time resulting in a CPUE of 0.71 shad/hr (Table 8). Five juveniles were captured in the Juniata River in 498 minutes of shock time resulting in a CPUE of 0.60 shad/hr (Table 9). Six juvenile shad (3 per each site) were observed but avoided capture (Tables 8 and 9). Juvenile American shad ranged from 80 to 153 mm TL; most were between 100 and 113 mm total length (Table 10). Shad from the Susquehanna were slightly larger (123.2 vs. 119.2 mm) than those from the Juniata River. The combined mean length for all shad captured was 121.4 mm TL (Table 10). The combined CPUE (number/hr) was just over one shad per hour (1.02). The CPUE (captured plus observed/hr) in the Susquehanna (1.07) and Juniata (0.96) was nearly identical (Table 11).

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner forebay resulted in the capture of 1,245 juvenile American shad in 300 lifts (Table 12). Geometric Mean Catch-Per-Unit-Effort (individual lift) was 0.43; Geometric Mean Catch-Per-Unit-Effort (daily combined lifts) was 1.37 (Table 13). Shad were captured at a wide range of temperatures and river flows between 26 September and 7 December (Table 12). The first juvenile shad captured occurred on 26 September at a water temperature of

22.2°C and a river flow of 11,750 cfs. Highest daily catch by lift-net (360) occurred on 7 December, the last day of sampling, at a water temperature of 10.0°C and a river flow of 22,300 cfs (Table 12 and Figure 1). Nearly 95% of the juveniles were captured when river temperature was less than 15.0° C (from 29 October to 7 December; Table 12 and Figure 1). Total length of specimens ranged from 107 to 186 mm; over 93% were 131 to 175 mm TL (Table 14). A total of 11 taxa were captured by lift-net with American shad being the most numerous.

Peach Bottom intake screens produced 65 juvenile American shad and 105 juvenile blueback herring (Table 15). Cooling water strainers at Conowingo produced 6 juvenile American shad and 82 juvenile blueback herring (Table 16).

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 23 juvenile American shad in the upper Chesapeake Bay during summer and fall 2001 (Table 17). Otolith analysis was not conducted on captured juveniles.

Otolith Mark Analysis

Results of otolith analysis are outlined in Table 18. Otoliths from 779 juvenile American shad taken in the summer and fall collections were analyzed for hatchery marks. A total of 361 juvenile shad otoliths from seine and electrofishing collections above Holtwood Dam were successfully processed. Of the juvenile shad collected above Holtwood, 68% (245) were marked and of hatchery origin and 32% (116) were wild. Otoliths from 418 juvenile American shad collected at Holtwood, Peach Bottom, and Conowingo were successfully processed. Of these, 240 (57%) were marked and of hatchery origin and 178 (43%) were wild. Wild fish were captured at Holtwood, Muddy Run, Peach Bottom, and Conowingo pool. The total percentage of hatchery fish above Conowingo was 60% with 40% being wild. Recapture of shad from various stocking sites is discussed in Job III.

DISCUSSION

In-Stream Movements and Outmigration Timing

Spring river conditions for the Susquehanna River basin during 2001 could be characterized as slightly higher than normal flows in April and below normal flows in May and June. Flows measured at Conowingo Hydroelectric Station only exceeded 60,000 cfs during the first day of east fish lift operation on 23 April; after 1 May, flows never exceeded 30,000 cfs until late June. Water temperature in the lower Susquehanna warmed to the upper 60's to mid 70's (Fahrenheit) where they remained until lift operations at Conowingo was suspended for the season on 6 June. The entire Susquehanna Basin was under drought conditions throughout the summer, fall and early winter. The only significant precipitation event occurred in late June in association with tropical storm Allison when flows at Conowingo exceeded 40,000-cfs for a 5-day period; flows never exceeded 28,000 cfs from July through December. Water clarity was very high throughout the Susquehanna Basin in summer and fall. A notable exception was the Juniata River that, despite low flows, was extremely turbid all summer.

Haul seine collections during 2001 were some of the highest on record (Table 4 and 19). Catches of juvenile shad in July (69) and October (7) were below, while those in August (162) and

September (139) were above, the twelve-year average of 149.5, 82.3, 114.8, and 26.1 for July, August, September, and October, respectively (Table 19).

Based on monthly CPUE (number captured/haul), juvenile shad at Columbia were most abundant in August (7.46), followed by July (4.89), September (4.29), and October (0.29) (Table 19). The fewest number of juveniles were captured in October with the most notable drop occurring in conjunction with a 2-fold increase in river flow and decrease in water temperature during the period from 18 September to 9 October (Table 2). Decreases in seine catches during October may be in response to decreased juvenile densities due to previous sampling or to triggered outmigration associated with marked changes in flow and temperature.

The first marked fish collected at Columbia by seine occurred on 16 July (Table 18). These included thirty shad stocked in the Juniata or Susquehanna rivers suggesting a movement of approximately 60-80 miles in 57 days or less. Of the juveniles captured by seine at Columbia, 68% were of hatchery origin and 32% were wild (Table 18). This compares to 100% hatchery fish captured at this site by seine in 2000.

Based on lift-net catches, outmigration of juvenile American shad occurred over a wide range of temperatures and river flows with peak outmigration occurring in the November through early December. This timing is later than observed in past years when peak outmigration occurred in October and November. The first American shad collected by lift-net occurred on 26 September at a water temperature of 20.2° C and a river flow of 11,750 cfs (Table 12 and Figure 1). Two distinct peaks in catches (Figure 1) occurred during the periods 29 October to 19 November and 28 November and 7 December when 33.8 and 60.7% of juveniles were captured, respectively. These peaks corresponded with increased outmigration behavior brought about by modest increases in river flow and/or decreased water temperature following fall freshets (Table 12 and Figure 1). High catches late in the season suggests that outmigration was delayed due suppressed flows attributed to drought conditions. The CPUE during December (30.9) was the second highest observed for that month since 1985 (Table 20). Nearly 95% of the shad were captured when river temperature was less than 15°C (from 29 October through 7 December; Table 12). During this period thousands of shad were observed in the Holtwood forebay.

Generally, outmigration of juvenile American shad based on lift-net sampling at Holtwood dam is episodic in nature. Typically it occurs when water temperature falls below 15.6° C and river flow increases, with the majority of the outmigration occurring in a one to four week period. During the 2001 season, outmigration occurred over an extended period and was the result of declining temperatures and short periods of increased river flows. In past years, river temperatures usually exhibit a sharp or steady decline during the outmigration, but this was not the case in 2001 due to unseasonably warm weather. In some years, outmigration could be attributed to a high flow event, like the increase of 30,000 cfs in 1997 or 55,000 cfs in 1999. During the 2001 season, no high flows of these magnitudes occurred. The greatest increase in flow between two consecutive sampling dates was 14,550 cfs occurring in late September (Figure 1). Even though a high flow event of significant proportions was absent this season, the increased river flow during 28 November through 7 December evidently pushed large numbers of American shad down river. During this surge, over 60% of the juvenile catch for the season occurred. Since the peak catches occurred on 7 December, it is likely that a large proportion of juveniles migrated past Holtwood after sampling was terminated for the season. This is particularly true for juveniles stocked in the upper basin that had to migrate much longer distances than their lower river counterparts. Based on otolith analysis, juveniles stocked in the North Branch of the Susquehanna comprised 28.6% of the lift-net catch during the last two sampling events in December (Table 18). Prior to 28 November, juveniles stocked in the North Branch were virtually absent from lift-net catches (Table 18). It is conceivable that the peak outmigration may have occurred post-sampling and true juvenile abundance and relative survival of stocked juveniles was not accurately reflected. American shad stocked in the North Branch of the Susquehanna River near Tunkhannock were first captured by lift-net on 28 November suggesting a movement of 194 miles in 186 days or less (Table 18).

Abundance - Main Stem

Comparison of relative abundance of juvenile shad 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. Overall, 2001 GM CPUE (individual seine hauls) of 1.42 was the second highest recorded since this estimate was required by ASMFC in 1997 (Table 4). GM CPUE (combined daily seine hauls) of 3.04 was the third highest recorded since 1990 (Table 4). Total catch in the lower Susquehanna by seine during 2001 was 12-fold higher than observed in 2000. Overall, GM CPUE (individual lifts) of 0.43 was the third highest recorded since this estimate was required by ASMFC in 1997 (Table 13). GM CPUE (combined daily lifts) of 1.37 was the second highest recorded since 1990 and well above the ten-year average of

0.976 (Table 13). GM CPUE's for lift-net may have been higher if sampling continued throughout the entire outmigration season. Catches of juvenile American shad by lift-net during 2001 were three times higher than those observed in 2000.

Tributaries

Tributary seining efforts resulted in modest catches in two of the five tributaries sampled. Juveniles captured in the Conestoga River and Swatara Creek were all of hatchery origin. No wild fish were captured indicating that natural reproduction of American shad in tributaries sampled is limited or nonexistent. Adult American shad from previous tributary stocking have demonstrated imprinting behavior in the Conestoga River in 2000 and 2001. Adult shad were also captured in West Conewago Creek during 2000 and 2001. However, these fish did not have the West Conewago Creek marking sequence of fry stocked in that system, indicating they were strays. Numbers of adults in the Conestoga and West Conewago may have been too few, or environmental conditions were not favorable, for successful reproduction to occur. No juvenile shad were captured in tributaries by seine in 2000. In both 1997 and 1998, seining was successful at collecting juvenile shad in tributaries. Although tributary seining for juvenile alosids is capturing few fish, it remains the only method currently employed to document natural reproduction in those systems.

Upper River

Despite higher than average GM CPUE's by seine and lift-net (Table 4 and 13), upper river electrofishing produced fewer numbers of juveniles as captured 1998 and 1999 (Table 21). However, numbers were higher than the zero captured by this gear type in 2000. Few juveniles captured by electrofishing in 2001 may be attributed to environmental factors that influenced juvenile distribution. Juveniles may have altered their habitat preferences to escape elevated water temperatures and reduced flows associated with drought conditions, thereby limiting densities in sampling areas. Enhanced water clarity may have also been a factor by making juvenile shad less susceptible to capture by this gear type. Fewer numbers of stocked fry may have also reduced numbers of juveniles available for capture in upper river areas. Wild shad comprised 50% and 100% of the juveniles captured by electrofishing in the Susquehanna and Juniata, respectively (Table 18), indicating reproductive success of adults passed at York Haven. The percentage of wild fish captured by electrofishing was higher than that observed in previous years. This may be attributed to increase in numbers of adults using the York Haven fish passage facility and enhanced spawning success and survival of young due to favorable environmental conditions. Electrofishing should become more efficient as a sampling method as juvenile densities increase and less than optimal habitat is utilized in response to overall increases in stock density.

Push-netting

As in previous years, push-netting in the lower Susquehanna impoundments resulted in the capture of few juvenile American shad. However, catches of blueback herring during 2001 were the highest ever recorded by that gear type (Table 7). Poor catches of American shad by push-net may reflect that Conowingo pool provides poor spawning habitat for American shad and/or juvenile shad are more adept at avoiding capture. High catches of juvenile blueback herring reflects large numbers of adults passed at Conowingo and favorable spawning conditions in Conowingo pool. Alosid catches in 2001 suggests 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. Push-netting is currently the only active method of sampling juvenile alosids below Holtwood.

Blueback herring were also abundant in Peach Bottom and Conowingo samples comprising 63 and 93% of alosids collected at these sites, respectively. The Conowingo East Lift passed a total of 284,921 blueback herring in 2001. This compares to 14,963 bluebacks passed in 2000. Increases in numbers of bluebacks passed are facilitated by low river flows and stable conditions during lift operations in early spring when numbers of returning bluebacks at Conowingo is highest. Of the blueback herring passed at Conowingo, only 1,300 and 710 were counted passing Holtwood and Safe Harbor, respectively. Additional sources of river herring above Conowingo Dam, albeit few in number, include those captured at Conowingo West Lift and transported upriver and released. Based on juvenile collections, production of blueback herring above Conowingo dam was higher than that observed in 2000 and is most likely attributed to increased numbers of bluebacks passed at the lower river hydroelectric projects. Over 300 blueback herring were collected during juvenile sampling in 2001 compared to only eight bluebacks collected in 2000.

Growth

Hatchery and wild juvenile American shad exhibited similar growth during 2001. Juvenile hatchery shad collected with seines at Columbia averaged 69.2 mm total length (TL) from 16 July (range 58 - 81 mm) and grew to an average 127.0 mm (range 123 - 129 mm) by 6 and 9

October (Table 4). Wild shad from Columbia averaged 68.5 mm TL (range 46 – 80 mm) and grew to an average of 130 mm (126 – 133 mm) by 6 and 9 October.

Juvenile American shad captured by lift-net from 20 October to 28 November, 2001 ranged from 106 - 185 mm with 80% of those captured measuring 141 - 170 mm TL (Table 14). In comparison, juvenile American shad captured by lift-net from 18 October to 29 November, 2000 ranged from 114 - 186 mm with 84% of those captured measuring 121 - 150 mm TL. Juvenile American shad captured in 2001 appeared to be slightly larger than those captured in 2000. Reasons for this may include a longer growing season associated with the delay in the outmigration period, or increased food abundance associated with favorable river conditions during the growing season. However, fish captured by lift-net late in the season were noticeably emaciated. Their condition is most likely associated with limited food availability during their extended residence resulting from the absence of significant precipitation and flushing flows during fall. Growth of the 2001 cohort does fall within ranges observed in previous years.

Stock Composition and Mark Analysis

Of the 779 otoliths analyzed from collections above Conowingo Dam, 560 (43.0%) were unmarked (Table 12). This compares to 2% wild fish in 2000 collections, and 2 - 58% from 1991 to 1999. Above Holtwood, 126 (32.0%) wild fish were captured in 2001. This compares to zero wild fish in 2000. The percentage of wild juveniles captured below Holtwood was more than 11% higher (43% verses 32%) than those captured above Holtwood (Table 18). The reason for this is unclear but maybe associated with greater density of adults, higher quality habitat, and concentration of larval drift in lower sections of the Susquehanna River. Abundance of wild fish increased significantly in 2001, as evident by an increase in the overall CPUE and the wild contribution (40% compared to 3% for 2000). This was likely due to the increases in the number of adult shad with access to spawning habitat above Safe Harbor and York Haven dams. Shad passage above Safe Harbor dam was 89,816 in 2001, compared to 21,079 and 34,210 in 2000 and 1999, respectively. Passage above York Haven was 16,200 in 2001, compared to 4,588 in 2000. Survival of the 2001 year-class will not be determined until they are fully recruited as adults. Relative survival of larval shad from the various stocking locations is discussed in Job III. All main stem and tributary stockings sites were represented in juvenile collections.

SUMMARY

- Juvenile American shad were successfully collected by haul seine, push-net, electrofisher, and lift-net.
- Haul seining GM CPUE (combined daily hauls) of 3.04 was the third highest recorded for that gear since sampling at Columbia was standardized in 1990.
- Lift-netting GM CPUE (combined daily lifts) of 1.37 was the second highest recorded for that gear type since 1990.
- Push-netting catches suggest good production of blueback herring in Conowingo pool.
- Juvenile alosids were collected in the Conestoga River and Swatara Creek.
- Peak out-migration based on lift-net catches occurred during December and was associated with modest increases in river flow and decreases water temperature.
- Lift-netting may have terminated before the outmigration was completely over.

- Otolith analysis determined that 40% of the juveniles collected above Conowingo Dam were of wild origin as compared to 2% observed in 2000.
- Juvenile production in the Susquehanna River basin appeared to be good and may have been influenced by: (1) increased numbers of adult fish passed by fish passage facilities, and (2) stable river conditions which favored natural reproduction, and survival of stocked and wild juveniles.

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Table 1

Location and description of Susquehanna River tributary stations sampled by seine in 2001.

Station Number	Latitude Longitude	Description
		Conestoga River
1	39°56'04"N 76°23'05"W	Head of pool below riffle; 1,700 ft downstream from River Road crossing at Safe Harbor park.
2	39°57'42"N 76°21'57"W	Back eddy/pool below riffle; 200 ft upstream of township road 561 crossing at Rock Hill.
3	39°57'59"N 76°21'28"W	Run below riffle; 300 ft downstream of Steinman Road crossing.
4	39°59'47"N 76°18'38"W	Pool on downstream side of island; 300 ft above Route 324 crossing.
5	40°00'40"N 76°18'16"W	Downstream end of pool (water funnel by rock ledge); 0.72 mi downstream of Route 222 crossing.
6	40°02'36"N 76°16'26"W	Run/pool; 0.375 mi upstream of Route 462 crossing.
		Little Conestoga Creek
1	40°00'19"N 76°22'27"W	Mid pool; 300 ft downstream of Route 999 crossing.
2	39°59'15"N 76°22'52"W	Mid pool; 1,700 ft upstream of Owl Bridge Road crossing.
3	39°59'02"N 76°22'42"W	Run; 150 ft upstream of Owl Bridge Road crossing.
4	39°58'20"N 76°22'32"W	End of pool; 450 ft upstream of Walnut Hill Road crossing.
5	39°57'59"N 76°22'26W	Pool formed by entry of Indian Run into Little Conestoga Creek, near junction of Walnut Hill Road and Creek Road.
6	39°57'39"N 76°22'20"W	Head of pool below riffle; 1,200 ft upstream of township road 561 crossing.
		West Conewago Creek
1	40°06'09"N 76°46'43"W	Pool under Route 83 crossing.
2	40°06'07"N 76°46'06"W	Downstream portion of pool; 250 ft above Hykes Dam.
3	40°06'00"N 76°45'48"W	Downstream end of pool; 1,350 ft below Hykes Dam.
4	40°06'24"N 76°44'28"W	Middle of pool; 300 ft downstream of Bowers Bridge Road crossing.
5	40°05'39"N 76°43'46"W	Downstream end of pool; 1.13 mi downstream of Bowers Bridge Road crossing.
6	40°04'55"N 76°42'57"W	Head of pool below riffle; 750 ft downstream of Route 181 crossing.

Table 1

Continued.

Station Number	Latitude Longitude	Description
		Swatara Creek
1	40°11'46"N 76°43'88"W	Pool; 300 ft downstream of Route 441 bridge, behind pavilion
2	40°13'79"N 76°43'60"W	Pool; mid-pool at Fulling Mill Road
3	43°43'46"N 78°34'88"W	Pool; under Route 322 bridge
4	40°17'19"N 76°40'74"W	Pool; mid-pool in Swatara Creek Park at bridge
5	40°19'11"N 76°37'78"W	Run; left bank, 300 ft below Route 743 bridge
6	40°19'48"N 76°31'60"W	Run; left bank at Old Mill Damon Bindage Road
		Conodoguinet Creek
1	40°16'00"N 76°54'45"W	Run; 150-300 ft upstream of railroad bridge
2	40°15'20"N 76°55'45"W	Under Center Street bridge; mid-pool just downstream of bridge supports
3	40°15'20"N 76°57'40"W	Run; 150 ft upstream of dock at Youth Park
4	40°15'40"N 76°58'45"W	Run; 50 ft upstream of PFBC boat access below Good Hope dam
5	40°15'30"N 77°02'25"W	Pool; lower end of pool in Willow Mill Park
6	40°15'40"N 77°02'30"W	Pool; upper end of pool in Willow Mill Park
7*	40°15'12"N 77°00'10"W	Run; under Lambsgap Rd. bridge; just upstream of bridge supports

* Alternate site - during the 2001 season, Site 7 was sampled instead of Site 5.

Table 2

Summary of juvenile American shad collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2001.

Date	Water Temp. (°C)	River Flow (cfs)	Secchi (in)	Time (h)	Upper Shore of East Bank	Upper East Shore of Tire Island	Lower East Shore of Tire Island	East Shore of 1st Old Bridge Pier	South End of 1st Old Bridge Pier	Columbia Boat Ramp	Total
16 Jul	27.0	8,000	43	2025-2208	1	0	0	9	4	32	**46**
24 Jul	30.0	5,990	28	2043-2145	1	0	0	1	14	7	**23**
31 Jul	26.0	5,360	40	2030-2150	0	1	3	4	6	5	**19**
7 Aug	32.0	5,240	35	2020-2145	5	0	8	46	7	4	**70**
15 Aug	29.0	5,690	34	2000-2115	0	0	1	6	30	0	**37**
20 Aug	28.0	5,900	32	2000-2110	0	1	0	11	6	18	**36**
27 Aug	28.0	5,060	23	1954-2100	5	0	2	1	25	3	**36**
5 Sep	25.5	6,080	35	1935-2053	1	1	0	8	7	6	**23**
10 Sep	26.0	4,790	28	1909-2038	0	0	0	23	2	6	**31**
18 Sep	22.0	4,880	25	1900-2021	0	0	1	5	5	4	**15**
25 Sep	21.0	9,450	12	1900-2025	0	0	0	0	32	2	**34**
3 Oct	18.5	10,900	34	1854-2015	0	0	4	0	0	2	**6**
9 Oct	15.0	5,990	34	1840-1950	0	0	0	0	0	1	**1**
16 Oct	16.0	5,360	35	1845-1955	0	0	0	0	0	0	**0**
24 Oct	18.0	6,170	55	1830-1925	0	0	0	0	0	0	**0**
TOTAL					**13**	**3**	**19**	**114**	**138**	**90**	**377**
MEAN	**24.1**	**6,324.0**	**32.9**								

Table 3

Summary of catch per unit effort (CPUE) and length data of juvenile American shad taken from the lower Susquehanna River near Columbia, Pennsylvania in 2001.

Date	No. Hauls	No. American Shad	CPUE	Total Length (mm)			Weekly Growth (mm)
				Minimum	Maximum	Mean	
16 Jul	6	46	7.67	46	83	67.1	
24 Jul	6	23	3.83	60	93	75.4	8.3
31 Jul	6	19	3.17	70	85	78.9	3.5
7 Aug	6	70	11.67	78	98	87.3	8.4
15 Aug	6	37	6.17	77	98	90.1	2.8
20 Aug	6	36	6.00	84	104	91.9	1.8
27 Aug	6	36	6.00	93	107	100.1	8.3
5 Sep	6	23	3.83	93	115	108.0	7.8
10 Sep	6	31	5.17	103	124	112.2	4.2
18 Sep	6	15	2.50	107	125	118.7	6.5
25 Sep	6	34	5.67	115	136	123.0	4.3
3 Oct	6	6	1.00	123	132	127.3	4.3
9 Oct	6	1	0.17		134	134.0	6.7
16 Oct	6	0	0.00	0	0	0.0	
24 Oct	6	0	0.00	0	0	0.0	
TOTAL	**90**	**377**		**46**	**136**		**66.9**
MEAN			**4.19**				**5.1**

Table 4. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990-2001.

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	0.00	0.00
2001	90	377	4.19	3.04	1.52	119	1.32	1.25

Table 5

Length frequency distribution of juvenile American shad collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2001.

TL (mm)	16 Jul	24 Jul	31 Jul	7 Aug	15 Aug	20 Aug	27 Aug	5 Sep	10 Sep	18 Sep	25 Sep	3 Oct	9 Oct	16 Oct	24 Oct	Total
46-50	1															1
51-55	1															1
56-60	4	1														5
61-65	9															9
66-70	18	4	1													23
71-75	10	8	4													22
76-80	1	5	5	4	2	1										18
81-85	2	4	9	10	4	3										32
86-90				11	14	9										34
91-95		1		7	11	18	3	1								41
96-100				3	6	3	16	1								29
101-105						2	12	4	3							21
106-110							3	9	9	1						22
111-115								8	12	2	1					23
116-120									5	7	13					25
121-125									2	5	10	2				19
126-130											6	3				9
131-135											2	1	1			4
136-140											2					2
TOTAL	**46**	**23**	**19**	**35**	**37**	**36**	**34**	**23**	**31**	**15**	**34**	**6**	**1**	**0**	**0**	**340**

Table 6

Length data taken from American shad collected by seine in the Conestoga River and Swatara Creek, 2001.

Date	Time	Tributary	Station	Water Temp. (°C)	Secchi (Inches)	Individual Total Lengths (mm)
25 Jul	1315	Swatara Creek	4	23.0	40	39,43,45,48,50
30 Jul	1058	Conestoga River	2	22.0	30	69,71,74,76,77
06 Aug	1238	Conestoga River	5	28.0	30	58
08 Aug	1304	Swatara Creek	4	25.5	36	67
21 Aug	1105	Conestoga River	2	24.5	30	91

Table 7

Summary of pushnet collections in Conowingo Pond (a main stem impoundment on the Susquehanna River) for alosids in June and July 2001.

Date	Water Temperature (°C)	Secchi Disk (inches)	Number of Replicates	Average Daily River Flow (cfs)*	Start Time (h)	End Time (h)	Number of American Shad	Number of Blueback Herring	CPUE Shad (No./50 min)	CPUE Herring (No./50 min)
4 Jun	19.0	21	10	18,600	2013	2220	0	0	0.000	0.000
7 Jun	20.0	24	10	19,300	2124	2332	1	35	0.020	0.700
10 Jun	23.0	29	10	13,800	2016	2215	0	8	0.000	0.160
13 Jun	24.7	29	10	11,500	2015	2225	0	2	0.000	0.040
16 Jun	25.0	28	10	11,400	2017	2210	0	10	0.000	0.200
19 Jun	25.7	33	10	13,700	2022	2216	0	5	0.000	0.100
22 Jun	26.0	30	10	23,200	2220	2357	0	4	0.000	0.080
25 Jun	24.5	16	10	45,800	2023	2248	1	41	0.020	0.820
28 Jun	25.0	32	10	40,200	2017	2233	0	10	0.000	0.200
1 Jul	27.5	22	10	22,100	2012	2225	0	11	0.000	0.220
3 Jul	26.0	31	10	17,000	2021	2228	0	5	0.000	0.100
6 Jul	25.0	28	10	16,400	2023	2208	0	3	0.000	0.060
9 Jul	26.0	32	10	12,800	2020	2231	0	0	0.000	0.000
Total			*130*				*2*	*134*	*0.003*	*0.206*
Mean	*24.4*	*27.3*		*20,446.2*						

* River flow taken from the USGS gauge station located in Marietta, PA.

Table 8

Summary of the electrofishing catch of juvenile American shad in the Susquehanna River near Clemson Island, 2001.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi Disk (in)	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Number of Shad Captured	Number of Shad Observed
7 Aug	4,830	30.0	62	64	160	6.0	No	0	0
14 Aug	5,180	28.2	30	64	160	6.5	Yes	0	1
21 Aug	5,640	26.0	35	63	200	6.5	No	0	0
28 Aug	4,250	26.0	35	60	290	7.0	No	1	1
4 Sep	5,639	26.0	34	60	190	5.5	No	0	0
11 Sep	3,860	24.0	67	65	180	6.5	Yes	1	0
17 Sep	4,090	22.0	70	66	200	6.5	Yes	4	1
25 Sep	5,930	20.0	35	64	200	6.5	No	0	0
Total				*506*				*6*	*3*
Mean	*4,927*	*25.3*	*46.0*		*197.5*	*6.4*			

Table 9

Summary of the electrofishing catch of juvenile American shad in the Juniata River at Mifflintown, 2001.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi Disk (in)	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Number of Shad	
								Captured	Observed
9 Aug	449	31.2	25	65	260	6.5	No	1	1
16 Aug	417	26.5	20	65	200	6.5	No	0	0
23 Aug	533	24.0	25	64	240	6.5	No	2	1
30 Aug	462	27.0	45	60	200	7.0	No	0	0
6 Sep	380	26.0	50	60	190	5.5	No	0	0
12 Sep	442	25.0	75	62	210	6.5	No	0	0
19 Sep	442	21.0	82	62	200	6.5	No	1	0
27 Sep	792	15.5	40	60	230	6.5	Yes	1	1
Total				*498*				*5*	*3*
Mean	*490*	*24.5*	*45.3*			*6.4*			

Table 10

Length frequency distribution of juvenile American shad captured with a boat-mounted electrofisher from the Susquehanna and Juniata Rivers, August through September 2001.

Total Length (mm)	9 Aug[2]	23 Aug[2]	28 Aug[1]	11 Sep[1]	17 Sep[1]	19 Sep[2]	27 Sep[2]	Total
80-89	1							1
90-99								0
100-109		1	1					2
110-119					1			1
120-129		1		1	2			4
130-139					1	1		2
140-149								0
150-159							1	1
Total	*1*	*2*	*1*	*1*	*4*	*1*	*1*	*11*

[1] Clemson Island site.

[2] Juniata River site.

Table 11

Catch per unit of effort (CPUE), mean, minimum, and maximum length for juvenile American shad collected with a boat-mounted electrofisher from the Susquehanna and Juniata rivers, August through September 2001.

Date	Number of Shad	CPUE (No./hour)	Total Length (mm)		
			Mean	Minimum	Maximum
9 Aug	2*	1.85	80.0		80
14-Aug	1*	0.94			
23 Aug	3*	2.81	114.5	104	125
28 Aug	2*	2.00	107.0		107
11 Sep	1	0.92	129.0		129
17 Sep	5*	4.55	125.8	115	139
19 Sep	1	0.97	134.0		134
27 Sep	2*	2.00	153.0		153
Total	*17*			*80*	*153*
Mean		*1.02*	*121.4*		

* Number includes one American shad observed but not boated.

Table 12

Number and percent composition of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 12 September through 7 December 2001.

Date:	*12 Sep*	*14 Sep*	*17 Sep*	*20 Sep*	*23 Sep*	*26 Sep*	*29 Sep*	*02 Oct*	*05 Oct*	*08 Oct*	*11 Oct*	*14 Oct*	*17 Oct*	*20 Oct*	*23 Oct*	*26 Oct*
Water Temp (C):	*25.5*	*23.5*	*23.0*	*22.0*	*22.0*	*20.2*	*19.5*	*16.0*	*17.0*	*16.0*	*16.5*	*17.0*	*16.0*	*15.0*	*16.0*	*15.0*
Secchi (in):	*45*	*30*	*40*	*50*	*40*	*35*	*28*	*20*	*35*	*30*	*32*	*42*	*38*	*40*	*31*	*30*
River Flow (cfs):	*4,340*	*4,160*	*4,250*	*4,880*	*4,520*	*11,750*	*26,300*	*13,300*	*8,360*	*6,580*	*7,920*	*4,850*	*6,230*	*6,720*	*6,200*	*5,870*
Start Time (hr):	*1912*	*1850*	*1850*	*1840*	*1845*	*1846*	*1830*	*1811*	*1832*	*1825*	*1817*	*1813*	*1808*	*1805*	*1755*	*1753*
End Time (hr):	*2038*	*2026*	*2000*	*2000*	*2009*	*1948*	*1952*	*1949*	*1955*	*1950*	*1957*	*1957*	*1929*	*1926*	*1925*	*1906*
American shad	-	-	-	-	-	41	11	10	-	-	-	2	-	4	-	-
Gizzard shad	-	-	-	-	-	2	214	2	1	-	-	94	-	51	2	-
Comely shiner	-	3	-	2	2	-	1	1	-	-	-	-	-	-	-	-
Spottail shiner	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Spotfin shiner	7	11	-	-	1	3	14	-	-	1	-	-	2	-	-	-
Mimic shiner	3	5	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Fallfish	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Channel catfish	1	-	1	-	-	-	-	-	-	1	-	-	2	-	-	-
Pumpkinseed	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Bluegill	8	1	2	1	-	-	5	-	-	-	-	-	-	1	-	-
Smallmouth bass	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***19***	***21***	***3***	***3***	***4***	***47***	***249***	***13***	***1***	***2***	***0***	***96***	***4***	***56***	***2***	***0***
No. of Species	*4*	*5*	*2*	*2*	*3*	*4*	*8*	*3*	*1*	*2*	*0*	*2*	*2*	*3*	*1*	*0*

Table 12

Continued.

Date:	*29 Oct*	*01 Nov*	*04 Nov*	*07 Nov*	*10 Nov*	*13 Nov*	*16 Nov*	*19 Nov*	*21 Nov*	*25 Nov*	*28 Nov*	*01 Dec*	*04 Dec*	*07 Dec*		
Water Temp (C):	*13.0*	*13.0*	*12.5*	*12.0*	*11.5*	*10.5*	*10.5*	*10.0*	*9.0*	*11.5*	*10.0*	*12.0*	*11.5*	*10.0*		
Secchi (in):	*42*	*41*	*40*	*40*	*55*	*52*	*48*	*48*	*45*	*55*	*61*	*42*	*42*	*38*		
River Flow (cfs):	*8,720*	*6,830*	*6,170*	*5,990*	*5,870*	*5,300*	*5,630*	*5,510*	*5,210*	*5,660*	*14,200*	*15,700*	*27,500*	*22,300*		
Start Time (hr):	*1715*	*1643*	*1713*	*1705*	*1620*	*1635*	*1628*	*1629*	*1623*	*1614*	*1640*	*1630*	*1625*	*1614*		
End Time (hr):	*1832*	*1801*	*1842*	*1851*	*1815*	*1747*	*1801*	*1802*	*1802*	*1739*	*1803*	*1812*	*1755*	*1808*	*TOTAL*	%
American shad	18	25	31	1	93	53	197	3	-	-	55	84	257	360	**1,245**	**65**
Gizzard shad	31	118	48	2	-	-	-	-	-	-	1	-	2	1	**569**	**30**
Comely shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**9**	**0**
Spottail shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	**0**
Spotfin shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**39**	**2**
Mimic shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**10**	**1**
Fallfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	**0**
Channel catfish	-	-	1	-	-	-	1	-	-	-	-	-	-	-	**7**	**0**
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**	**0**
Bluegill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**18**	**1**
Smallmouth bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**	**0**
Total	***49***	***143***	***80***	***3***	***93***	***53***	***198***	***3***	***0***	***0***	***56***	***84***	***259***	***361***	***1,902***	***100***
No. of Species	*2*	*2*	*3*	*2*	*1*	*1*	*2*	*1*	*0*	*0*	*2*	*1*	*2*	*2*	**11**	

Table 13. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2001.

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)
1985	378	3,626	20.31	7.55		***	***	
1986	404	2,926	10.30	5.71		***	***	
1987	428	832	3.17	1.90		***	***	
1988	230	929	3.87	1.28		***	***	
1989	286	556	0.86	0.43		***	***	
1990	290	3,988	13.75	3.67		70	0.24	0.18
1991	370	208	0.56	0.39		19	0.05	0.05
1992	250	39	0.16	0.12		14	0.06	0.05
1993	250	1,095	4.38	1.20		669	2.79	0.86
1994	250	206	0.82	0.48		35	0.15	0.13
1995	115	1,048	9.11	1.26		83	0.72	0.32
1997	300	1,372	4.57	0.88	0.61	100	0.33	0.23
1998	300	180	0.60	0.37	0.22	9	0.03	0.03
1999	300	490	1.63	0.78	0.50	19	0.06	0.07
2000	300	406	1.35	0.61	0.18	4	0.01	0.01
2001	299	1,245	4.18	1.37	0.43	538	1.81	0.45

* Required by ASMFC

**Mean flow during outmigration.

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

Table 14

Length frequency distribution of juvenile American shad collected for otolith analysis by an 8 x 8 ft lift net in the Holtwood Power Station inner forebay, 26 September through 7 December 2001. Only those dates when American shad were caught are presented.

Total Length	September		October				November								December			Total
(mm)	26	29	2	14	20	29	1	4	7	10	13	16	19	28	1	4	7	
106-110												1						1
111-115				1		1		1		1		1						5
116-120		1									1		1					3
121-125																1		1
126-130	2	1								1								4
131-135	9	1	3		2		3	3			1					1		23
136-140	13	2	1	1		2	2	1		4	2	2	1		1			32
141-145	6	3	2		1	2	6	5		6	3	4		2	1	4	6	51
146-150		2	2			1	7	2		7	3	3		2	3	6	2	40
151-155		1	1			4	1	6	1	10	13	8	1	8	5	6	8	73
156-160			1			4	3	5		1	4	1		7	3	3	3	35
161-165					1	3	1	2		1	1	5		6	8	3	6	37
166-170						1	1	5		1		2		2	5	5	3	25
171-175							1	1			1	2		3	2	3	2	15
176-180															1	1	2	4
181-185											1	1			2			4
186-190															1			1
Total	*30*	*11*	*10*	*2*	*4*	*18*	*25*	*31*	*1*	*32*	*30*	*30*	*3*	*30*	*32*	*33*	*32*	354

Table 15

Number of fish collected during intake screen sampling by unit at Peach Bottom Atomic Power Station in fall, 2001.

Species	Unit 2	Unit 3	Total
American shad	26	39	**65***
Blueback herring	50	55	**105**
Alewife	1	0	**1**
Gizzard shad	346	935	**1,281**
Rock bass	2	1	**3**
Bluegill	42	29	**71**
Largemouth bass	5	12	**17**
Yellow perch	7	4	**11**
Spotfin shiner	3	1	**4**
Comely shiner	3	2	**5**
Channel catfish	407	919	**1,326**
Smallmouth bass	11	29	**40**
Redbreast	1	1	**2**
Walleye	2	4	**6**
Common carp	0	4	**4**
White crappie	5	10	**15**
Spottail shiner	1	6	**7**
Pumpkinseed	3	6	**9**
Black crappie	1	3	**4**
Striped bass	1	0	**1**
Green sunfish	2	1	**3**
Mummichog	0	1	**1**
Golden shiner	1	2	**3**
TOTAL	***920***	***2,064***	***2,984***

* Includes 2 adult American shad.

Table 16

Species and number of fish collected during cooling water intake sampling at Conowingo Dam in fall, 2001.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	5	1	**6**
Blueback herring	0	82	**82**
Gizzard shad	519	3,126	**3,645**
Striped bass	0	1	**1**
Quillback	0	1	**1**
Channel catfish	9	1	**10**
Smallmouth bass	0	1	**1**
TOTAL	*533*	*3,213*	*3,746*

TABLE 17

Catch, effort, and catch-per-unit-of-effort of juvenile American shad by location from the upper Chesapeake Bay during the 2001 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									
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	1	2	0	2	1	6	9.8
Parlor Pt.	0	2	0	2	0	2	0	6	2.0
Elk Neck Pk.	0	2	0	2	0	2	0	6	6.8
Welch Pt.	4	2	0	2	0	2	4	6	45.0
Hyland Pt.	1	2	0	2	0	2	1	6	4.5
TOTALS	5	14	1	14	0	14	5	42	
CPUE	0.36		0.07		0.0		0.12		
B. Auxiliary									
Carpenter Pt.	2	1	0	1	0	1	2	3	11.3
Plum Pt.	8	1	4	1	0	1	12	3	12.3
Spoil Is.	1	1	2	1	0	1	3	3	9.7
Tydings Est.	0	1	0	1	0	1	0	3	14.0
Tolchester	0	1	0	1	0	1	0	3	0.0
TOTALS	11	5	6	5	0	5	17	15	
CPUE	2.20		1.20		0.0		1.13		
C. GRAND TOTALS	16	19	7	19	0	19	23	57	
CPUE	0.84		0.37		0.0		0.50		

Table 18. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2001.
Subsample of 30 per date were processed. Data were expanded to reflect entire catch.

Collection Site	Coll. Date	Immersion marks: Day 3 Jun. R./ Susq. R.	Days 3,6,9 Jun. R./ Susq. R.*	Days 3,6,9 12,18 Conodo- guinet Cr.*	Days 9, 12,15 W. Cone- wago Cr.*	Days 3,6,9, 15,18 Swat- ara Cr.*	Days 3,9, 12,15 Conest- oga Cr.*	Days 3,6, 9,15 W. Br. Sus. R.*	Days 3,6,12, 15,18 N. Br. Sus. R.	Days 3,9,12 Lehigh River?	Hatchery Total	Wild	Total Processed	Total Collected
Clemson I.	8/28/01	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	9/11/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	9/17/01	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	2.0	4	4
Juniata River Mifflintown	8/9/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	8/23/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	9/19/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	9/27/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
Swatara Cr.	7/25/01	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	5.0	0.0	5	5
	8/8/01	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
Conestoga R.	7/30/01	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	5.0	0.0	5	5
	8/6/01	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
	8/21/01	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
Columbia (haul seine)	7/16/01	26.6	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.6	16.4	45	46
	7/24/01	13.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	9.0	23	23
	7/31/01	11.6	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	6.3	18	19
	8/7/01	46.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.0	16.0	35	70
	8/15/01	24.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	11.0	37	37
	8/20/01	26.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	10.0	36	36
	8/27/01	22.2	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	24.4	11.6	34	36
	9/5/01	12.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	10.0	23	23
	9/10/01	18.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.6	11.4	30	31
	9/18/01	8.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	4.0	15	15
	9/25/01	23.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	10.0	34	34
	10/3/01	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	2.0	6	6
	10/9/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
Above Holtwood		234.0	25.2	0.0	1.1	6.0	7.0	0.0	1.0	0.0	274.3	126.7	361	401
Percent		58.4%	6.3%	0.0%	0.3%	1.5%	1.7%	0.0%	0.2%	0.0%	68.4%	31.6%		
Holtwood	9/26/01	17.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	19.8	21.2	29	41
	9/29/01	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	6.0	11	11
	10/2/01	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	7.0	10	10
	10/14/01	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0	2	2
	10/20/01	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4	4
	10/29/01	10.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	12.0	6.0	18	18
	11/1/01	11.5	4.2	0.0	0.0	0.0	0.0	0.0	1.0	0.0	16.7	8.3	24	25
	11/4/01	15.5	4.1	0.0	1.0	1.0	0.0	0.0	1.0	0.0	22.7	8.3	30	31
	11/7/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/10/01	32.0	17.4	0.0	0.0	2.9	0.0	2.9	0.0	0.0	55.2	37.8	32	93
	11/13/01	17.7	12.4	0.0	0.0	0.0	1.8	0.0	0.0	0.0	31.8	21.2	30	53
	11/16/01	85.4	13.1	0.0	0.0	13.1	0.0	0.0	0.0	0.0	111.6	85.4	30	197
	11/19/01	1.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	3.0	0.0	3	3
	11/28/01	23.8	9.2	0.0	0.0	0.0	0.0	0.0	5.5	0.0	38.5	16.5	30	55
	12/1/01	31.5	23.6	0.0	0.0	0.0	0.0	0.0	5.3	0.0	60.4	23.6	32	84
	12/4/01	62.3	54.5	0.0	0.0	0.0	0.0	0.0	23.4	0.0	140.2	116.8	33	257
	12/7/01	56.3	90.0	0.0	0.0	0.0	0.0	0.0	33.8	0.0	180.0	180.0	32	360
Conowingo Res. (push net)	6/25/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	7/1/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
Peach Bottom Impingement	10/5/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	10/10/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	10/24/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	10/31/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/2/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1	1
	11/9/01	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	1	2
	11/12/01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2	2
	11/14/01	2.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	2.0	7	7
	11/16/01	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/19/01	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.0	5	5
	11/21/01	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/26/01	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/30/01	1.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	4.0	2.0	6	6
	12/3/01	4.0	3.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	10.0	3.0	13	13
	12/5/01	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	3.0	7	7
	12/7/01	8.6	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	4.3	13	14
Conowingo Strainers	11/12/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/26/01	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
Holt./P. Bot./Con.		402.4	245.6	1.0	3.0	21.1	4.6	2.9	71.9	1.0	753.6	560.4	418	1314
Percent		30.6%	18.7%	0.1%	0.2%	1.6%	0.3%	0.2%	5.5%	0.1%	57.4%	42.6%		
Total		636.5	270.8	1.0	4.1	27.1	11.6	2.9	72.9	1.0	1027.9	687.1	779	1715
Percent		37.1%	15.8%	0.1%	0.2%	1.6%	0.7%	0.2%	4.3%	0.1%	59.9%	40.1%		

*Susquehanna River source eggs

Table 19

Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River, 1989 through 2001.

Week	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
I Jul				0		2								**2**
II Jul	1,048		0	120	0	27		2	44	10	0	7		**1,258**
III Jul			0	6		70	53	18	28	14	0	3	46	**238**
IV Jul	45	31			0	60	24	15	22	144	1	0	23	**365**
I Aug		0	0	20	0	24	29	32	14	30	1	2	19	**171**
II Aug	61	0	0	2	8	13	35	56	20	0	0	6	70	**271**
III Aug	7	69	0	16	0	46	40	43	171	9	0	1	37	**439**
IV Aug					13		42	39	120	10	8	0	36	**268**
I Sep		25	12		20		43	34	129	3	2	0	36	**304**
II Sep		4			15	50	31	3	46	3	*	0	23	**175**
III Sep		93	16		26	25	34	1	89	3	264	0	31	**582**
IV Sep		28	30		27	14	46	12	59	1	17	0	15	**249**
V Sep		0	73		11	5	15	15	32	0	20	1	34	**206**
I Oct		0	69	2	22	5	19	10	91	3	1	0	6	**228**
II Oct		0	7		0	2	31	3	0	0	3	11	1	**58**
III Oct			5			10			14	0	5	0	0	**34**
IV Oct			0	0			0	0					0	**0**
TOTAL	**1,161**	**250**	**212**	**166**	**142**	**353**	**442**	**283**	**879**	**230**	**322**	**31**	**377**	**4,848**

* No sampling due to high river flow.

Table 20

Historical weekly catch per unit effort (CPUE) of juvenile American shad collected by an 8 ft x 8 ft lift net at Holtwood Power Station inner forebay, August-December 1985-2001*.

	Historical Years															Year
Week	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	1997	1998	1999	2000	**2001**
II Aug	-	-	-	-	-	-	*0.0*	-	-	-	*0.0*	-	-	-	-	-
III Aug	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-	-
IV Aug	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-	-
I Sep	-	-	-	*0.0*	-	*0.8*	*0.0*	*1.4*	*0.0*	*0.5*	*0.0*	-	-	-	-	-
II Sep	-	-	*1.3*	-	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.0*	0.0	0.0	0.4	0.0	**0.0**
III Sep	-	-	*0.7*	-	*2.3*	*0.0*	*0.0*	*0.5*	*0.0*	*0.0*	-	0.0	0.0	9.7	0.0	**0.0**
IV Sep	-	-	*0.3*	-	-	*7.5*	*0.0*	*0.0*	*0.3*	*0.1*	*0.0*	0.0	0.0	0.3	0.0	**2.6**
V Sep	-	-	*0.9*	*0.0*	*1.2*	*3.9*	*0.1*	*0.1*	*0.2*	*4.3*	*0.1*	0.0	0.1	4.7	0.0	**0.5**
I Oct	-	*16.7*	*4.1*	*0.1*	*1.2*	*2.0*	*0.1*	*0.0*	*0.2*	*3.5*	*0.0*	0.0	0.8	3.7	0.0	**0.1**
II Oct	*0.1*	*30.3*	*4.5*	*0.0*	*3.2*	*52.0*	*0.6*	*0.2*	*0.1*	*0.7*	*5.0*	0.0	1.9	2.1	0.1	**0.2**
III Oct	*1.0*	*5.4*	*1.3*	*10.0*	*0.5*	*50.2*	*0.9*	*0.3*	*17.5*	*0.3*	*68.9*	0.2	1.3	1.0	0.7	**0.0**
IV Oct	*41.6*	*5.3*	*4.8*	*19.1*	*0.0*	*34.3*	*1.1*	*0.1*	*14.8*	*0.1*	*56.0*	0.0	1.7	0.0	2.5	**2.5**
I Nov	*28.6*	*4.1*	*4.5*	*2.0*	*0.0*	*1.7*	*2.4*	*0.0*	*19.0*	*0.6*	*9.3*	25.1	1.6	0.0	0.6	**4.7**
II Nov	*10.8*	*19.5*	*0.3*	*0.3*	*0.0*	*0.4*	*0.5*	*0.7*	*1.6*	*0.1*	*0.0*	27.1	0.1	0.0	13.2	**4.2**
III Nov	*57.6*	*6.3*	*0.7*	*0.5*	-	*0.0*	*0.8*	*0.0*	*0.1*	*0.0*	*0.0*	3.0	0.1	0.0	5.5	**0.1**
IV Nov	*15.1*	-	-	*0.3*	-	*0.0*	*1.6*	-	*0.0*	*0.0*	*0.0*	0.5	0.0	0.0	1.2	**7.0**
I Dec	*62.8*	*14.2*	*0.0*	*0.0*	-	-	-	*0.9*	-	*0.0*	-	0.0	0.0	0.0	0.0	**30.9**
II Dec	*4.3*	*0.1*	-	-	-	-	*1.2*	-	-	-	-	-	0.6	-	-	-
III Dec	*0.5*	*0.0*	-	-	-	-	*0.0*	-	-	-	-	-	-	-	-	-
Total shad	3,626	2,926	832	929	556	3,988	208	39	1,095	206	2,100	1,372	180	490	406	**1,245**
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	290	**300**
CPUE	9.6	7.2	1.9	4.0	1.9	13.8	0.6	0.2	4.6	0.8	9.1	4.6	0.6	1.6	1.4	**4.2**

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

Table 21

Summary of information collected from the Susquehanna and Juniata rivers by a boat-mounted electrofisher, 1999 through 2001.

Year	SUSQUEHANNA RIVER											
	River Flow (cfs)			Water Temperature (°C)			Secchi Reading (inches)			American Shad		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Taken	Obs.	Total
1999	2,950	33,200	10,651	16.3	29.0	23.6	8.0	71.0	48.6	2	0	2
2000	6,130	14,600	8,970	17.0	27.0	23.0	80.0	110.0	87.8	0	0	0
2001	3,860	5,930	4,927	20.0	30.0	25.3	30.0	70.0	46.0	6	3	9
	JUNIATA RIVER											
1999	553	1,220	736	18.5	28.0	24.1	20.0	95.0	59.9	124	65	189
2000	573	1,690	796	16.0	25.5	22.4	45.0	150.0	98.0	0	0	0
2001	380	792	490	15.5	31.2	24.5	20.0	82.0	45.3	5	3	8

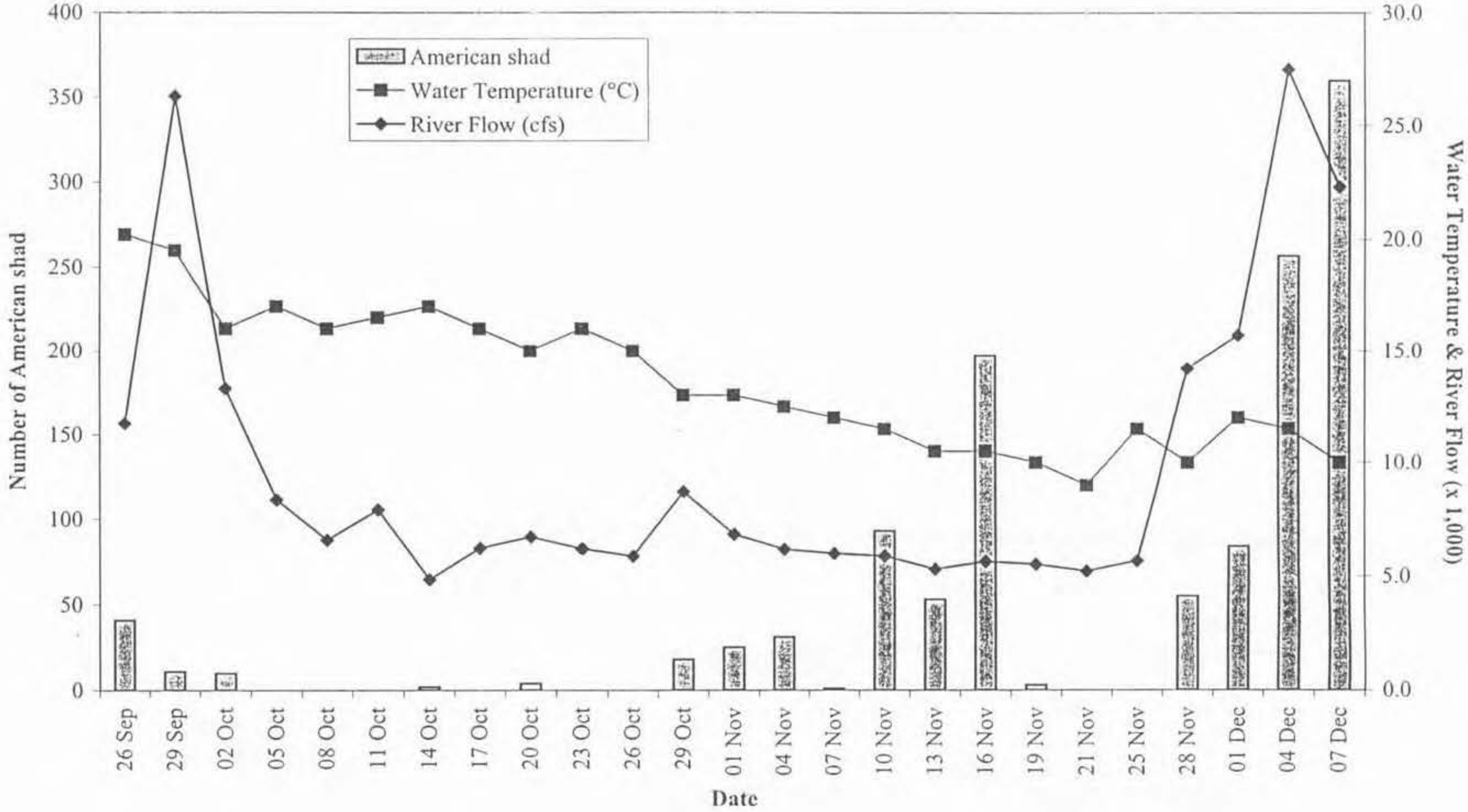

Figure 1

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, 12 September through 7 December 2001.

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 to this effort have been the development of fish passage facilities at the lower Susquehanna hydroelectric projects, and 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 in 2000 re-opening portions of the upper Susquehanna and tributaries to spawning runs of migratory fishes. Completion of a fishway at the inflatable dam at Sunbury, PA in 2003 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 two million adult American shad and 5 million river herring above York Haven 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 waters. Waters stocked include Muddy Creek, West Conewago Creek, Conestoga River, Conodoguinet Creek, Swatara Creek, Juniata River, West Branch of the Susquehanna River, and North Branch of the Susquehanna River. It is hoped that these stockings will expand the distribution of alosids to waters other than the Susquehanna and Juniata 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. Information obtained in this study will provide insights on fidelity to natal waters, prioritize blockages for fish passage, and refine strategies for restoring extirpated populations of American shad and river herring to specific waters.

METHODS

Distribution and relative abundance of adult alosids was evaluated by conducting daytime electrofishing surveys in the Susquehanna River and selected tributaries at or near the base of first upstream blockages to migration. Fifteen surveys were conducted at the inflatable dam on the Susquehanna River; about every three days from the onset of inflation of the dam on 16 May through 28 June 2001. Five surveys each were conducted on Muddy Creek, West Conewago Creek, Little Conestoga Creek, Conestoga River, and Conodoguinet Creek between 1 May and 27 June 2001. Fishing Creek and Peters Creek were surveyed on three dates each during the period 17 May through 12 June. Timing of sampling and frequency was based on number of alosids passed at the main stem hydroelectric projects. Otoliths from captured adult American shad were analyzed for tetracycline marks to determine origin (hatchery versus wild) and stocking location (for hatchery fish).

RESULTS

Boat electrofishing at the base of the Sunbury inflatable dam (rm 125.5) on the Susquehanna River resulted in the capture of 24 adult American shad in 1,800 minutes of shock time (Table 1). Daily catch per unit effort (CPUE) ranged from zero to 4.50 shad per hour of sampling (Table 2). Captured shad consisted of 15 males and 9 females. Males averaged 486 mm total length (range

454 to 518 mm) and weighed 868 g (range 765 to 1,050 g) while females averaged 514 mm total length (range 475 to 546 mm) and weighed 1,098 g (range 860 to 1,290 g). Shad were captured at water temperatures from 18.5 to 26.0°C and flows from 6,950 to 13,700 cfs (Table 1). Twenty-four additional adult shad were observed during sampling but eluded capture.

Twenty-one adult American shad were collected from tributaries between 1 May and 27 June (Table 3). Shad were captured in the Conestoga River (17), West Conewago Creek (2) and Muddy Creek (2). Total CPUE (no./hr) for all tributaries combined was 0.108 (Table 3). Of the shad captured, 10 were males and 11 were females. Captured males averaged 482 mm total length (range 465 to 510 mm) and weighed 881 g (range 700 to 1,070 g); females averaged 539 mm total length (range 532 to 547 mm) and weighed 1,469 g (range 1,140 to 1,870 g. American shad were captured at water temperatures ranging from 13.0 to 17.5° C. Daily CPUE ranged from zero to 0.133 fish per hour in tributaries where shad were captured. Adult shad from the Conestoga River and West Conewago Creek were collected at the base of the Lancaster Water Works Dam (rm 32.8) and Detter's Mill Dam (rm 27.7), respectively. Adult shad were also captured at the base of a natural barrier in Muddy Creek. Five adult American shad were observed in the Conestoga River but eluded capture. No alosids were captured or observed in the other waters sampled.

Results of adult American shad otolith analysis are summarized at Table 1 in Job V, Task 2. Of the shad otoliths analyzed from the Fabri-dam collections, 11 were wild fish, and 5 were hatchery fish. Of the latter, three individuals had a day 3 or 5 tag indicating they were stocked in the Susquehanna or Juniata; one individual had a day 3, 6, 9, 12 tag and one had a day 5, 9, 13, 17 tag, in both cases indicating they were stocked in the North Branch of the Susquehanna. Of the 8 adults analyzed from collections made at the base of the Lancaster Water Works Dam, six individuals had a day 3, 9, 12, 15 tag indicating they were stocked in the Conestoga River; one individual had a day 5, 9, 13, 17 tag indicating it was also stocked in the Conestoga River; and one had an anomalous day 3, 6 tag indicating it was stocked in the Susquehanna or Juniata River. Of the two adults captured in West Conewago Creek, one individual had a day 3 tag indicating it was stocked in the Susquehanna or Juniata and one was wild. The two adults captured in Muddy Creek were both wild. A single adult blueback herring was captured in the Little Conestoga and was most likely part of a shipment of pre-spawn adults from the Conowingo West Lift.

DISCUSSION

Distribution and Relative Abundance

American Shad

The distribution and abundance of adult American shad in the Susquehanna River Basin is influenced by the efficiency of main stem fish passage facilities. Numbers of American shad and river herring passed at Susquehanna hydroelectric projects decreases with upstream progression due to the cumulative inefficiencies of fish passage facilities. In 2001, The Conowingo East Lift passed 194,574 American shad while lifts at Holtwood (rm 24.3), Safe Harbor (rm 31.9), and York Haven (rm 56.7) passed 109,976, 89,816, and 16,200, respectively. As a result, only 8.3% of the adults American shad passed at Conowingo Dam had access to the Susquehanna River and tributaries above York Haven Dam. This being the case, stock restoration is expected to proceed in a progressional manner beginning in the lower basin and ultimately expanding toward headwater areas. Likewise, alosid populations in lower basin tributaries are likely to be restored sooner than upper tributaries since more fish are available for re-colonization and the impact of fish passage efficiency is less pronounced.

Muddy Creek flows into the west side of Conowingo pool approximately 4 miles downstream from Holtwood Dam. Prior to 2001, no adult American shad were documented in Muddy Creek. Stocking of shad fry and adult herring in Muddy Creek occurred in 1995 but was discontinued after the discovery of a natural barrier to fish migration. Expanded distribution in response to overall increases in stock abundance may account for the presence of shad in Muddy Creek during 2001.

The confluence of the Conestoga River with the Susquehanna is located on the east shore immediately below Safe Harbor Dam. Based on fish counts at Holtwood Dam, up to109,976 American shad would have had access to the Conestoga River. Adult shad captured at the Lancaster Water Supply Dam would have traveled a distance of 32.8 miles up the Conestoga to the base of the dam. In 2000, the fishway at the Lancaster Water Works Dam was completed and saw limited service. Additional shad may have used the fishway and were not available for capture during adult surveys. Catches of adults in the Conestoga increased significantly from 2000 to 2001. Reasons for this increase are most likely associated with increase numbers of adults passed at lower river hydroelectric facilities and the return of multiple year-classes whereas in 2000 only a single year class from the first year of stocking was represented. Despite the number of adult American shad in the Conestoga during 2001, no wild reproduction was documented during juvenile sampling. The only juveniles captured from the Conestoga were hatchery fish stocked well upstream of the Lancaster Water Supply Dam. A threshold number of adults may need to be present before spawning will occur. Enhanced efficiency at main stem fish passage facilities and increases in overall stock abundance may be needed to facilitate successful reproduction in the future.

The confluence of West Conewago Creek with the Susquehanna is located on the west shore below York Haven Dam. Based on fish counts at Safe Harbor Dam, up to 89,816 American shad would have had access to West Conewago Creek during the 2001 spawning migration. Adult shad captured in West Conewago used the lifts at Conowingo, Holtwood, and Safe Harbor dams then traveled up West Conewago Creek 27.7 miles to the base of the dam. Numbers of adult shad captured in West Conewago in 2001 were comparable to those captured in 2000. The location of York Haven Dam and its influence on river flows in the Susquehanna may be limiting adult numbers by attracting migrating shad away from the mouth of West Conewago Creek. Sampling by seine in West Conewago failed to capture any juvenile shad suggesting that if natural reproduction occurred it was limited.

The confluence of Conodoguinet Creek with the Susquehanna is located on the west shore several miles upstream of York Haven Dam. Sampling for adult alosids was conducted at the base of Good Hope Dam which is located some 13.5 miles upstream from the confluence. No adult American shad were observed at the base of the dam during surveys in 2001 or 2000. Stocking of shad fry in Conodoguinet Creek was first conducted in 1995 and these fish could have begun returning as adults in springs of 1998 and 1999. However, prior to 2000, adults did not have access to Conodoguinet Creek because the fish passage facility at York Haven was not yet completed. Numbers of fry stocked may be too few to overcome losses associated with downstream fish passage efficiency and would account for the absence of adults in 2000 and 2001. This problem may diminish in the future as additional year-classes are recruited and the size of the spawning population increases. Higher stocking rates may be required to insure sufficient numbers are passed at lower river fish passage facilities.

The inflatable or Fabri-dam (rm 125.5) is located just downstream of the confluence of the North and West branches of the Susquehanna at Sunbury. Adult American shad are required to use fish passage facilities at the four downstream hydro-projects and travel an additional 70 miles upstream from York Haven to reach the base of the Fabri-dam. In 2001, the York Haven fishway began operation on 3 May and continued until 8 June. Based on catch and fish passage data, American shad could have reached the Fabri-dam from York Haven in 13 days or less. Increased adult abundance is reflected in catch statistics at the Fabri-dam. In 2000, electrofishing at the base of the dam resulted in a CPUE (no./hour) of 0.40 verses a CPUE of 2.40 observed during 2001 (Table 2). Increased abundance of shad at the Fabri-dam is directly related to increased passage of adults at York Haven. In 2001, 16,200 shad were passed at York Haven verses 4,687 in 2000.

Increases in the number of adults passed at the lower Susquehanna River fish passage facilities and favorable river conditions most likely contributed to significant increases in wild juvenile shad abundance in upper basin areas. During the fall 2001 sampling season, wild juveniles comprised 32% of those shad collected at Holtwood compared to zero wild collected in 2000 (see Job IV). Likewise, juvenile indices of abundance in 2001 were some of the highest ever recorded.

River Herring

Adult river herring in the Susquehanna River Basin are derived from two sources: (1) those using the fish passage facilities at the main stem dams, and (2) those captured by the Conowingo West lift, transported and released. Numbers of river herring passed at Conowingo, Holtwood, and Safe Harbor during 2001 were 292,745 (284,912 blueback herring, 7,824 alewife), 1,301 (1,300 blueback herring, 1 alewife), and 723 (710 blueback herring, 13 alewife), respectively. Alewives were transported from Conowingo West lift and released in the Little Conestoga River (1,500) and Conestoga River (300), respectively. Blueback herring transports included 5,049 adults released in the Conestoga (2,690), Little Conestoga (1,510) and Conodoguinet (849). Survival of transported river herring was 99.7%.

Based on fish passage counts few herring would have had access to spawning areas above Holtwood Dam. The only tributary waters that would be freely accessible to herring in numbers would have been Peters Creek and Fishing Creek – both tributaries to Conowingo pool. However, sampling at the first blockage on both waters failed to document the presence of any herring. A single adult blueback was collected in Little Conestoga Creek, most likely as part of a shipment of pre-spawn adults transported from the West lift.

Numbers of alewife using the Safe Harbor fish lift was higher than those using the lift at Holtwood. The only plausible explanation for this discrepancy is that alewives in the Conestoga or Little Conestoga moved downstream and proceeded up the Susquehanna shortly after release. A similar post-release movement was observed in herring stocked in the Conestoga during 2000.

Fidelity to Natal Waters

American shad

Information obtained in 2001 supports findings from previous years and suggests that straying of American shad into tributaries is occurring, however, otolith analysis of adult shad captured in the Susquehanna and Conestoga suggested high fidelity of stocked fry to natal waters. The presence of a Conestoga River tag on otolths of 7 of the 8 adult shad analyzed from the base of the Lancaster Water Supply Dam is strong evidence of stocked fry imprinting to the system. This supports previous evidence of imprinting to the Conestoga obtained in 2000 when a single captured adult was also determined to have a Conestoga tagging sequence. The presence of a Susquehanna or Juniata tag on the remaining adult shad, as well as the origin of other adults captured in West Conewago and Muddy Creek confirms that straying also occurs. Both adult shad captured in Muddy Creek during 2001 were determined to be wild fish and originated from adults passed at Conowingo that strayed into the system.

The presence of the Juniata-Susquehanna tag on the otolith from one of the shad captured at Detter's Mill Dam suggests that this individual was a stray. The wild adult captured was also a stray since progeny of fry stocked in West Conewago are not likely to return to spawn for some years and no wild reproduction has been documented in the system during juvenile surveys. In 2000, a single adult shad was captured in West Conewago Creek and identified as a stray.

The five hatchery adults collected at the base of the Fabri-dam originated from fry stockings in the Susquehanna, Juniata, or North Branch of the Susquehanna. The 11 wild adult shad captured at the base of dam could have originated from two sources: (1) progeny of adults transported and released above York Haven Dam, or (2) progeny of fish spawned below York Haven Dam. The number of adults collected is encouraging and tetracycline tags among hatchery fish are consistent with shad likely to be imprinted to upper basin areas. Of the adult shad captured during 2000, two were identified as hatchery and two were identified as wild.

River Herring

River herring in the Susquehanna Basin are derived from wild stocks, hence, no tetracycline tag is available to determine river of origin. Despite several years of stocking pre-spawn adult herring, no spawning migrations or indications of reproduction have been documented in Susquehanna tributaries. If herring are returning to natal tributary waters and reproducing, adults and young are eluding capture by leaving the tributary shortly after spawn. Natural reproduction of river herring has been documented during juvenile alosid surveys on the main stem Susquehanna River. The inability to consistently pass large numbers of herring at Holtwood may be influencing recruitment by disrupting spawning continuity of subsequent year classes, particularly in waters where pre-spawn adults have been released in the past. Habitat quality and quantity may also be limiting factors to establishing herring populations in tributaries.

Future Fish Passage Projects and Adult Monitoring Activities

Completion of a fishway at the Fabri-dam will provide American shad with access to the North Branch and portions of the West Branch of the Susquehanna. However, fish passage efficiency at the lower river hydroelectric projects may need to improve to ensure shad will reach upstream sections in sufficient time and numbers to reproduce. Provisions for fish passage at Detter's Mill Dam (West Conewago Creek) and Iron Stone Mill Dam (Conestoga River) should be provided to ensure passage of adults in the future. Adult monitoring by electrofishing should continue in all waters except the Conestoga River and be expanded to include the base of Warrior Ridge Dam on the Juniata, Raystown Dam on the Frankstown Branch of the Juniata, and Cave Hill Dam on the Conodoguinet Creek (Good Hope Dam was removed in fall 2001). The presence of adult alosids in the Conestoga River will be evaluated by monitoring utilization of the fishway at the Lancaster Water Supply Dam. Electrofishing for adults in the Conestoga will cease since it may impact American shad reproduction by removing potential spawners and/or changing behavior. The numbers of shad fry stocked may need to increase in upper basin tributaries to offset inefficiencies at main stem passage facilities. Due to the apparent lack of success with the herring transport program, it should be discontinued.

SUMMARY

- Adult American shad were captured by electrofishing at the base of the Fabri-dam on the Susquehanna River; Lancaster Water Works Dam on the Conestoga River; Detter's Mill Dam on West Conewago Creek; and a natural barrier in Muddy Creek.

- Distribution of American shad expanded to include waters where they were not previously documented and abundance of adults increased in tributaries where they were detected in the past.

- Stocked American shad fry will imprint to receiving waters and may be a useful management tool in stock restoration efforts.

- Straying of American shad into tributaries is occurring.

- Transport and release of river herring should be discontinued.

- Monitoring main stem and tributaries waters should continue in order to track adult alosid abundance, distribution, wild production, and success of the restoration effort.

Table 1

Summary of American shad collected in 2001 with a boat-mounted electrofisher downstream of the Shikellamy State Park inflatable dam on the Susquehanna River near Sunbury, Pennsylvania.

Date	River Flow (cfs)	Water Temperature (°C)	Duration (min)	Volts Pulsed DC	Amps	No. of Shad Captured*	Shad Observed
16 May	8,620	18.5	120	380	7.0	2	1
18 May	7,740	17.0	120	225	4.0	0	1
21 May	6,950	18.0	120	220	5.0	3	1
24 May	7,830	19.5	120	390	6.5	9	4
27 May	11,400	18.0	120	385	7.0	5	7
30 May	13,500	18.5	120	350	7.5	1	2
2 Jun	11,200	17.0	120	390	6.0	1	3
5 Jun	12,900	18.2	120	300	4.0	2	2
8 Jun	12,000	20.2	120	250	4.0	0	1
11 Jun	8,760	22.0	120	250	4.0	0	1
14 Jun	7,830	25.0	120	230	4.0	0	0
17 Jun	10,300	26.0	120	200	4.0	0	0
20 Jun	13,700	26.0	120	150	4.0	1	0
23 Jun	12,700	25.0	120	200	4.0	0	1
28 Jun	26,500	22.5	120	405	4.5	0	0
Total			*1,800*			*24*	*24*
Mean	*11,462*	*20.8*		*288.3*	*5.0*		

* After 24 May no shad were sacrificed for otolith analysis, but a determination of sex was made on those shad netted, before returning them unharmed back to the river.

Table 2

Catch per unit of effort (CPUE) of American shad collected in 2001 with a boat-mounted electrofisher downstream of the Shikellamy State Park inflatable dam on the Susquehanna River near Sunbury, Pennsylvania.

	Sex		Total Length (mm)			Weight (g)			CPUE
Date	Male	Female	Mean	Minimum	Maximum	Mean	Minimum	Maximum	(No./hour)
16 May	1				465			795	1.00
		1			518			1,180	
21 May	2		504	490	518	908	870	945	1.50
		1			511			1,125	
24 May	5		484	454	507	867	765	1,050	4.50
		4	514	475	546	1,070	860	1,290	
27 May	3		NA	NA	NA	NA	NA	NA	2.50
		2	NA	NA	NA	NA	NA	NA	
30 May	0		NA	NA	NA	NA	NA	NA	0.50
		1	NA	NA	NA	NA	NA	NA	
02 Jun	1		NA	NA	NA	NA	NA	NA	0.50
		0	NA	NA	NA	NA	NA	NA	
05 Jun	2		NA	NA	NA	NA	NA	NA	1.00
		0	NA	NA	NA	NA	NA	NA	
20 Jun	1		NA	NA	NA	NA	NA	NA	0.50
		0	NA	NA	NA	NA	NA	NA	
Total No. Males	*15*		*486*	*454*	*518*	*868*	*765*	*1,050*	*2.40*
Total No. Females		*9*	*514*	*475*	*546*	*1,098*	*860*	*1,290*	

NA = Not Available.

Table 3

Summary of PFBC electrofishing surveys conducted in large tributaries to the Susquehanna River during spring 2001.

Date	Location	Water Temp. (°C)	Time (h) Start	End	No. American Shad Captured	Observed	CPUE (No./h)
01 May	Muddy Creek	13.0	1025	1150	0	0	0.000
				Subtotal	*0*	*0*	*0.000*
07 May	Muddy Creek	13.0	0830	0950	0	0	0.000
07 May	Conestoga River	16.0	1150	1300	1	0	0.017
08 May	West Conewago Creek	18.0	0915	1025	0	0	0.000
08 May	Little Conestoga Creek	14.5	1145	1255	0	0	0.000
				Subtotal	*1*	*0*	*0.004*
14 May	Conestoga River	15.0	0840	0947	2	1	0.033
14 May	Muddy Creek	14.5	1130	1245	0	0	0.000
15 May	West Conewago Creek	17.0	0905	1015	0	0	0.000
15 May	Little Conestoga Creek	14.0	1140	1250	0	0	0.000
				Subtotal	*2*	*1*	*0.013*
23 May	Conestoga River	16.0	0835	0942	5	1	0.083
23 May	Muddy Creek	15.5	1130	1235	1	0	0.017
22 May	West Conewago Creek	15.5	0905	1020	0	0	0.000
22 May	Little Conestoga Creek	13.0	1150	1305	0	0	0.000
				Subtotal	*6*	*1*	*0.029*
29 May	West Conewago Creek	19.0	0925	1029	2	0	0.033
29 May	Little Conestoga Creek	16.0	1210	1317	0	0	0.000
31 May	Conodoguinet Creek	16.0	1005	1115	0	0	0.000
31 May	Muddy Creek	15.0	1335	1442	1	0	0.017
01 Jun	Conestoga River	15.0	0825	0930	8	3	0.133
				Subtotal	*11*	*3*	*0.058*
04 Jun	West Conewago Creek	18.0	0900	1006	0	0	0.000
04 Jun	Little Conestoga Creek	15.5	1140	1246	0	0	0.000
05 Jun	Conestoga River	17.5	0815	0919	1	0	0.017
05 Jun	Conodoguinet Creek	19.0	1130	1238	0	0	0.000
				Subtotal	*1*	*0*	*0.004*
13 Jun	Conodoguinet Creek	22.5	0915	1021	0	0	0.000
				Subtotal	*0*	*0*	*0.000*
20 Jun	Conodoguinet Creek	24.0	0935	1045	0	0	0.000
				Subtotal	*0*	*0*	*0.000*
27 Jun	Conodoguinet Creek	21.0	0940	1045	0	0	0.000
				Subtotal	*0*	*0*	*0.000*
			Large Tributary Total		*21*	*5*	*0.108*

Job V., Task 2. Analysis of adult American shad
otoliths, 2001

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Abstract

A total of 215 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2001. Based on tetracycline marking 38% of the 208 readable otoliths were identified as wild and 62% hatchery. Double marked fish (released below Conowingo Dam) represented 9.3% 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 1986-1995 year classes, stocking of approximately 284 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 134 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.79 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1995 year classe 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). Funding for the project was provided by an agreement between the three upstream utilities and the appropriate state and federal agencies. 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 and beyond), 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.

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 were recruited into the fishery, 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 2001.

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 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 acrylic.

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

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

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 2001. Age composition data was gathered as follows: for 1996 to 2001, age composition data was collected from the otolith analysis above. 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 transport 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 caculated 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 215 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 2001. No samples were collected from the East lift since it was operated in fish passage mode. For 7 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 208 readable otoliths (Table 1). A total of 79 (38%) otoliths exhibited wild microstructure and no tetracycline mark. One hundred and twenty-nine (62%) exhibited tetracycline marks including single, double, triple, and quadruple 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 1989-1999 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 been increasing since 1993 (Figure 2).

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 3). Overall mean age was 4.6 years for males and 5.2 years for females. For wild fish, mean ages were 4.5 for males and 5.0 for females (Table 4). For hatchery fish, mean age was 4.7 for males and 5.4 for females. Overall sex ratio was 0.74 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. Hatchery fish appeared to be slightly older and larger than wild 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, data 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 1986-1995, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 164 to 620, with an overall value of mean of 284 (Table 10). This is a maximum estimate since the 1995 year class is not fully recruited. L/A was highest (431-620) for the early cohorts (1986 – 1989). During 1990 to 1995, L/A improved to 164-289, presumably due to improvements in fish culture practices. L/A will continue to decrease since L/A for the 1996 and 1997 cohorts is already below the overall.

L/A was surprisingly low in comparison to the reproductive potential of wild fish. If fecundity of wild shad 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 1986-1995, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 40 to 386, with an overall value of 134. Again, this is a maximum estimate since the 1995 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 220 recruited adults for the 1995 cohort and 42 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 0.79 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 for recent years and must continue to do so to allow for successful restoration.

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

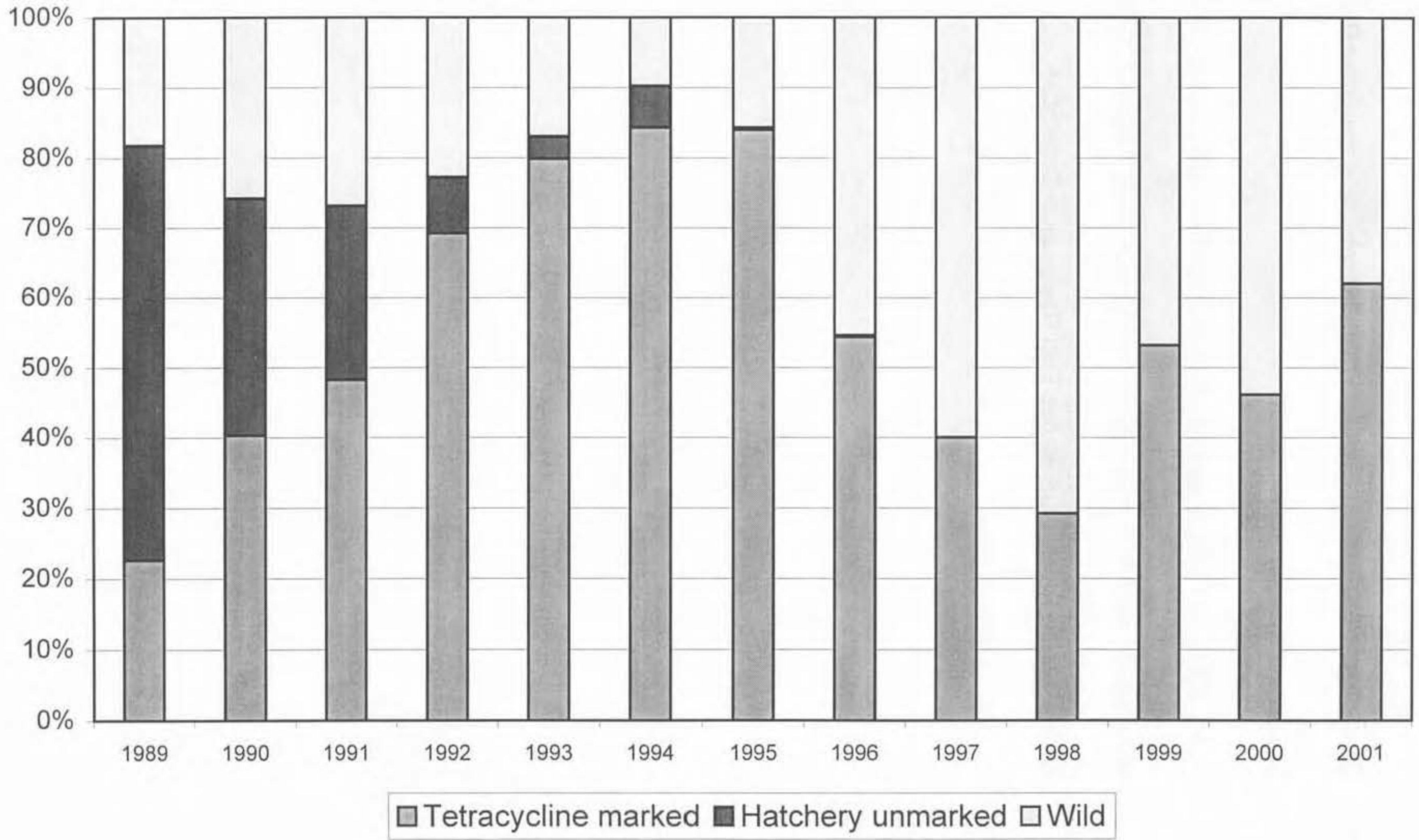

Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts

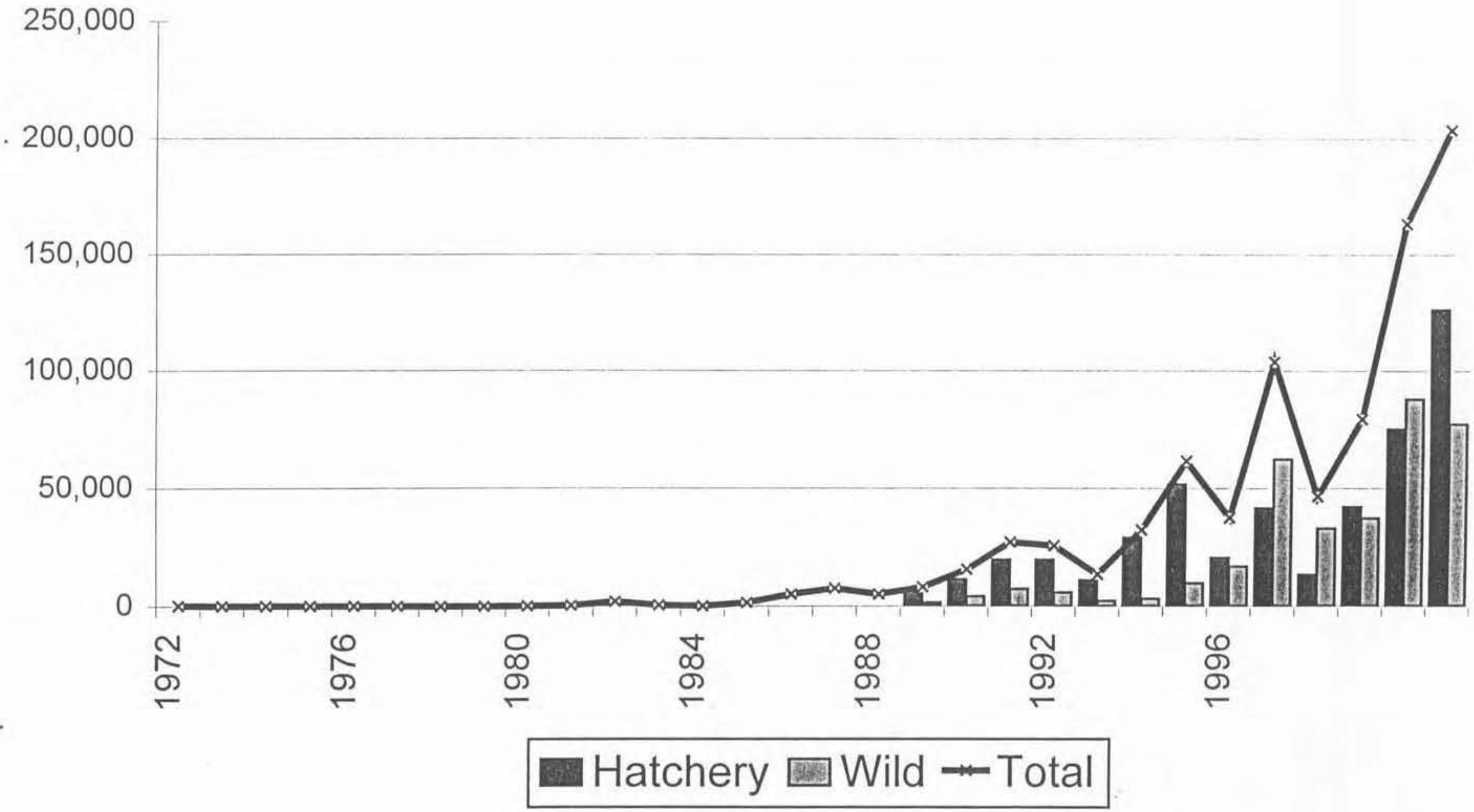

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2001.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

Conowingo Dam		N	%
Wild Microstructure, No TC Mark		79	38%
Hatchery Microstructure			
No TC Mark*		0	0%
Single TC Mark	Day 3 or 5	99	48%
Double TC Mark	Days 5,9, 3,6 or 3,7	8	4%
	Days 3,17	3	1%
	Days 6,12	1	0%
Triple TC Mark	Days 5,9,13	0	0%
	Days 3,13,17	3	1%
	Days 3,9,12	2	1%
	Days 9,12,15	3	1%
	Days 11,14,17 or 12,15,18	1	0%
Quadruple TC Mark	Days 3,13,17,21	1	0%
	Days 5,9,13,17 or 3,6,9,12	7	3%
	Days 5,9,13,21	1	0%
	Total Hatchery	129	62%
	Total readable otoliths	208	
	Unreadable Otoliths**	7	
	Total	215	
Other sites			
Fabri-Dam	No mark	11	
	Day 3 or 5	3	
	Days 3,6,9,12	1	
	Days 5,9,13,17	1	
Conestoga R.	Day 3,6	1	
	Days 3,9,12,15	6	
	Days 5,9,13,17	1	
W. Conewago Cr.	No mark	1	
	Day 3	1	
Muddy Cr.	No mark	2	

*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. Every 50th or 100th fish to enter the lifts was sacrificed for analysis.

	Hatchery									
	Larvae									
	Susquehanna		below Conowingo Dam		Fingerling		Unmarked**	Naturally reproduced		Total sample
Year	N	%*	N	%*	N	%*	N	N	%	size
1989	36	82	-		-		94	29	18	159
1990	49	73	1	1	-		42	32	26	124
1991	111	67	8	5	3	2	63	68	27	253
1992	154	73	8	4	2	1	19	54	23	237
1993	76	64	21	18	2	2	4	21	17	124
1994	217	81	22	8	3	1	17	28	10	287
1995	255	77	19	6	4	1	1	52	16	331
1996	180	48	22	6	4	1	1	172	45	379
1997	84	34	12	5	4	2	0	150	60	250
1998	29	22	7	5	2	2	0	92	71	130
1999	90	48	9	5	1	1	0	88	47	188
2000	78	40	11	6	0	0	0	104	54	193
2001	120	58	9	4	0	0	0	79	38	208
Totals	1,479	59	149	6	25	1	241	969	34	2,863

*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, 2001.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male		4	29	42	7				82	4.6
Female			18	56	34	4			112	5.2
Unknown				1	1				2	
Totals	0	4	47	99	42	4	0	0	196	5.0

Table 4. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2001.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male- Wild		2	12	11	2				27	4.5
Male- Hatc.		2	17	31	5				55	4.7
Female- Wild			11	27	10				48	5.0
Female- Hatc.			7	29	24	4			64	5.4
Totals	0	4	47	98	41	4	0	0	194	5.0

Table 5. Length frequency by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2001.

Sex	301-325	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	576-600	Total
Male		1	3	10	28	35	9						86
Female					7	27	41	34	5				114
Unknown					1		1						2
Totals	0	1	3	10	36	62	51	34	5	0	0	0	202

Table 6. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2001.

Sex	301-325	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	576-600	Total
Male- Wild			2	2	14	9							27
Male- Hatc.		1	1	8	14	24	7						55
Female- Wild					5	17	15	10					47
Female- Hatc.					2	9	25	22	5				63
Totals	0	1	3	10	35	59	47	32	5	0	0	0	192

Table 7. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2001.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male			421	(3)	408	(29)	429	(42)	434	(7)	415	(1)		
Female					447	(18)	466	(55)	476	(34)	476	(4)		

Table 8. Mean length at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2001.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male- Wild			445	(2)	406	(12)	423	(11)	433	(2)				
Male- Hatc.			372	(1)	409	(17)	431	(31)	435	(5)	415	(1)		
Female- Wild					438	(11)	449	(27)	472	(10)				
Female- Hatc.					461	(7)	483	(28)	477	(24)	476	(4)		

Table 9. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-2001.

									Hatchery Release Site			Wild
									Above Dams		Below Dams	
	Fish lift	% Age composition							larvae	fingerlings		
Year	catch	8	7	6	5	4	3	2	%	%	%	%
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4	71% *		6% *	23% *
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%		1%	26%
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	2%	5%	27%
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	1%	4%	23%
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	2%	18%	17%
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	1%	8%	10%
1995	61,650	0.0	3.2	12.4	51.9	28.5	4.0	0.0	77%	1%	6%	16%
1996	37,513	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	10.5	18.1	44.8	26.2	0.4	34%	2%	5%	60%
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370	0.5	1.1	7.9	32.6	45.3	10.0	0.0	48%	1%	5%	47%
2000	163,331	0.0	1.0	9.9	27.6	51.0	10.4	0.0	40%	0%	6%	54%
2001	203,776	0.0	2.1	22.0	51.8	24.6	2.1	0.0	56%	0%	4%	38%

*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						200	400	3,000	12,399	17,198	3,800	0
2000							0	688	6,532	18,221	33,692	6,876
2001								0	2,401	25,205	59,412	28,206
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,957	15,819	25,730	34,431	61,088	96,904	35,082
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	254	186	164	77	229

Overall number of larvae to return 1 adult (1986-1995): 284

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
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	4	33	138	191	42
2000							0	0	0	0	0
2001								0	0	0	0
Total recruits to lifts:	285	211	262	350	524	560	548	1,152	841	220	42
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
ber of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	166	0	0

Overall number of fingerlings to return 1 adult (1986-1995): 134

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
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						196	391	2,933	12,123	16,816	3,715
2000							0	917	8,710	24,295	44,923
2001								0	1,621	17,019	40,116
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,816	21,390	48,872	51,088	59,402	88,754
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
No. of adults transported to return 1 adult:	0.73	1.93	1.56	1.73	1.79	1.47	0.73	0.24	0.56	0.95	0.38

Overall number of adults transported to return 1 adult (1986-1995): 0.79

JOB V – Task 3

ADULT AMERICAN SHAD MOVEMENT IN THE VICINITY OF CONOWINGO AND HOLTWOOD HYDROELECTRIC STATIONS, SUSQUEHANNA RIVER, DURING SPRING 2001

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EXECUTIVE SUMMARY

A study was commissioned to provide information on the migration of American shad entering Conowingo Pond via the Conowingo East fish lift. A total of 204 radio tagged shad were studied to provide information on the proportion of fish migrating from Conowingo to Holtwood, the proportion of shad falling back through Conowingo after passage, areas of concentration including Broad Creek, Peach Bottom Atomic Power Station (PBAPS) and Muddy Run Pumped Storage Station (MRPSS), timing of migration through the Conowingo Pond, distribution patterns in the project area, and residence time. Since operation of the Holtwood fish lift began in 1997 the proportion of American shad that were passed into Conowingo Pond from the Conowingo east fish lift at Conowingo Dam and subsequently utilized the Holtwood fish lift has ranged from 21% to 50%.

One of the objectives in the study design was to assess the efficiency of the spill pool lift entrance at Holtwood Dam. No spill occurred during the 2001 study, therefore this objective could not be addressed.

One hundred eighty three shad (90.1% of 204) were subsequently monitored at detection sites upstream of Conowingo Dam. The remaining 20 (9.9% of 204) shad entering Conowingo Pond were not detected on upstream monitors; 16 of those returned to and passed through Conowingo and 4 were never detected again after exiting the fish lift. Immediate fallback of fish leaving the exit flume at Conowingo during the study was minimal. Four (1.9% of 204) fish passed through the Station within 8 h. One additional fish dropped back within 24 h following exit from the trough.

The majority of fish traveled through the lower Pond along the western shoreline. More than 60% of the fish detected were initially located at Broad Creek or PBAPS. The flow field to the powerhouse is likely stronger on the western side of the Pond due to the location of the powerhouse, which is located along the western shoreline. Once fish left the Broad Creek and Peach Bottom regions of the Pond they tended to cross over the impoundment at some point and travel to the east side of the Pond as evidenced by the numbers subsequently detect at MRPSS and Deepwater Island.

Greater than 98% of the fish detected at Broad Creek were located at upstream monitoring sites indicating they are likely not using Broad Creek as a spawning tributary.

PBAPS had little impact on the upstream migration of American shad through Conowingo Pond. The majority (82.1%) of the fish detected at PBAPS were subsequently located at upstream detection sites. It is likely, due to the low flow conditions that occurred in 2001, shad were attracted along the western shoreline to this site due to the water velocity from the PBAPS discharge. However, due to water temperatures likely higher than the preferred temperatures of shad, residency times during migration were short (<1 h).

MRPSS had little impact on the continued upstream movement of shad to Holtwood. Seven fish were entrained during the course of the study, only two detected during initial migration were entrained prior to reaching Holtwood. The remaining five went to Holtwood during daily lift operation hours and were available for passage prior to being entrained at the MRPSS.

Shad made repeated forays between MRPSS and the Holtwood tailrace. Most of the forays initiated at MRPSS began at or near daybreak. Additionally, a high proportion of shad began to move downstream of the tailrace around 1600 h while generation conditions remained constant during this time period. The high incidence of forays between MRPSS and Holtwood tailrace in this study did not seem to be related to flow conditions in the tailrace but may be related to other environmental variables such as the onset of day light for fish departing from MRPSS and shadows forming over the tailrace late in the afternoon causing fish to leave Holtwood tailrace.

One hundred thirty six shad (67% of 204) migrated to Holtwood tailrace, 46 subsequently passed the Project. The proportion of telemetered shad passing the project was less than that observed for untelemetered fish counted. Increased water temperatures and low flows in 2001 caused the migration and advancement of spawning condition to occur early in the season. Therefore, shad that were at or near maturity for spawning were tagged and released. It is possible these fish did not have as strong of migratory urge as those migrating early in the migration season. It is also possible spawning by some of these fish may have occurred in the flowing water section of the upper portion of the Conowingo Pond and Holtwood tailrace.

Shad spent a substantial amount of time (median >4 days) in the main study area (*i.e.*, Holtwood to MRPSS reach) upon initial detection in the Holtwood tailrace. The reason for this is unknown. The rate of detection and passage relative to the different flow scenarios evaluated was consistent. For example, the highest percentage of shad detected and passed at Holtwood corresponded with the highest percent of time given flow conditions evaluated occurred. This behavior was also consistent across the range of flows evaluated.

Some 63% (n=86) of the shad entering the Holtwood tailrace entered the fish lift entrance on at least one occasion; 54% of those subsequently passed. The timing of entrance detections corresponded with the timing of peak numbers of shad in the tailrace. Most made forays between 1200 and 1800 h. There was a difference in the number of forays into the fish lift entrance by those that utilized the fish lift versus those that did not pass. One-half of the shad that utilized the fish lift made only a single foray and the remainder made less than three forays. This indicates these fish may have demonstrated a stronger urge to continue upstream.

Some 37% of the shad that entered the Holtwood tailrace were never detected in the entrance of the fish lift. It is unknown from the monitoring design utilized in this study where the fish concentrated in the tailrace. However, it was derived from the design that 50% of the fish that entered the tailrace and did not pass the Project moved to the upper end of the tailrace in the vicinity of the fish lift entrance structure and entered the upstream corner monitoring site on at least one occasion. The reason for this is unclear since the distance between the corner monitoring site and the entrance is small (<50 ft).

INTRODUCTION AND BACKGROUND

Since operation of the Holtwood fish lift began in 1997 the proportion of American shad passed into Conowingo Pond from the Conowingo east fish lift at Conowingo Dam that subsequently utilized the Holtwood fish lift ranged from 21% to 50%. It has been unclear what proportion of American shad entering Conowingo Pond migrate to the Holtwood tailrace, fallback through Conowingo Dam, are delayed by the Peach Bottom Atomic Power Station (PBAPS) or Muddy Run Pumped Storage Station (MRPSS), or simply mill within Conowingo Pond.

To date, a comprehensive study of shad utilizing the east side fish lift at Conowingo and their subsequent migration through Conowingo Pond to Holtwood had not been conducted. Previous telemetry studies of American shad conducted in Conowingo Pond evaluated movement and behavior relative to both upstream and downstream passage (RMC 1993, 1994). Each of these studies was designed with specific objectives such as fishway entrance siting at Holtwood and preliminary investigation of fallback at Conowingo. The study objective in the previous fallback investigation was to examine turbine discharge effects on fallback under two 12-hour test conditions (Unit 11 on and Unit 11 off). Additionally, information on fallback was obtained during the 48-hour period following the start of each release. This evaluation of fallback at Conowingo indicated that the rate of fallback within 8 h could be greater than 10% (RMC 1995).

The objective of this study was to determine the fate of radio tagged American shad lifted into Conowingo Pond by the Conowingo east fish lift and, more specifically, to provide information on the proportion of fish migrating from Conowingo to Holtwood, the proportion of shad falling back through Conowingo after passage, areas of concentration, including PBAPS and MRPSS, timing of migration through the Conowingo Pond, distribution patterns in the project area, and residence time.

METHODS AND MATERIALS

Tagging and Release of Test Specimens

Migrating adult American shad were taken from the East lift and radio tagged. Fish were captured by netting them from a holding tank, held immobile in order to reduce stress, and tagged. A transmitter was inserted orally through the esophagus into the stomach. The transmitter's trailing whip antenna was allowed to run along the specimen's body from it's mouth. Fish were then sexed and placed into a holding tank for recovery prior to release.

Radio Telemetry Equipment Deployment and Operation

Radio Transmitters

Coded radio transmitters supplied by Lotek Engineering Inc. (Lotek), Newmarket, Ontario, Canada were utilized for this study. Transmitters propagated signals on frequencies between 149.380 and 149.420. Each transmitter contained a unique pulse code to allow for individual fish identification.

Radio Receivers

Lotek SRX_400 telemetry receivers installed with version W30 software were utilized to monitor tagged American shad. Receivers were configured to exclude background noise by utilizing specific features within the receiver's software. Receivers were set to scan each frequency for specific time periods, depending upon location. When a signal was received, the scan program was temporarily suspended and the validity of the signal was verified and logged or rejected. All receivers were time synchronized and reset if deviation exceeded 10 seconds. Data were stored in the SRX_400 as either a single event or a period of multiple events.

Receiver Deployment

A total 11 remote monitoring stations were installed in the vicinity of Holtwood Dam, Conowingo Dam, Broad Creek, and PBAPS (Figures 1 through 3). Stations 1 through 9 were deployed to detect shad migrating through Conowingo Pond and subsequently migrating to Holtwood. Stations 10 through 12 monitored fallback and fish lift utilization at Conowingo.

Monitoring Stations 1 and 2 monitored fish passing the Holtwood Project. Station 1 consisted of a receiver coupled to limited range underwater antenna in the exit flume (Figure 1). This station was calibrated to only detect signals of shad in the flume channel. Station 2 consisted of a receiver coupled to a limited-range underwater antenna deployed in the spillway fish lift entrance channel (Figure 2).

Monitoring Station 3 was deployed in the Holtwood tailrace to detect fish that migrated to the Holtwood tailrace (antenna zone 1), fish lift entrance (antenna zone 2), and the eddy between the fish lift entrance structure and Unit No. 1 (hereafter, corner site (antenna zone 3); Figure 1). This site incorporated a receiver coupled to a 4-element Yagi antenna (Cushcraft model P150-4) and two limited range underwater antennas. The Yagi antenna was mounted on the fish lift's entrance structure and oriented parallel to the tailrace discharge. It was calibrated to detect fish entering the tailrace just downstream of the lower end of the powerhouse. The underwater antennas were deployed in the corner site and fish lift entrance channel and calibrated to a limited range in each of those areas.

Station 4 was deployed downstream of the Holtwood Dam to monitor shad utilizing the spillway. This station incorporated a receiver coupled to a 9-element Yagi antenna oriented parallel to the dam. This station was calibrated to maximize detection across the width of the river. Due to absence of spill during the study no fish were recorded at this site.

Monitor Station 5 was deployed along the east shoreline of the Susquehanna River in the vicinity of Deepwater Island, just downstream of the Holtwood tailrace. This station incorporated a receiver coupled to a 4-element Yagi antenna oriented from the shoreline to Deepwater Island (Figure 2).

Monitor Stations 6 and 7 were installed to monitor shad in the vicinity of the MRPSS to detect shad migrating to, or passing, this point. Station 6 incorporated a receiver coupled to two 4-element Yagi antennas installed and oriented approximately 45° to the shoreline; one antenna faced upstream and the other faced downstream. The zone of reception of this receiving station encompassed about one-third the width of the river from the eastern shoreline. Fish that entered the discharge or pumping flow of MRPSS were subject to detection by this monitoring station (Figure 2).

Monitor Station 7 was deployed at the intake/discharge canal of the MRPSS reservoir. This station utilized a receiver coupled to two 4-element Yagi antennas oriented upstream from the canal intakes to the canal. The receiver was calibrated to monitor the width of the canal (Figure 2).

Station 8 was deployed at the downstream end of the PBAPS discharge canal. This station consisted of a receiver coupled to a 4-element Yagi antenna oriented downstream parallel to the west shoreline. The station was calibrated to detect shad that may enter the heated effluent of PBAPS.

Station 9 monitored the mouth of Broad Creek located just below the Pennsylvania/Maryland state border. The station consisted of a receiver coupled to a 4-element Yagi antenna located on a cabin owner's porch on the south side of the entrance to Broad Creek.

Monitoring Stations 10 and 12 were deployed on the west and east sides of the Conowingo tailrace, respectively, to monitor shad falling back through Conowingo Dam. Each of these monitoring stations utilized a receiver coupled to a 4-element Yagi antenna oriented perpendicular to the river. The receivers were calibrated to monitor the width of the tailrace (Figure 3).

Monitor Station 11 obtained data on shad utilizing and exiting the Conowingo east fish lift. It incorporated a receiver coupled to a tuned, suspended, stripped coaxial cable antenna. The antenna was deployed and calibrated to detect shad moving upstream through the fish lift and leaving the exit flume (Figure 3).

Data Collection and Analysis

Continuous remote monitoring of all release groups occurred for the duration of the spring migration season. Data were downloaded from the receivers three times per week or when feasible utilizing a laptop computer and stored on duplicate 3.5" diskettes.

Environmental Variables

Water temperature throughout the study period ranged from 16.7 to 22.2°C. Flow conditions (Holtwood generation) ranged from 0 to 26,650 cfs. No spillage at Holtwood occurred during the study period. Hourly average discharge at Holtwood ranged from 0 to 22,599 cfs (Table 1 and Figure 4). Generation occurred for a period of 845 h during the course of the study. Flows of 20,000 to 25,000 cfs occurred most often at 49.8% of the time. These flows generally occurred between 1100 and 2200 h. Non-generation occurred for 23.4% of the time and generally occurred between 0100 and 0600 h (Table 2).

RESULTS

Tagging, Release, and Initial Upstream Passage

A total 301 tagged fish was released for the study. Fish were released in seven separate groups between 1 and 23 May 2001 (Table 3).

The first three groups of fish were released downstream of Conowingo with the intent of allowing fish to demonstrate natural passage behavior. The fish were collected from the fish lift sorting tank, radio tagged, and hoisted back down to the entrance channel in water-filled containers. Following release of the first two groups, it was evident that a substantial amount of dropback below Conowingo was occurring and an adequate number of fish may not re-enter the East fish lift to provide a reasonable sample size in Conowingo Pond. The release procedure was modified slightly for Release Group 3. For that release, the fish were again tagged and hoisted down to the entrance channel but were instead placed upstream of the V-gates with the V-gates closed. The following morning the V-gates were opened into the normal fishing position as daily fish lift operation began. During the first lift of the day, which likely contained a fair number of radio tagged shad from the third release group, the fish lift hopper door opened during hopper ascent causing the fish and water in the hopper to plunge to the draft tube deck and/or back into the entrance channel. One radio tagged fish was recovered from the deck. Due to this incident, Release Group 3 was excluded from subsequent analysis. Only 14 of 82 fish from the first two groups eventually re-entered the lift and passed into Conowingo Pond.

Following failure of the third release attempt method, the remaining groups of fish were tagged and released directly into the fish lift hopper and lifted up to the exit flume. Release of the remaining four fish groups directly into the exit flume was successful in ensuring an adequate number of shad in Conowingo Pond for study. All 189 fish released in Groups 4 through 7 exited the flume and passed into Conowingo Pond.

An additional two fish from Release Groups 1 through 3 that did not pass into Conowingo Pond were recaptured at the Conowingo west fish lift. One of these shad was sacrificed due to poor physical condition and the tag was reused at a later date. The other fish was released back into the tailrace.

A total of 204 fish passed into Conowingo Pond during the study; 14 fish were from Release Groups 1 and 2 and the remaining fish from Release Groups 4 through 7. All 14 fish from Release Groups 1 and 2 and 169 fish from Release Groups 4 through 7 were subsequently detected on at least one of the upstream monitors, providing a sample of 184 fish detected within the Pond upstream of Conowingo.

The remaining 20 shad were never detected upstream beyond Conowingo; 3 were last detected on the exit flume monitor and the remaining 17 eventually returned to and passed Conowingo.

Fallback Through Conowingo Dam

As stated above, 20 fish entering Conowingo Pond were never detected on upstream monitors; 17 of those returned to and passed downstream through Conowingo. However, immediate fallback of fish leaving the exit flume at Conowingo during the study was minimal. Four (1.9% of 204) fish passed through the Station within 8 h (Table 4). One additional fish dropped back within 24 h following exit from the flume. The remaining fish that were never detected at upstream monitoring sites remained in the Pond for up to 18 days before returning to the Dam. The four fish that demonstrated immediate fallback are excluded from subsequent analysis.

Detection in Conowingo Pond

Initial upstream detections were determined for the remaining 184 fish passing into Conowingo Pond. Their initial detections at upstream monitoring sites are as follows:

Broad Creek	PBAPS	MRPSS	Deepwater Island	Holtwood
80 (43.4%)	31 (16.8%)	48 (26.1%)	20 (10.9%)	5 (2.7%)

Details on detections and subsequent movement patterns at each site are described below and expressed as a fish budget in Figure 5.

Broad Creek

The largest group of shad (n=80) passing Conowingo were initially detected at Broad Creek during migration. Of these, 36 (45%) and 27 (33.8%) were next detected at PBAPS and MRPSS, respectively. Sixteen (20%) other fish were subsequently located at Deepwater Island (Table 5, Figure 5). The remaining fish (1.2%) was last detected at Conowingo ten days later.

Time from passage at Conowingo to initial detection at Broad Creek ranged from 1 h 29 min to >6 days (median=6 h 55 min; Table 6, Figure 6). Detection time while at Broad Creek ranged from <1 min to >4 days (median=17 min; Table7 and Figure 7).

Peach Bottom Atomic Power Station

A total 67 fish passing Conowingo were detected at PBAPS during migration. Thirty-one (45%) were initially detected there and the remaining 36 (55%) were located there after being initially detected at Broad Creek (Table 5 and Figure 5). Fifty-five (82.1%) of the fish detected at PBAPS were subsequently detected at one or more of the upstream monitoring sites; 52 were next detected at MRPSS, two were next detected at Deepwater Island, and the remaining shad was detected at Holtwood. Among those (12) that did not continue upstream from PBAPS, eight were last located at Conowingo Dam and four (6%) others were not detected again after leaving PBAPS. Time from passage at Conowingo to initial detection at PBAPS for the 31 fish initially detected there ranged from 2 h 35 min to 7 days 9 h (median=19 h 11 min; Table 6 and Figure 6) Overall detection time at PBAPS during initial migration ranged from <1 min to 10 days (median=1 h 13 min; Table 7 and Figure 7). Most (49 or 73%) of the fish were detected at PBAPS for <4 h.

Average calculated daily discharge at the end of the discharge canal was relatively consistent and ranged from 3,377 to 3,410 cfs (median=3,378 cfs; Figure 8). PBAPS discharge water temperature ranged from 27.2 to 36.0°C and generally increased throughout the study period (Figure 8). The maximum temperature fish were exposed to during migration was 32.2°C, which occurred from 8 to 10 May. Three fish were detected at PBAPS on these dates.

Muddy Run Pumped Storage Station

A total of 127 fish passing Conowingo were detected at MRPSS during migration. Forty-eight (37.8%) were initially detected at this location. Twenty-seven (21.3%) were located there after being initially detected at Broad Creek and the remaining 52 (40.1%) were located there after being detected at PBAPS (Table 5, Figure 5). More than 92% (117) of fish detected at MRPSS continued upstream and were next detected at either Deepwater Island (n=109) or Holtwood (n=8). Two fish during their initial migration were pumped into the MRPSS reservoir.

Four of the remaining eight fish that did not continue upstream were last located at Conowingo, one other returned to PBAPS and was last detected there, and the remaining three were last detected at MRPSS. Time from passage at Conowingo to initial detection at MRPSS for the 48 fish initially detected there ranged from 6 h 29 min to almost 9 days (median=1 day 40 min; Table 6 and Figure 6). Overall detection time at MRPSS during initial migration ranged from <1 min to >13days (median=2 h 13 min; Table and Figure 7).

Deepwater Island

A total of 147 fish passing Conowingo were detected at Deepwater Island during migration, including 20 (13.6%) initially detected there (Table 5 and Figure 5). Eighteen (12.3%) were located there after being last detected at Broad Creek and the remaining 109 (74.2%) were located there after being detected at MRPSS. One hundred twenty two (85.3%) of the fish detected at Deepwater Island continued upstream to Holtwood. The remaining 25 fish that did not continue upstream were last located at Conowingo (n=13), MRPSS (n=2), MRPSS reservoir (n=1), Deepwater Island (n=8), and Broad Creek (n=1). Time from passage at Conowingo to initial detection at Deepwater Island for the 20 fish initially detected there ranged from 4 h 55 min to >3 days (median=17 h 52 min; Table 6, Figure 6). Overall detection time at Deepwater Island during initial migration ranged from 1 min to >5 days (median=1 h 54 min; Table 7 and Figure 7).

Holtwood Dam

Ultimately, a total 136 of the 204 fish (67%) passing into Conowingo Pond migrated to Holtwood (Figure 5), including 5 (3.7%) initial detections. One (0.7%) was located there after being last detected at PBAPS. Eight (5.9%) others were located there after last being detected at MRPSS and the remaining 122 (89.7%) of the fish detected at Deepwater Island continued upstream to Holtwood (Figure 5). Time from passage at Conowingo to initial detection at Holtwood (five fish) ranged from 18 h 15 min to just under 3 days (median=2 d 17 h 28 min; Table 6 and Figure 6). The median travel time for all fish reaching the Holtwood Dam from Conowingo Dam was 2 d 1 h (range 7 h 55 min to 9 days 21 h; Table and Figure 6).

Movement Between MRPSS and Holtwood

A foray was defined as a fish leaving MRPSS and moving upstream to the Holtwood tailrace. A total of 107 fish made forays between MRPSS and Holtwood tailrace (Table 8). Fifty-nine (55.1%) American shad made a single foray to the tailrace from MRPSS, forty-two (42 %) made two to five forays, and six (5.6 %) made more than five forays. Times of initiation of forays to the tailrace from MRPSS and departure times from the tailrace are presented in Figure 9. The majority of forays from MRPSS to Holtwood occurred between 0400 and 0800 h. In contrast, the peak time period of shad movement out of the Holtwood tailrace to MRPSS was 1600 to 2000 h.

Diel Movement of Shad in the Holtwood Tailrace

Diel movement was examined for 136 shad that entered the Holtwood tailrace on at least one occasion. All shad were present at some point during daily lift operations and therefore were theoretically available for capture in the Holtwood fish lift. The fewest detections in the tailrace by hour of day ranged from 30 during the 2200 to 2300 h period to 121 during 1300 to 1400 h (Figure 10). The greatest numbers of shad occurred in the tailrace from 0700 h to 1700 h; fewest occurred during 2100 to 0200 h. Capture and passage of both telemetered and untelemetered shad at the Holtwood lift followed a similar temporal trend (Figure 10).

Time Spent in the Holtwood Tailrace by American Shad

The amount of time shad spent in the main study area (*i.e.*, upper reservoir) following initial migration varied. Upon reaching the Holtwood tailrace, the time shad spent prior to passing upstream via the lift or exiting the tailrace for a final time ranged from <1 min to >26 days (median=4 d 6 h 17 min; Figure 11). Fish made repeated forays into and out of the tailrace (*i.e.*, left the tailrace and then returned). The number of forays among individual shad ranged from 1 to 18. Of the 136 shad entering the tailrace, the majority (n=70) made between 2 and 5 forays. An additional 29 fish made >5 forays and the remaining 37 only made a single foray (Table 10 and Figure 10).

American Shad Behavior in the Holtwood Tailrace

While in the tailrace, shad were located either at the fishway entrance and the vicinity of the corner of the Station near Unit 1. A total 86 fish of 136 fish entering the Holtwood tailrace made from 1 to 14 forays into the fish lift entrance (*i.e.*, entered and left the entrance). Fifty percent of the shad made between 2 and 5 entrance forays (Table 10 and Figure 12). Forty-six (54%) of the 86 shad detected in the fish lift entrance subsequently passed the Project. Of those, 50% made one approach into the entrance and >90% made three or fewer forays. The proportion of single forays by fish that passed the Project was 20% greater than that for those that did not pass. In other words, there were more forays made per fish into the entrance by those shad that did not pass Holtwood (Figure 12). Approximately 74% of the 86 fish were detected at the fishway entrance between 1200 and 1800 h. Another 16% were detected at the entrance between 0800 and 1000 h. Residency times of fish detected in the entrance ranged from <1 min to 1 h 55 min (median=12 min, Table 9). The proportion of time spent by fish in the vicinity of the entrance of the total time spent by fish in the tailrace for all fish detected was 1.9%.

The percent of forays by time and flow at the fish lift entrance followed a trend similar to the time of day when most fish were detected in the tailrace. The peak time periods of detection were between 0800 to 1000 h and 1200 to 1800 h under low flow conditions of 20,000 to 25,000 cfs (Tables 11 and 12, Figures 13 and 14). The percent of detection relative to the percent of time the flow conditions evaluated occurred were similar.

More shad (114) made forays to the corner monitoring site (*i.e.*, entered the corner monitoring site then left). Of those, most (55.3%) were detected in the corner more than 5 times (Table 10). The number of forays by individual shad to the corner ranged from 1 to 59. As with entrance forays, shad that passed the Project made fewer forays into the corner than those that did not pass. Eighty percent of the fish that passed the Project made 10 or fewer forays. Eighty-three (74%) of the fish detected at the corner were also detected in the fishway entrance; 44 of 83 subsequently passed the Project. Residency times of fish detected in the corner were greater than those observed for the fish lift entrance and ranged from <1 min to 11 h (median=37 min; Table 9). The percent of time spent in the vicinity of the corner (6.8%) of the total time spent in the tailrace for all fish detected was greater than that observed for the fish lift entrance (1.9%). The percent of forays by time to the corner site were more evenly distributed by hour than that observed for the entrance forays with a higher proportion detected there in the morning hours (Table 11 and Figure 13).

The percent of forays by flow were consistent with the percent of time the flow conditions evaluated occurred (Table 12 and Figure 14).

The percent of fish passing the Project versus flow conditions evaluated followed trends similar to those observed for detections in the tailrace, corner site, and fish lift entrance. The majority (62.5%) passed in the 20,000 to 25,000 cfs flow range (Table 13, Figure 15), which was the normal release volume on most days.

Entrainment into MRPSS Reservoir

Seven shad were entrained into the MRPSS reservoir during the study. Of those, five had reached Holtwood prior to entrainment (Table 14). The time from initial detection at Holtwood to entrainment at MRPSS ranged from 20 h to nearly 14 days. Additionally, the number of forays these fish made between MRPSS and Holtwood prior to entrainment ranged from 1 to 6. Four shad were entrained when MRPSS was pumping with eight units. The operating conditions could not be determined for the remaining three fish as they were only detected in the upper reservoir while avoiding detection at MRPSS. It is possible they were at depths below radio signal detection during pumping operations.

DISCUSSION

The primary objective of the study, estimation of the proportion of American shad released at Conowingo reaching Holtwood tailrace and eventually entering the Holtwood fish lift was fulfilled. Of the 204 radio tagged fish leaving the Conowingo fish lift exit flume, 136 (67%) reached Holtwood tailrace. Of those reaching the Holtwood tailrace, 85 (62.5%) entered the Holtwood fish lift; 46 of the 136 (33.8%) subsequently passed Holtwood.

A previous pilot study conducted in 1995 (RMC 1995) indicated re-entrainment of shad at Conowingo may be significant. However, immediate (<8h) re-entrainment of fish leaving the exit flume at Conowingo during the study was low (1.5%) and less than that observed previously. In that study 11% (5 of 45) shad passed through Conowingo within 8 h of exiting the trough. Although each group of 20 radio tagged fish was released into the flume with 30 untagged fish in 1995 to elicit schooling behavior, it is possible the numbers of shad were not large enough to provide adequate schooling behavior, therefore causing the fish to behave abnormally and discouraging upstream movement. During the current study fish were placed into the flume with larger numbers (hundreds) of fish not subjected to any handling which may have created better schooling behavior. It is also possible fish tagged in the 1995 study developed a higher level of stress which discouraged continued upstream movement due to the technique utilized to get fish into the trough. The fish were hoisted up to the trough in a similar fashion to that which was attempted in the first three release trials of this study.

Initial detections of fish entering into Conowingo Pond suggest that the majority of fish travel along the western shoreline. More than 60% of the fish detected were initially located at Broad Creek or PBAPS. This finding is further supported by the fact that most fish subsequently detected after passing Broad Creek continued along the west shoreline and were next detected at PBAPS. It is likely this travel route may be related to a stronger flow on the west side due to the location of the powerhouse, which is located along the western shoreline. Once fish leave the Broad Creek and Peach Bottom regions of the Pond they tended to cross over the impoundment at some point and travel to the east side of the Pond.

Although most fish were initially detected at Broad Creek, more than 98% were later located at upstream monitoring sites. The remaining fish also located there was subsequently located at Conowingo. This suggests Broad Creek is not being used as a spawning tributary.

The thermal discharge from PBAPS did not appear to be a barrier to the upstream migration of shad. Although a high proportion (33%) of shad were detected at PBAPS, 82.1% of those were located at an upstream detection site. The water velocity at the point of discharge is generally >5ft/sec and may attract shad along the western shoreline. However, due to water temperatures likely higher than the preferred temperatures of shad, residency time was short. The median residency time as indexed by detection time was about 1 h.

Although there is a likelihood of some proportion of shad being pumped into the MRPSS reservoir the impact appears to be minimal. Seven fish (3.8%) were entrained during the course of the study. However, only two (1.7%) detected during initial migration were entrained prior to reaching Holtwood. The remaining five went to Holtwood first, thus available for continued passage upstream prior to being entrained at the MRPSS.

A previous study at Holtwood revealed there was a tendency of fish to move out of the tailrace during the evening and to congregate in a pool area south of Piney Island and downstream to MRPSS (RMC 1993). These fish made repeated runs back to the Holtwood tailrace at or near daybreak. The high incidence of forays between MRPSS and Holtwood tailrace in this study does not seem to be related to flow conditions in the tailrace but may be related to other environmental variables such as shadows forming over the tailrace late in the afternoon and natural biological triggers. A high proportion of shad begin to move downstream of the tailrace around 1600 h while generation conditions remained constant during this time period (see Figure 9). Visual observations during a study conducted in the Merrimac River indicated shad would be deterred by distinct shadow lines on sunny days (RMC 1988).

Further, the highest proportion of shad departing MRPSS on forays upstream to the Holtwood tailrace did so in the 0400 to 0600 h when Holtwood Station generation was at or near 0 cfs. This appears to be a biological behavior with the shad cueing on onset of daylight as opposed to cueing in on a certain flow or water velocity. As stated previously, 136 of the 204 fish passing into Conowingo Pond migrated to Holtwood and 46 (34%) of those that passed the Project.

Shad spent a substantial amount of time (median >4 days) in the Holtwood tailrace upon initial detection there. The reason for this is unknown. The rate of detection and passage relative to the different flow scenarios evaluated was consistent. For example, the highest percentage of shad detected and passed at Holtwood corresponded with the highest percent of time given flow conditions evaluated occurred (refer to Figure 10). This behavior was also consistent across the range of flows evaluated.

Some 63% (n=86) of the shad entering the Holtwood tailrace entered the fish lift entrance on at least one occasion; 54% of those subsequently passed. The timing of entrance detections corresponded with the timing of peak numbers of shad in the tailrace. Most made forays between 1200 and 1800 h. There was a difference in the number of forays into the fish lift entrance by those that utilized the fish lift versus those that did not pass. One-half of the shad that utilized the fish lift made only a single foray and the remainder made less than three forays. This indicates these fish may have demonstrated a stronger urge to continue upstream.

Some 37% of the shad that entered the Holtwood tailrace were never detected in the entrance of the fish lift. It is unknown from the monitoring design utilized in this study where the fish concentrated in the tailrace. However, it was derived from the telemetry monitoring system setup design that 50% of the fish that entered the tailrace and did not enter the fish lift entrance moved to the upper end of the tailrace and entered the upstream corner monitoring zone on at least one occasion, and spent nearly 7% of their total tailrace detection time there. Visual observations by Normandeau personnel also indicated large numbers of shad in this area. The reason for this occurrence can not readily be explained since the distance between the corner site and the entrance is relatively small.

The proportion of telemetered fish that passed the Project was less than that observed for untagged fish at the Holtwood fish lift. This observation is likely related to the fact that peak passage at Conowingo occurred near the date when the first successful release of radio tagged fish occurred (Release Group 4 on 10 May). By 12 May, greater than 80% of the run had passed Conowingo. If the tagging methodology employed for Release Groups 4 through 7 was utilized for Release Groups 1 through 3, it is likely the proportion of radio tagged shad passing the Holtwood fish lift would have been similar to the actual proportion of untagged fish passed. Additionally, increased water temperatures and low flows in 2001 caused the migration and advancement of spawning condition to occur early in the season. Therefore, shad that were at or near maturity for spawning were tagged and released may not have a strong urge to continue upstream. Several previous studies conducted by RMC indicated that fish collected, tagged, released, and monitored later in the season did not demonstrate as much migratory urge as those released early in the migration season.

It is also possible spawning by some of these fish may have occurred in the flowing water section of the upper portion of the Conowingo Pond and Holtwood tailrace. Carlson (1968) indicated marginal spawning habitat exists in this portion of the Susquehanna River.

LITERATURE CITED

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RMC. 1988. Passage of radio tagged American shad at the Eldred L. Field Hydroelectric Station Northern Canal, Lowell, MA. Report prepared for Harza Engineering Company, Chicago, IL.

RMC. 1993. Report on the distribution of telemetered shad in the tailwaters and spillage areas of the Holtwood, Safe Harbor, and York Haven Hydroelectric Projects, Susquehanna River, Pennsylvania. Report prepared for Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company.

RMC. 1994. Draft report on the restoration of telemetered shad in the tailwaters and spillage areas and forebays of the Holtwood, Safe Harbor, and York Haven Hydroelectric Projects, Susquehanna River, Pennsylvania. Report prepared for Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company.

RMC. 1995. Assessment and dropback of adult American shad using the Conowingo East Fish Passage Facility. Report prepared for the Susquehanna Anadromous Fish Restoration Committee, Harrisburg, PA.

Table 1

Hourly Holtwood Dam operations, 1 May through 15 June 2001.

Time of Day	Hours Generated	Average Discharge (cfs)	Median Discharge (cfs)
1:00	20	8,975	0
2:00	15	6,652	0
3:00	11	4,636	0
4:00	9	3,462	0
5:00	9	2,899	0
6:00	13	3,224	0
7:00	29	8,331	6,490
8:00	37	12,832	13,470
9:00	42	17,186	20,870
10:00	45	19,583	21,955
11:00	46	21,095	22,170
12:00	46	20,723	21,965
13:00	46	20,938	22,410
14:00	46	20,835	22,240
15:00	46	21,388	22,660
16:00	46	22,654	22,970
17:00	46	23,617	23,660
18:00	46	23,277	22,660
19:00	46	22,177	22,000
20:00	45	22,151	22,275
21:00	45	22,599	23,195
22:00	43	19,997	22,015
23:00	37	16,803	21,950
24:00	31	12,375	11,760
0100-0600	*76*	*4,975*	*0*
0700-1200	*246*	*14,711*	*19,880*
1300-1800	*276*	*21,886*	*22,925*
1900-2400	*247*	*19,350*	*22,085*

Table 2

Holtwood dam operations by flow range, 1 May through 15 June 2001.

Station Discharge (cfs)	Total Hours at a Given Discharge	Percentage of Time
0	258	23.4%
500-5,000	20	1.8%
5,001-10,000	50	4.5%
10,001-15,000	65	5.9%
15,001-20,000	64	5.8%
20,001-25,000	550	49.8%
>25,000	97	8.8%
Total	***1,104***	***100.0%***

Table 3

Summary of tagging and release of American shad, spring 2001.

Release Group	Tag Date	Release Date	Release Time[4]	Number Released	Water Temperature (°C)
1[1]	1-May	2-May	7:00	41	16.7
2[1]	3-May	4-May	7:00	41	20.2
3[2]	8-May			30	21.7
4[3]	10-May	10-May	17:00	40	20.6
5[3]	15-May	15-May	16:00	50	20.6
6[3]	17-May	17-May	16:00	49	21.0
7[3]	23-May	23-May	16:00	50	18.8
Totals				*301*	

1- Fish hoisted down to entrance channel and held with only downstream weir gate overnight. The hoisting procedure likely caused undue stress to fish.

2- Fish hoisted down to entrance channel and held uptreram of crowder gate with gate closed overnight. During the initial lift on the following morning, which likely contained the majority of tagged shad, the sorting mode hopper door opened causing the fish to plunge onto the deck and back into the water.

3- Fish were tagged and relased directly into the hopper and lifted into the exit flume.

4-Approximate times.

Table 4

Summary of fish fallback less than 24 h at Conowingo Dam, spring 2001.

Fish ID	Date and Time	Time in Reservoir (d-hh:mm)	River Flow (cfs)	Number of Units Operating
5-83	18 May 12:07:07	0-03:32	9,830	2
6-63	17 May 18:25:32	0-00:53	15,190	2
6-73	18 May 9:42:11	0-00:57	9,830	2
6-76	18 May 16:05:06	0-00:18	9,830	2
6-56	25 May 7:39:16	0-22:03	13,270	2

Table 5

Number of fish initially detected by site and their subsequent migration to Holtwood, spring 2001.

	Initial Detection	Total	Number from Initial Detection Locations to Holtwood	Number from Initial Detections Passing Holtwood
Broad Creek	80 (43.5%)	85	55 (68.8%)	14 (17.5%)
PBAPS	31 (16.8%)	67	19 (61.3%)	8 (25.8%)
MRPSS	48 (26.1%)	127	39 (81.3%)	17 (35.4%)
Deepwater Island	20 (10.9%)	147	18 (90.0%)	7 (35.0%)
Holtwood	5 (2.7%)	136	5	
Total	*184 (100.0%)*		*136 (73.9%)*	*46 (25.0%)*

Table 6

Travel times of shad from Conowingo to initial detection location and from Conowingo to Holtwood relative to travel routes taken, spring 2001.

	Time (dd:hh:mm)			
	Minimum	Maximum	Average	Median
		Conowingo to Initial Detection Location		
Broad Creek	0-01:29	6-15:16	0-21:56	0-06:55
PBAPS	0-02:35	7-09:43	1-11:36	0-19:11
MRPSS	0-06:29	8-19:09	1-18:29	1-00:40
Deepwater Island	0-04:55	3-10:52	0-23:25	0-17:52
Holtwood	0-18:15	2-23:57	2-01:34	2-17:28
Combined	*0-01:29*	*8-19:09*	*1-06:27*	*0-18:15*
		Conowingo to Holtwood		
Broad Creek	0-09:06	8-23:57	2-22:04	2-17:30
PBAPS	0-07:55	6-23:40	2-21:09	2-04:33
MRPSS	0-09:46	9-21:25	2-14:11	1-20:21
Deepwater Island	0-10:36	6-13:45	1-18:17	1-12:44
Holtwood	0-18:15	2-23:57	2-01:34	2-17:28
Combined	*0-07:55*	*9-21:25*	*2-15:15*	*2-01:29*

Table 7

Detection times of shad during migration from Conowingo Dam, spring 2001.

Initial Detection Location	Time (dd:hh:mm)			
	Minimum	Maximum	Average	Median
Broad Creek	0-00:00	4-03:27	0-07:47	0-00:17
PBAPS	0-00:00	10-03:24	0-21:02	0-01:13
MRPSS	0-00:00	13-08:22	0-14:44	0-02:13
Deepwater Island	0-00:01	5-15:51	0-06:32	0-01:54

Table 8

Number of forays taken between MRPSS and Holtwood's tailrace by all fish, spring 2001.

Release Group	Number of Fish	Number of Forays		
		1	2 to 5	>5
1	6	5 (83.3%)	1 (16.7%)	0 (0.0%)
2	5	2 (40.0%)	3 (60.0%)	0 (0.0%)
3*				
4	27	14 (51.9%)	11 (40.7%)	2 (7.4%)
5	30	19 (63.3%)	10 (33.3%)	1 (3.3%)
6	23	12 (52.2%)	9 (39.1%)	2 (8.7%)
7	16	7 (43.8%)	8 (50.0%)	1 (6.3%)
Total	*107*	*59 (55.1%)*	*42 (39.3%)*	*6 (5.6%)*

* Excluded from data analysis.

Table 9

Time spent by fish at Holtwood tailrace monitoring locations, spring 2001.

	Time Spent			
	Minimum	Maximum	Average	Median
Tailrace	0-00:01	4-02:12	0-13:32	0-07:57
Entrance	0-00:00	0-01:55	0-00:17	0-00:12
Corner	0-00:01	0-11:04	0-01:15	0-00:37

Table 10

Number of forays taken to the tailrace, tailrace corner, and fish lift entrance at Holtwood Dam.

	Number of Fish	Number of Forays		
		1	2 to 5	>5
Tailrace forays	136	37 (27.2%)	70 (51.5%)	29 (21.3%)
Fishlift entrance forays	86	35 (40.7%)	43 (50.0%)	8 (9.3%)
Tailrace corner forays	114	10 (8.8%)	41 (36.0%)	63 (55.3%)

Table 11

Percent of forays, by time period, made to the Holtwood fish lift entrance and corner, spring 2001.

		Percent of Forays	
Time Period	Average Flow (cfs)	Fish Lift Entrance	Corner
00:00-02:00	10,675	0.0%	1.9%
02:00-0400	5,644	0.0%	3.3%
04:00-06:00	3,180	0.0%	8.3%
06:00-08:00	5,778	3.7%	14.8%
08:00-10:00	15,009	16.0%	12.3%
10:00-12:00	20,339	8.9%	11.6%
12:00-14:00	20,831	18.8%	11.3%
14:00-16:00	21,111	23.0%	16.7%
16:00-18:00	23,136	16.2%	20.8%
18:00-20:00	22,727	7.1%	10.4%
20:00-22:00	22,375	6.0%	1.9%
22:00-24:00	18,400	0.3%	0.2%

Table 12

Percent of forays, by flow range, at the Holtwood fish lift entrance and corner, spring 2001.

Station Discharge (cfs)	Percent of Hours	Percent of Forays	
		Fish Lift Entrance	Corner
0	23.4%	13.7%	27.0%
500-5,000	1.8%	0.7%	0.5%
5,001-10,000	4.5%	7.7%	3.9%
10,001-15,000	5.9%	15.5%	4.8%
15,001-20,000	5.8%	5.6%	3.4%
20,001-25,000	49.8%	52.1%	56.0%
>25,000	8.8%	4.6%	4.5%
Total	*100.0%*	*100.0%*	*100.0%*

Table 13

Percent of fish that passed Holtwood by flow range, spring 2001.

Station Discharge (cfs)	Percentage of Time Flow Occurred	Percent of Fish Passed
0	5.6%	6.3%
500-5000	1.3%	0.0%
5001-10,000	6.5%	4.2%
10,001-15,000	7.6%	16.7%
15,001-20,000	6.3%	2.1%
20,001-25,000	65.4%	62.5%
>25,000	7.2%	8.3%
Total	*100%*	*100.0%*

Table 14

Summary of fish passing into the MRPSS reservoir, spring 2001.

Fish ID	Date Detected in MRPSR	Day of Week Entrained	First Detection at Holtwood	Time Spent Between MRPSS and Holtwood Prior to Entrainment	Number of Forays Between MRPSS and Holtwood Prior to Entrainment	Number of MRPSS Units	Holtwood Discharge (cfs)
5-68	25 May 05:06:46	Friday	24 May 08:30:23	00-20:36	1	8	0
5-99	22 May 02:28:48	Tuesday	None			8	0
6-2	25 May 14:52:55	Unknown	19 May 09:13:40	06-05:39	3	Unknown[1]	Unknown
6-68	05 Jun 05:28:57	Tuesday	22 May 08:23:32	13-21:05	6	8	0
6-71	06 Jun 02:18:03	Wednesday	25 May 06:20:48	11-19:57	1	8	8,030
6-80	25 May 20:01:10	Unknown	None			Unknown	Unknown
6-98	28 May 10:39:36	Unknown	19 May 17:01:12	08-17:38	3	Unknown	Unknown

1- fish were only located in resevoir after passage.

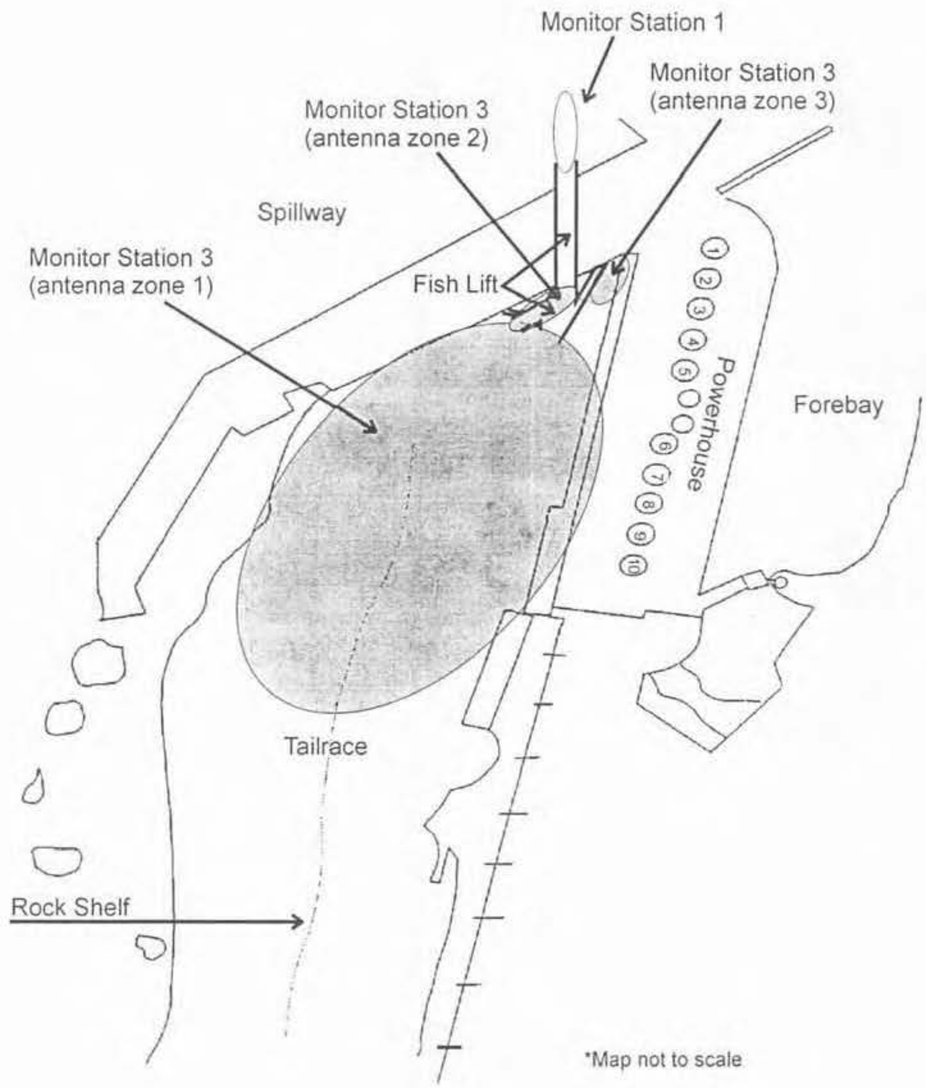


Figure 1

Radio telemetry monitoring stations at Holtwood Dam, spring 2001. [Note: Monitor Stations 2 and 4 not shown.]

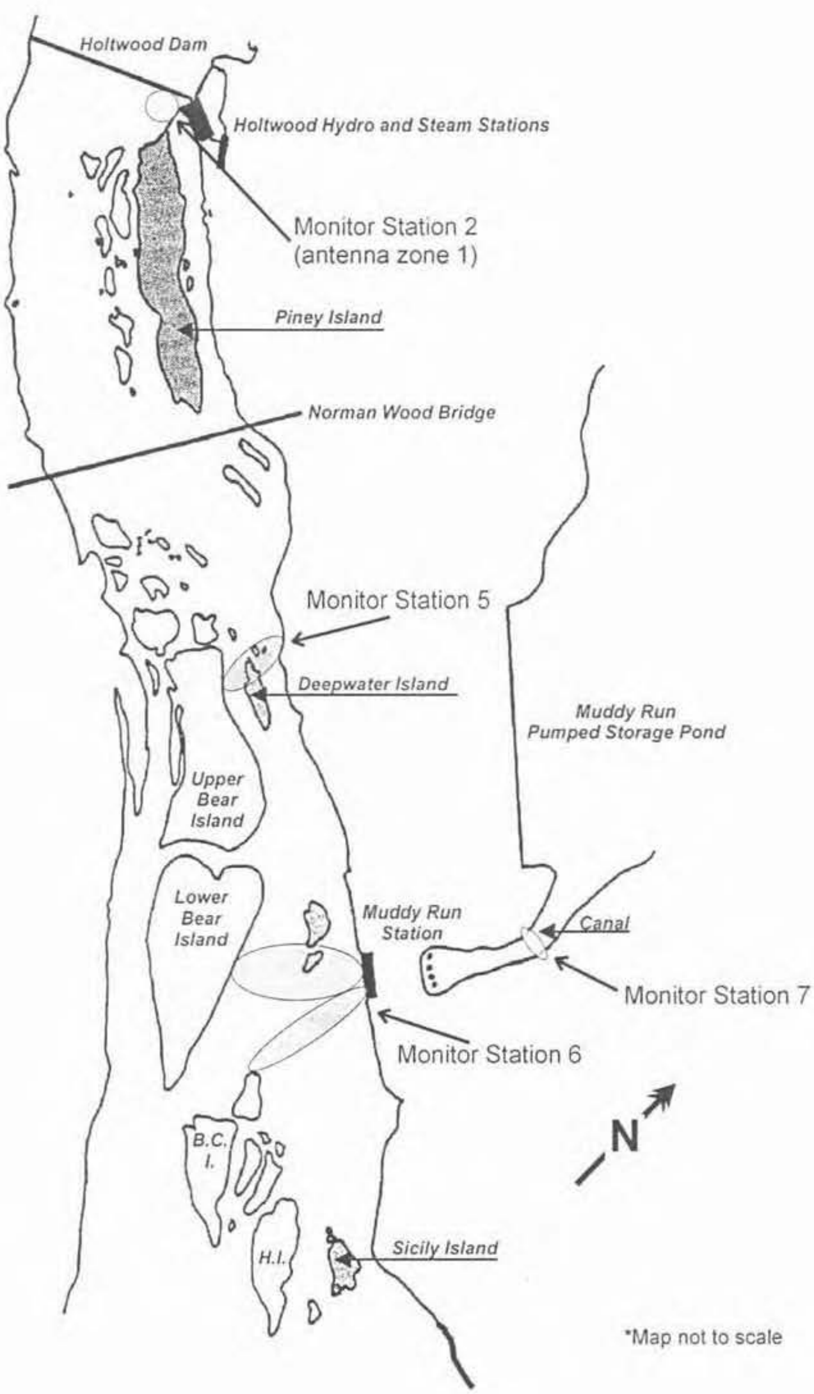


Figure 2

Radio telemetry monitoring stations at Muddy Run Pumped Storage Station and Deepwater Island, spring 2001.

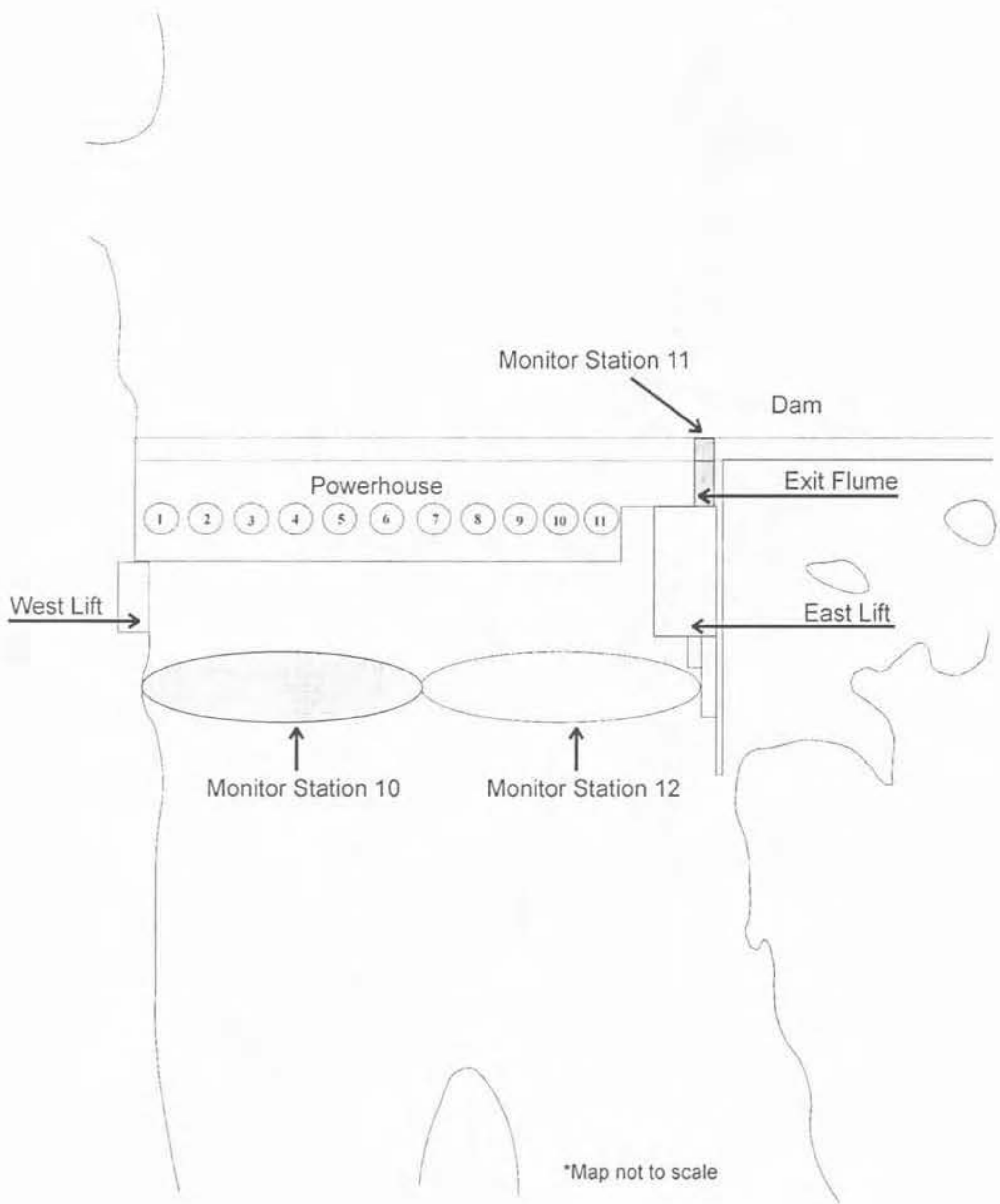


Figure 3

Radio telemetry monitoring stations at Conowingo Dam, spring 2001.

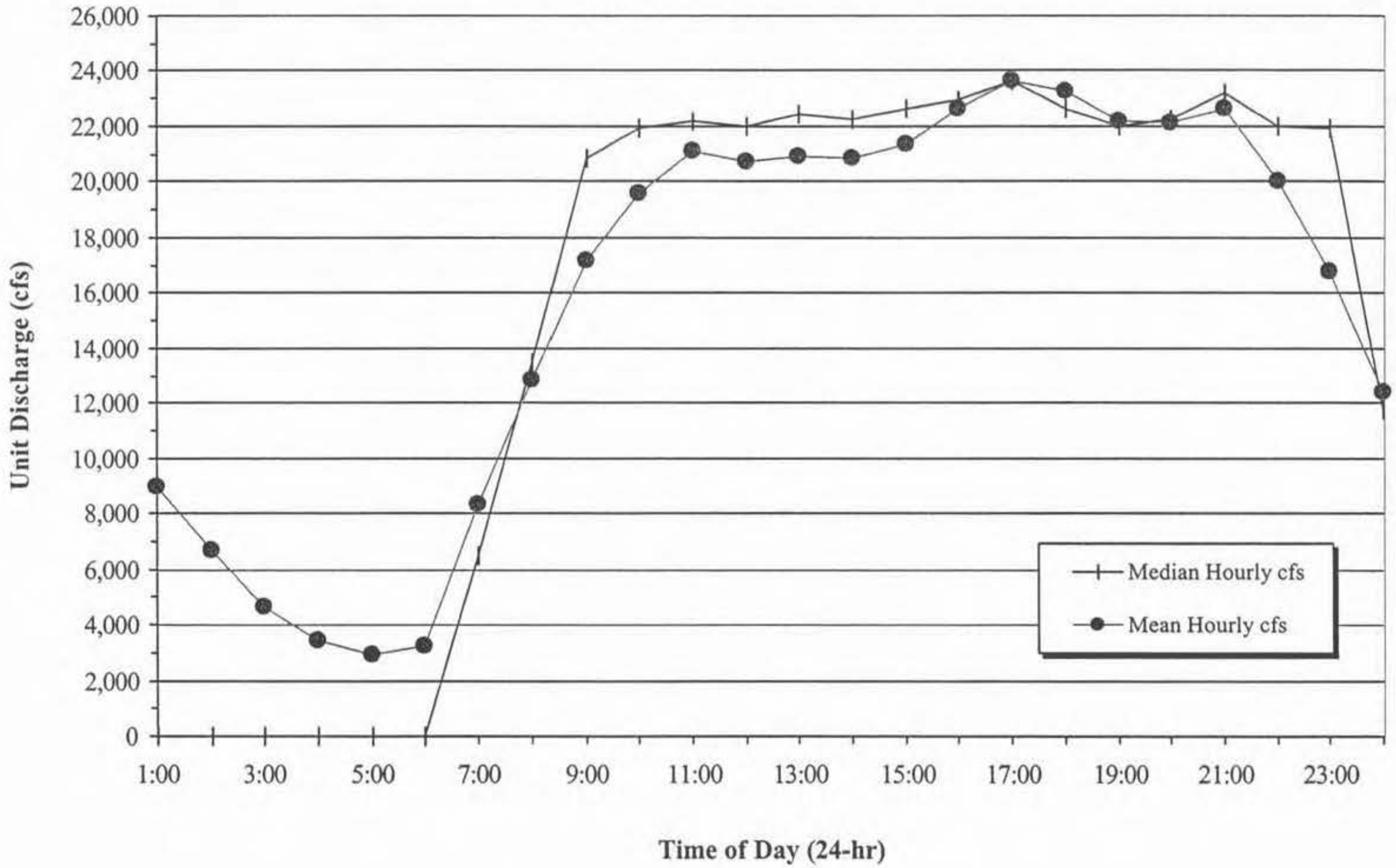


Figure 4

Mean and median hourly turbine discharge at Holtwood Dam, 1 May through 15 June 2001.

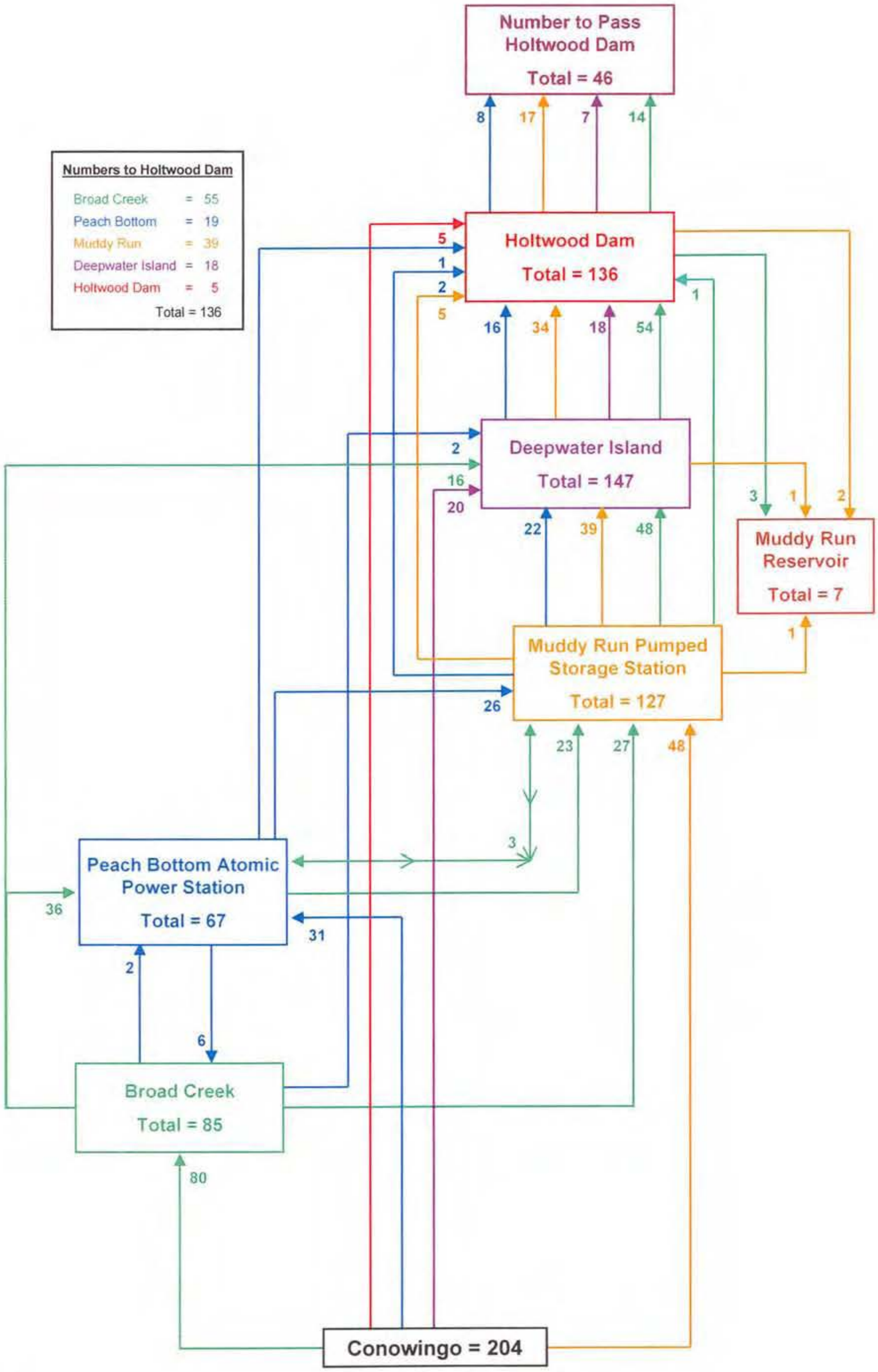
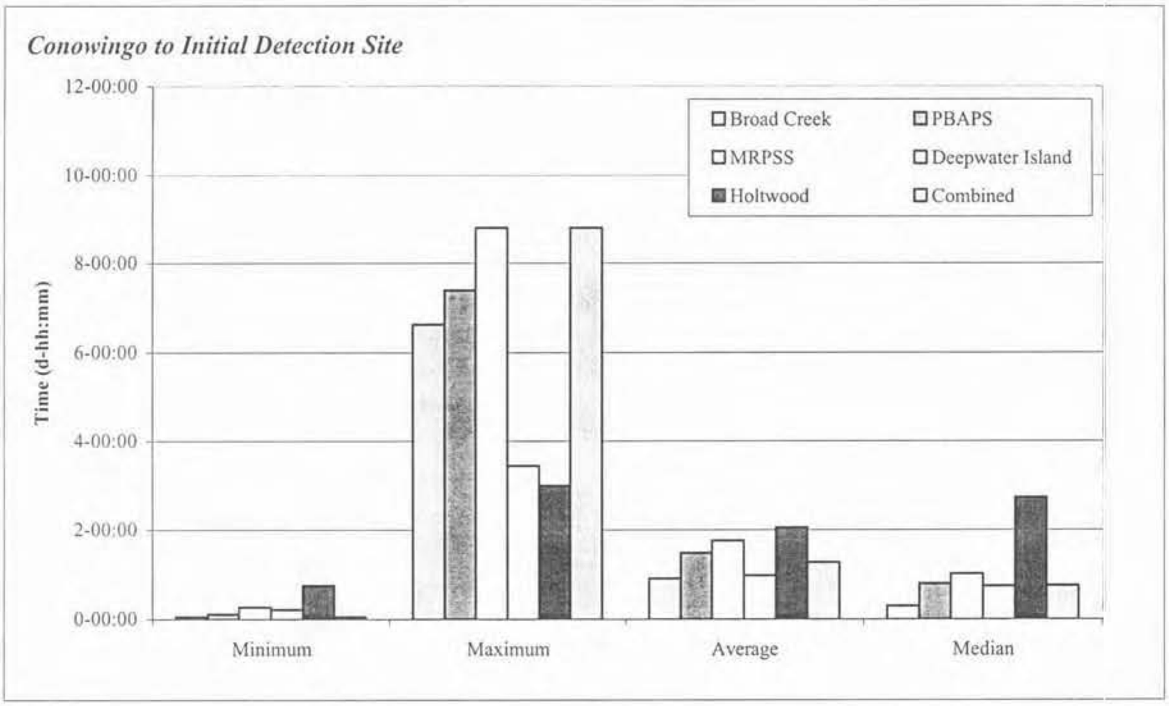


Figure 5

Fish movement throughout Conowingo Pond, spring 2001.



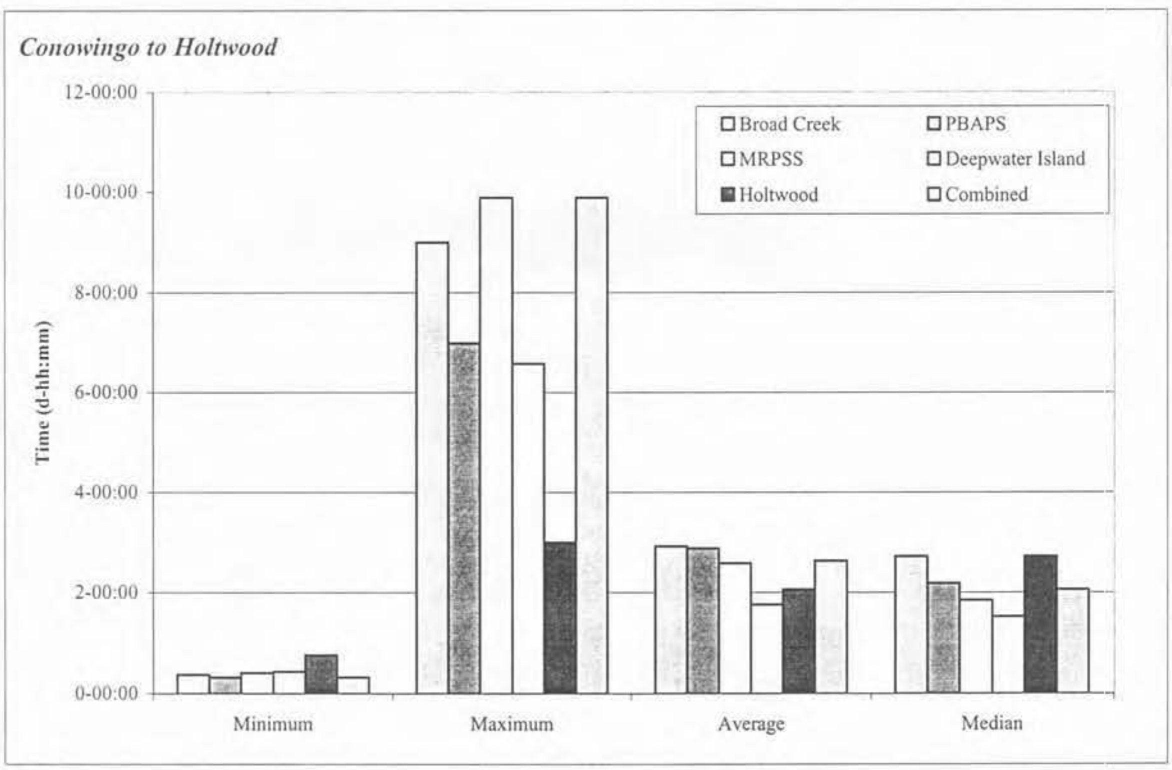


Figure 6

Travel times of shad from Conowingo to initial detection location and from Conowingo to Holtwood relative to travel route taken, spring 2001.

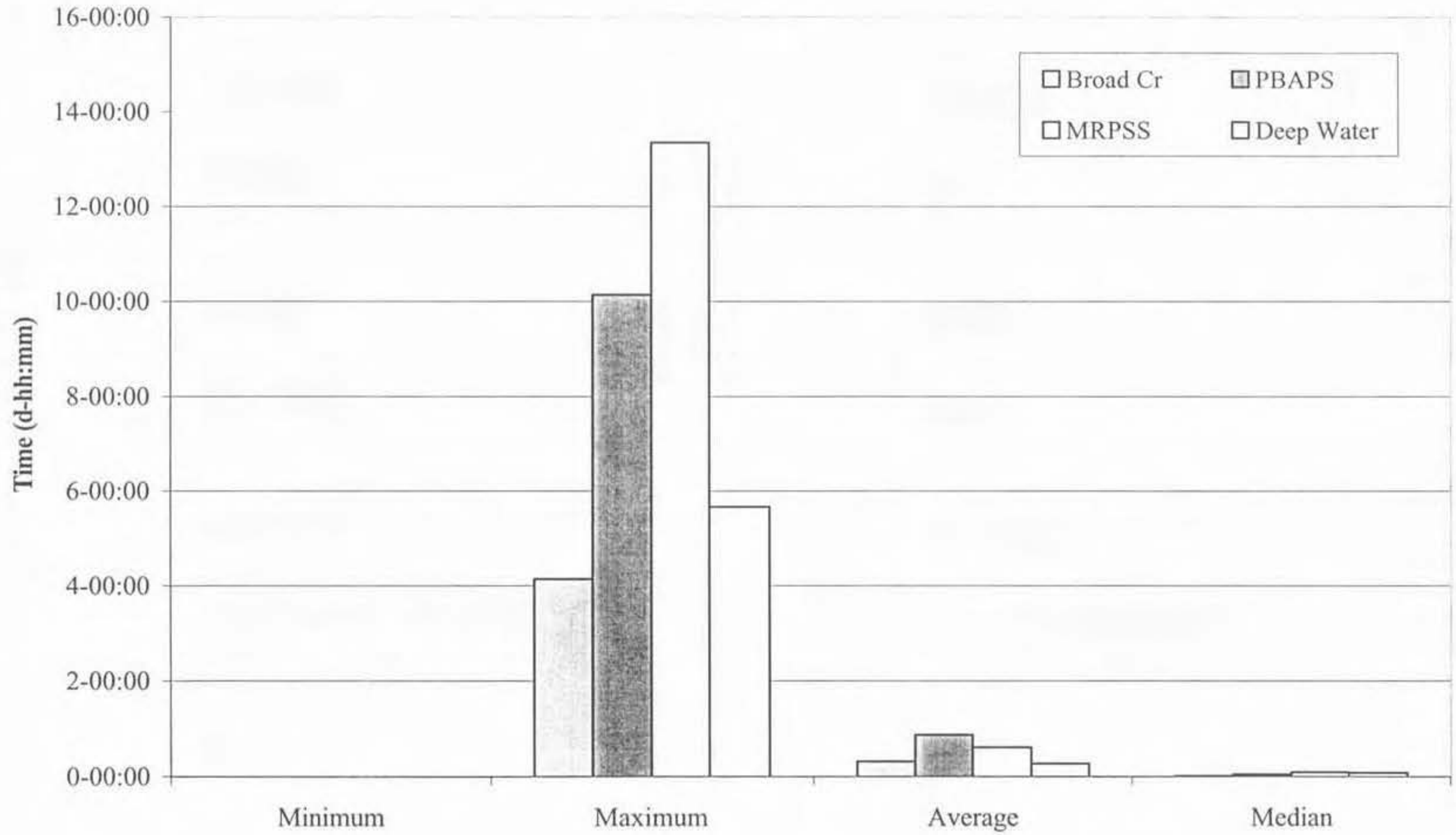


Figure 7

Detection times of shad at monitoring stations during initial migration, spring 2001.

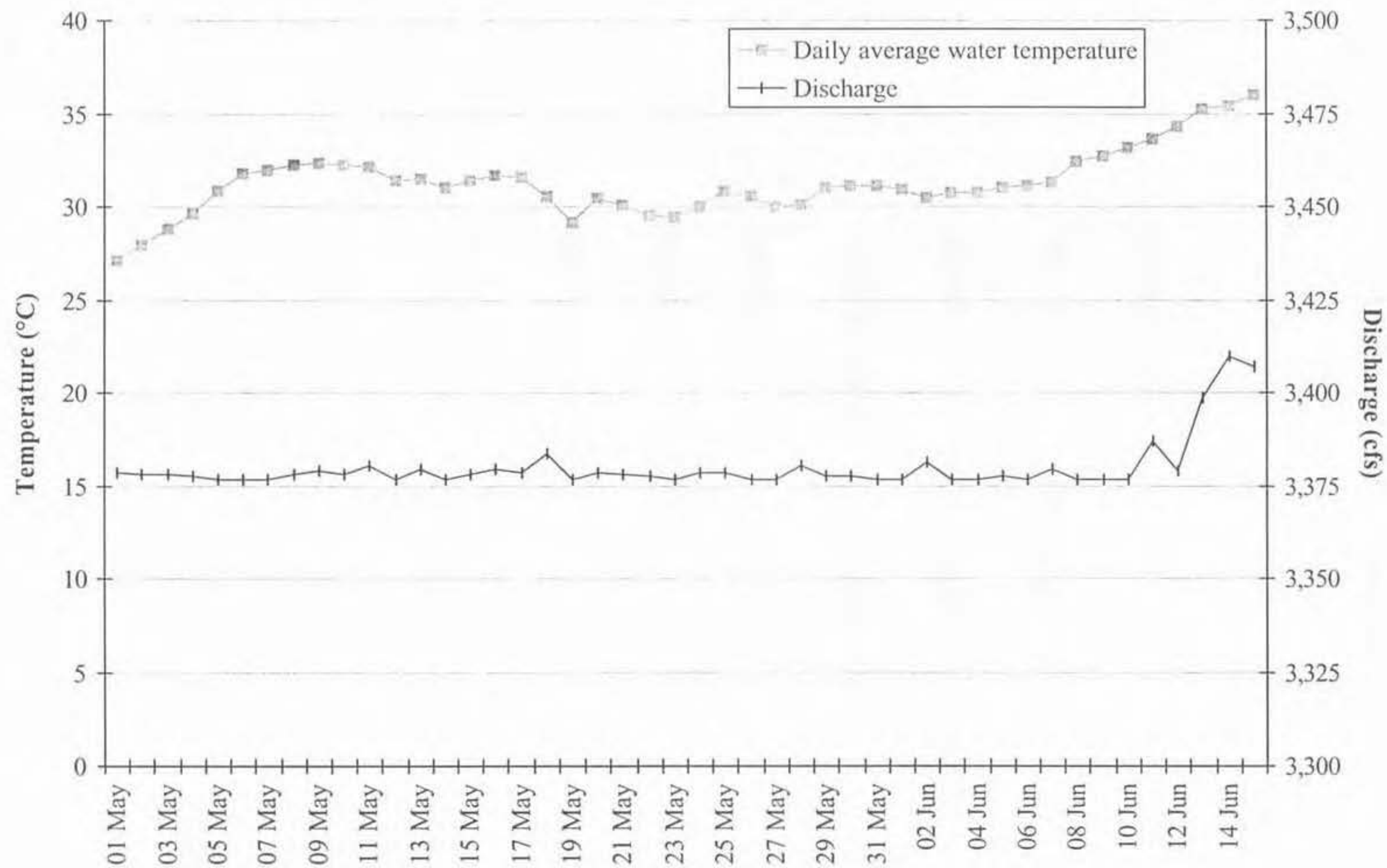


Figure 8

Daily average water temperature (°C) and discharge (cfs) at Peach Bottom Atomic Power Station, 2001.

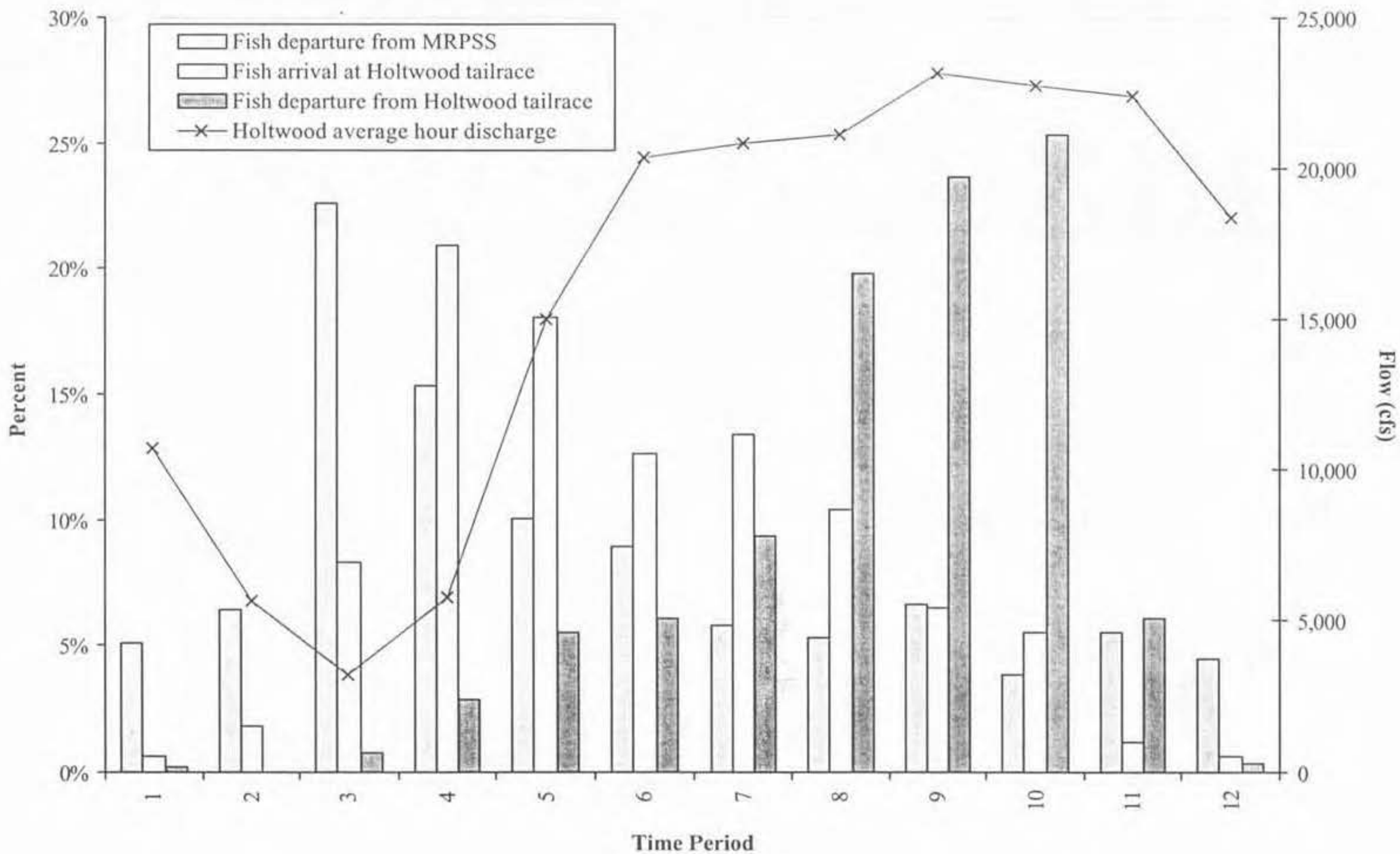


Figure 9

Diel movement of fish making forays between MRPSS and Holtwood tailrace, spring 2001.

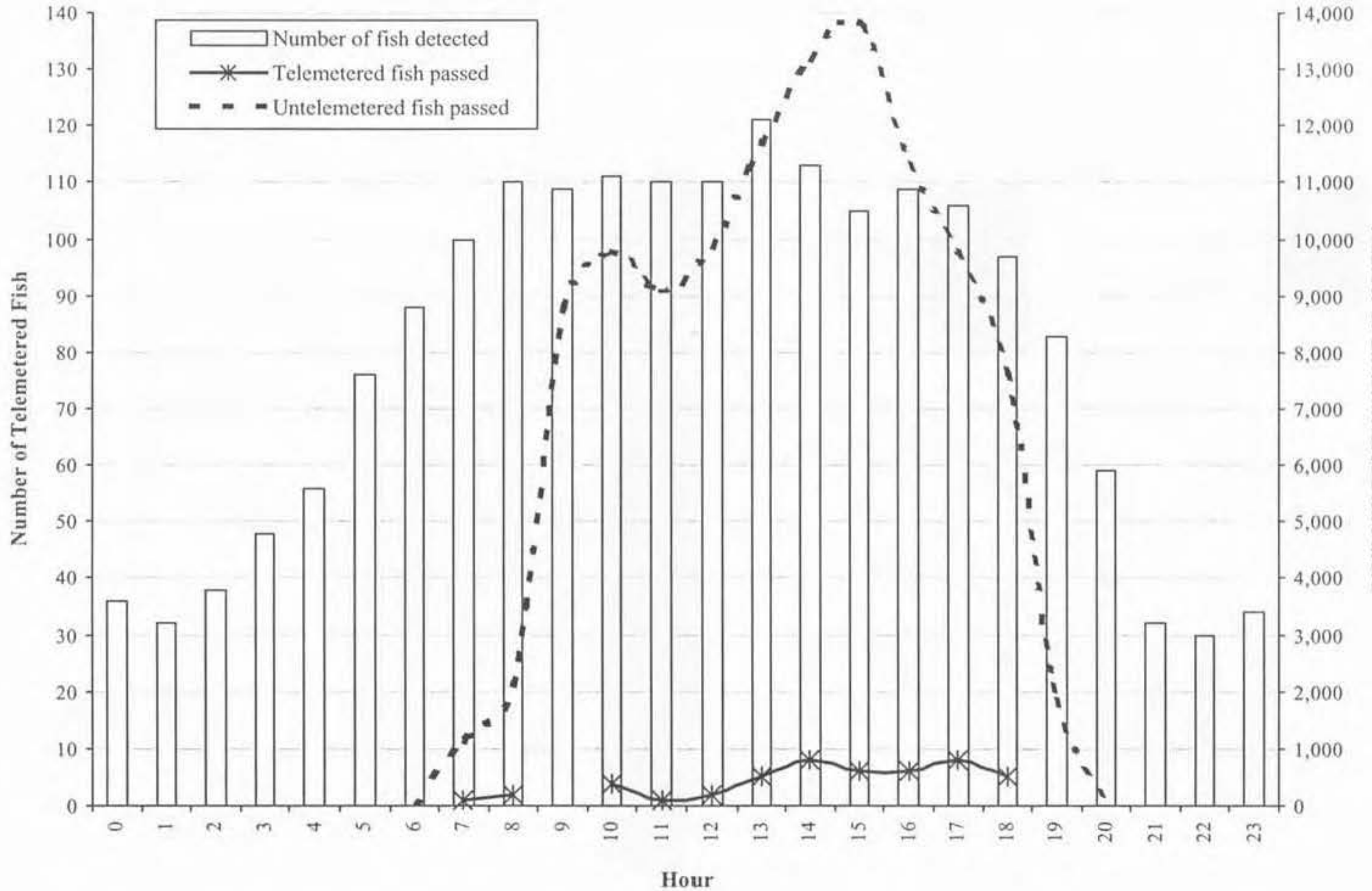


Figure 10

Hourly number of telemetered fish detected in the Holtwood tailrace (bars). Also shown is the number of telemetered fish (line with marker) and untagged fish (dashed line) passed hourly through the fish lift, spring 2001.

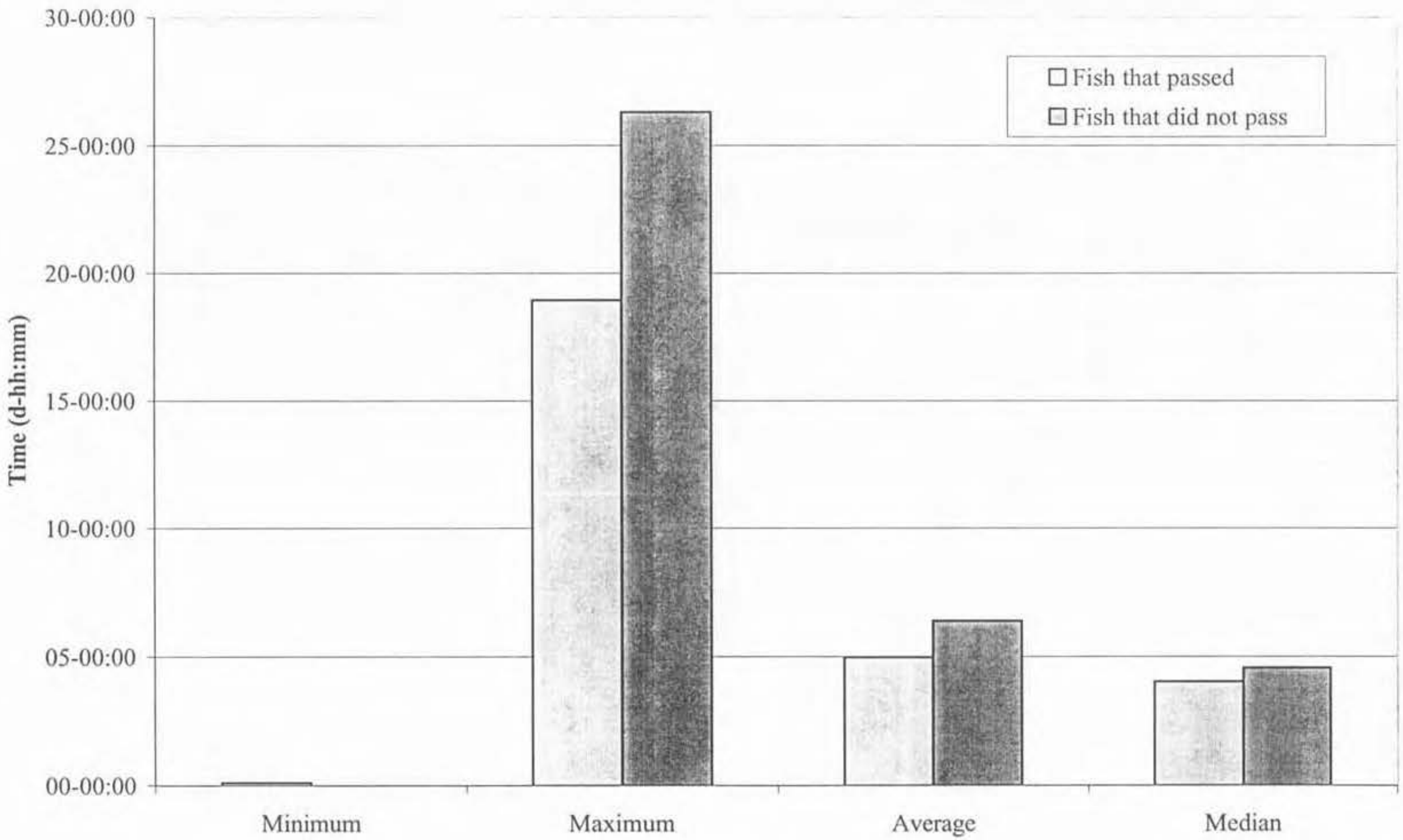


Figure 11

Residency times of shad in the upper portion of the study area for fish that passed and did not pass Holtwood Dam, spring 2001.

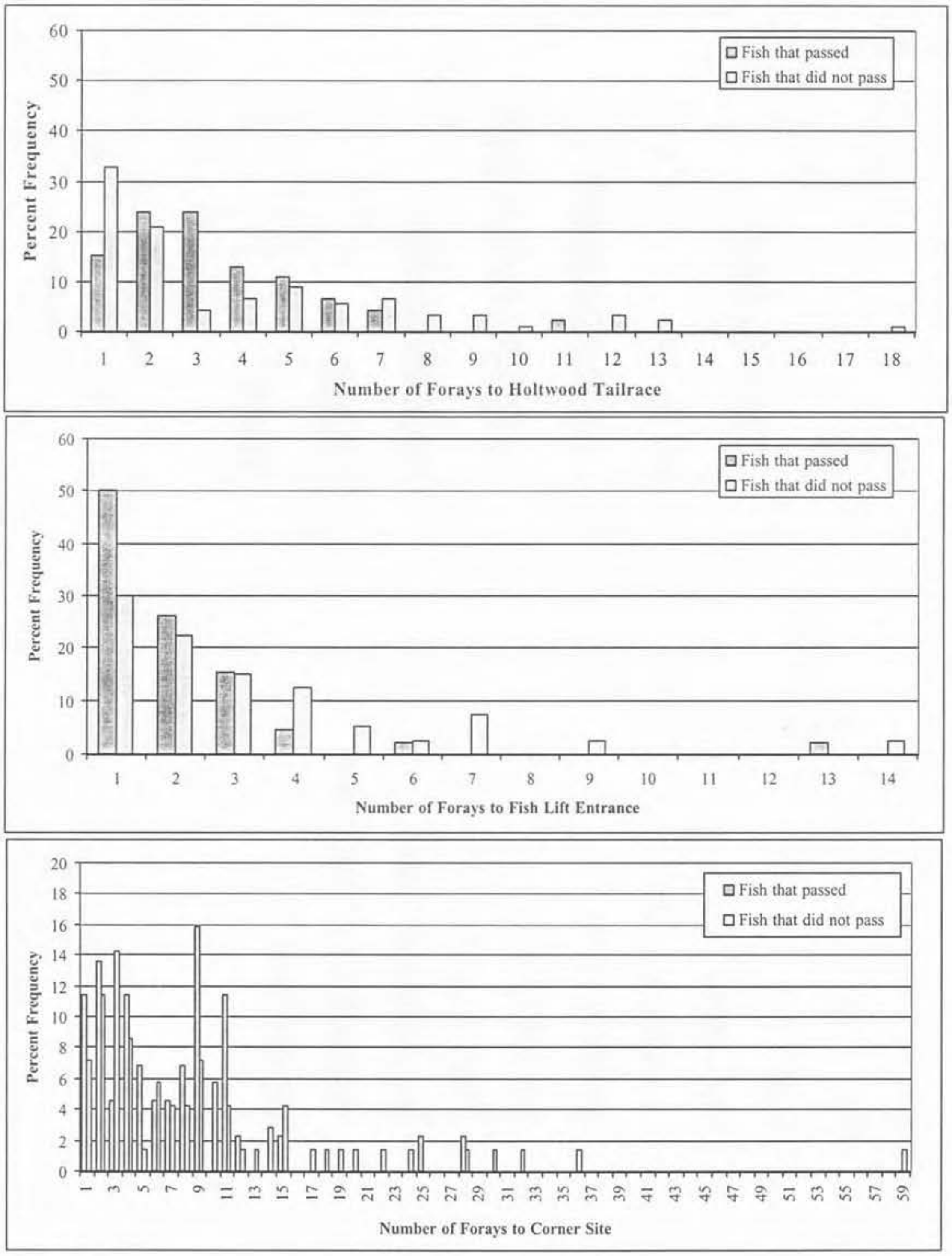
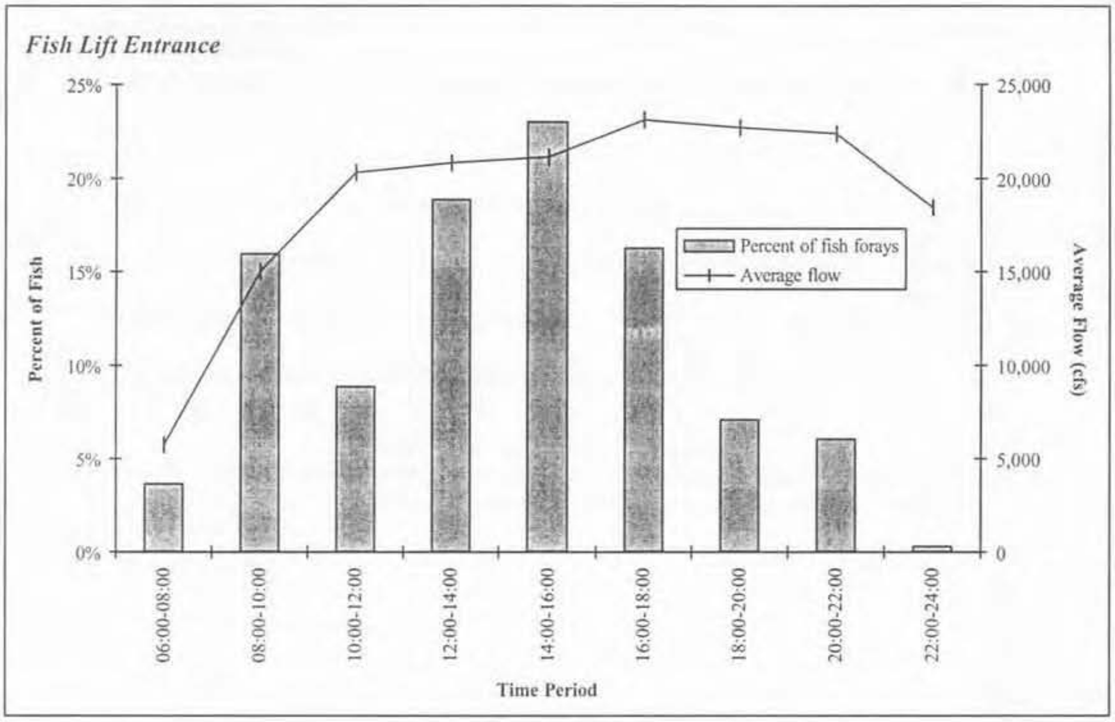


Figure 12

Percent of forays made to Holtwood's tailrace monitoring locations for fish that passed and did not pass Holtwood Dam, spring 2001.



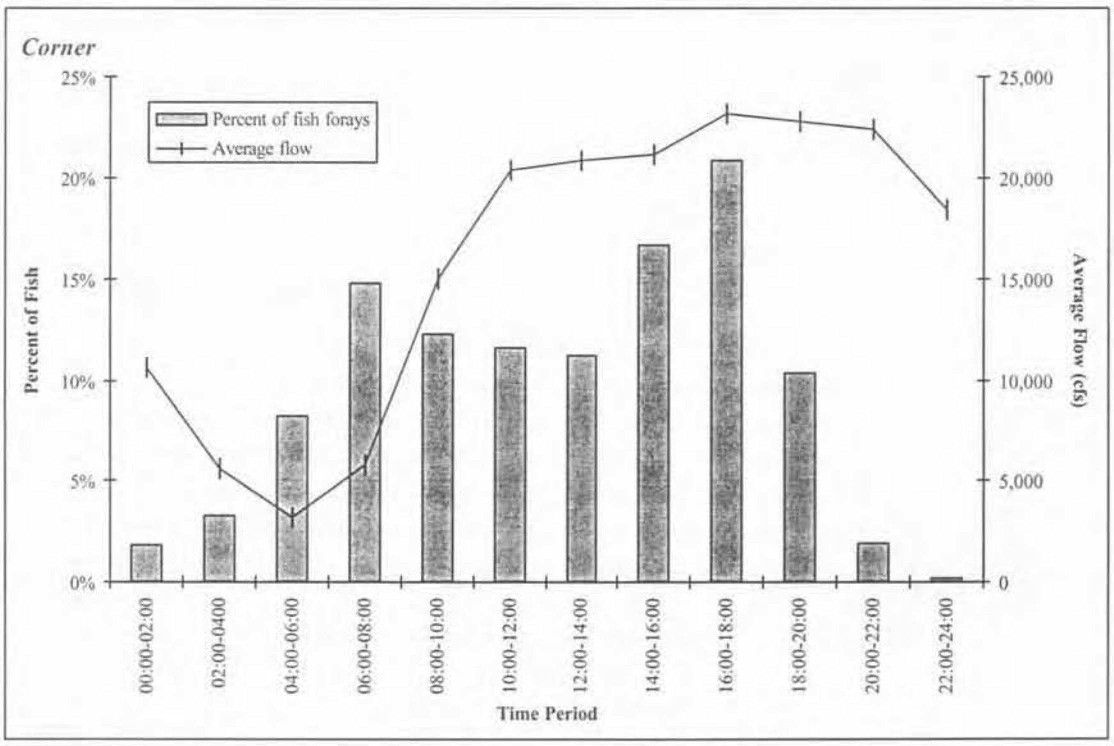


Figure 13

Percentage of fish forays, by time period, entering the fish lift entrance or tailrace corner at Holtwood, spring 2001.

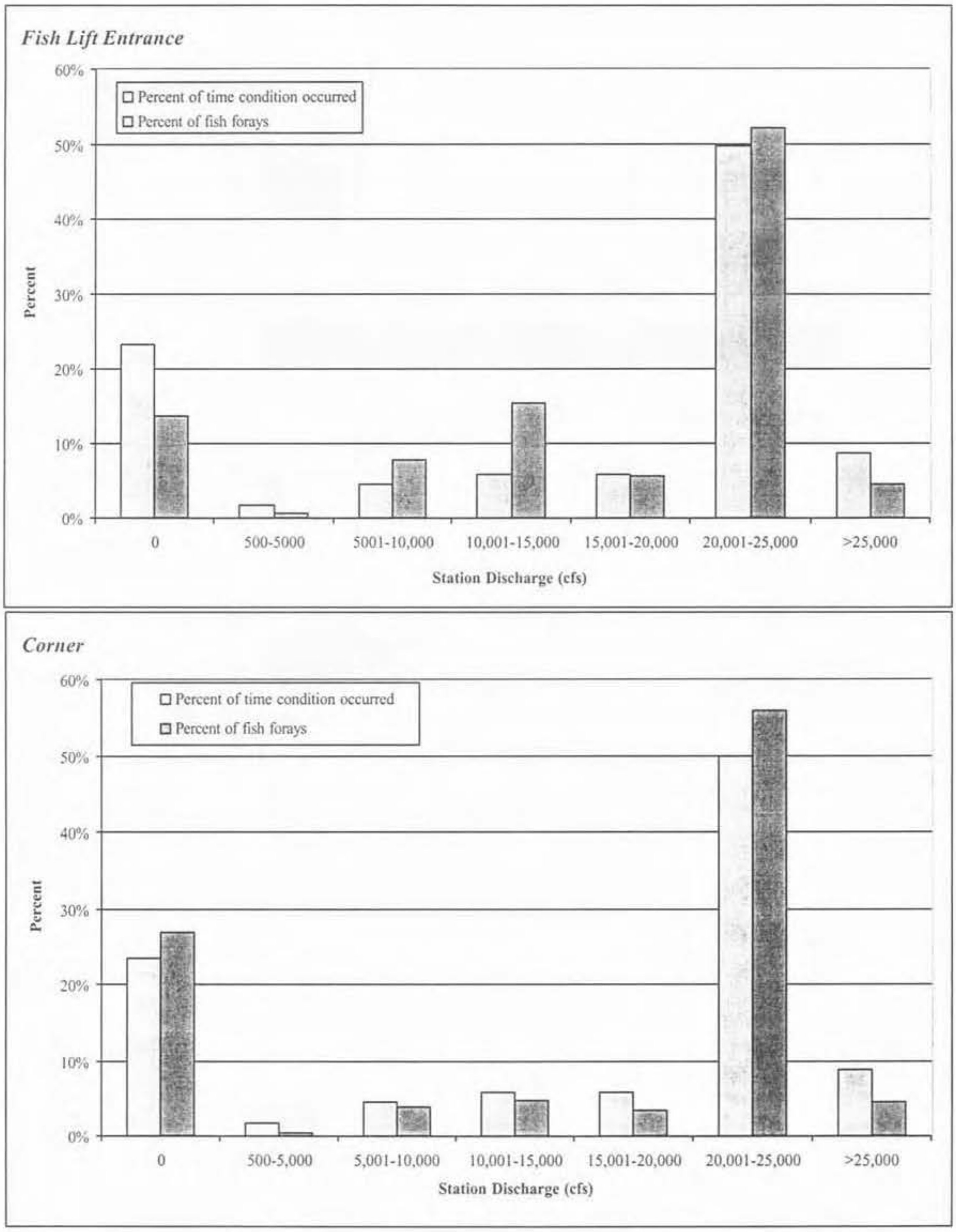


Figure 14

Percent of fish forays, by flow range, at the fish lift entrance or in the tailrace corner at Holtwood, spring 2001.

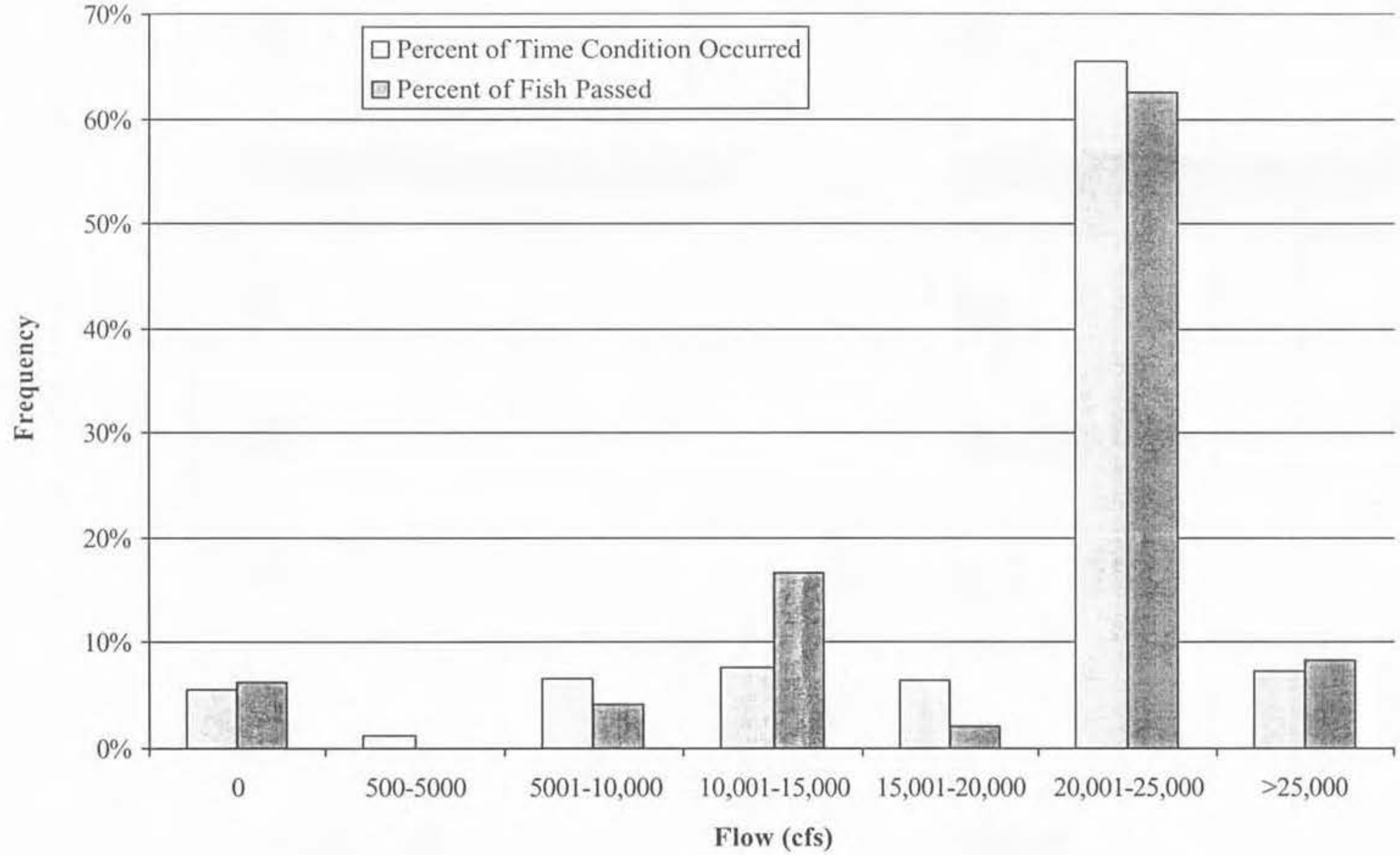


Figure 15

Fish passage at Holtwood by flow range, spring 2001.

Job V - Task 4
Effect of Hormone Selection and Water Salinity upon Tank Spawning Performance of American Shad

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Background

The U.S. Fish and Wildlife Service and partners in the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) have been involved in the restoration of American shad to the Susquehanna River for over 25 years. In 1998, the Northeast Fishery Center (NEFC) began a cooperative effort to develop and conduct tank spawning technology to establish self-sustaining populations of American shad imprinted to the West Branch of the Susquehanna River and to augment egg production for Pennsylvania Fish and Boat Commission (PFBC). Annual goals were to provide 5 to 10 million fertilized shad eggs for PFBC's Van Dyke Shad Hatchery and for the NEFC to produce one to two million oxytetracycline-marked (OTC) fry for the West Branch drainage of the Susquehanna River.

Techniques using hormone implants to induce natural tank spawning of shad have been under development since 1993 by Maryland DNR (Manning Hatchery) and for the past several years at Waldoboro Shad Hatchery (both with and without hormone implants) in Maine. Beginning in 1999, American shad restoration efforts for the Roanoke River by Edenton National Fish Hatchery and North Carolina Wildlife Resources Commission (Watha Hatchery), have employed tank spawning techniques. Results from different tank spawning efforts have differed greatly based upon site location, year and specific transport loads.

A tank spawning work shop conducted at Lamar, PA in September 1999, reviewed variables which influence survival and reproduction of American shad broodfish collected for NEFC during late April through May from the West lift of Conowingo Dam, Susquehanna River. Principle stressors affecting survival discussed were: Adaptation by an anadromous species to fresh water osmotic regime, sexual maturation, lift confinement, abundance of non-target species such as gizzard shad in lift hopper, water temperatures, sorting, holding, transport, tank spawning environment, hormone implant, and spawning. Also discussed were variable reproduction results reported with the use of different spawning hormones and delivery systems. Maryland found that synthetic analogue of Gonadotropin Releasing Hormone (GnRHa) at 75 ug for females and 25 ug for males encapsulated in ethyl vinyl acetate copolymer (EVAC) provided good results when compared to implants which relied upon similar hormone doses but were administered in cholesterol/cellulose implant carriers. A more uniform release was obtained from EVAC vs. the latter. Maine experienced acceptable tank spawning results by discontinuation of implant injections and holding the brood for extended periods to allow for natural maturation. Mixed to poor tank spawning results in a fresh water recirculation system were observed by the NEFC when utilizing Luteinizing Hormone-Releasing Hormone analogue (LHRHa) 80% cellulose implants at doses varying from 15 to 150 ug per fish. During the 2001 spawning season, EVAC in addition to cholesterol-based pellets became available under Investigational New Animal Drug (INAD) permits for trials.

In examining the effects of sedatives upon transport, Millard et al. (2001) determined that American shad captured at the Conowingo Dam West lift, transported and held in a fresh water recirculation system at NEFC presented physiological profiles consistent with severe stress. Fletcher, et al. (2001) observed that seven-day survival of American shad held at the NEFC was greater (71 %) when salinity was maintained at 2 to 4 ppt when compared to fresh water (19 %).

The relative significance of transport stress factors as they relate to capture, spawning, and tank environment stressors has not been determined.

Objectives

1. *Hormone evaluations*

- Compare effect of three hormone applications upon shad reproduction in a low salinity recirculating tank spawning system as measured by number of eggs produced per day per available female

2. *Water salinity evaluations*

- Determine shad survival held in low salinity (3 ppt) vs fresh water recirculation tanks.
- Determine impact of water salinity upon reproduction as measured by number of viable eggs produced per available female from low salinity vs. freshwater recirculation tank.
- Determine impact of water salinity upon egg size.
- Examine blood plasma of shad taken upon arrival at NEFC to determine levels of stress indicators (lactate, cortisol, glucose, sodium, potassium and chloride) following West lift capture, overnight holding and transport.
- Examine blood plasma of shad collected 96 hours post-tank spawning to measure stress indicators (lactate, cortisol, glucose, sodium, potassium and chloride).

3. *Tank spawning of American shad at Conowingo Dam*

- Determine if shad egg production per broodstock is improved by eliminating transport to NEFC and utilizing ambient river water in a spawning system adjacent to the West Lift.
- Examine blood plasma of shad collected at capture from the West Lift for baseline lactate, cortisol, glucose, and electrolyte levels.

- Examine blood plasma of shad 96 hours after tank spawning to measure stress indicators (lactate, cortisol, glucose, sodium, potassium and chloride).

Methods

1. Hormone evaluations

Trials were conducted to assess the effectiveness of three hormone implants for inducing tank spawning of American shad : (1) cholesterol-based implant containing 150 ug of LHRHa - Ovaplant ® L 150 Syndel Laboratories Ltd.; (2) cholesterol-based implant containing 150 ug of Salmon Gonadotropin Releasing Hormone analogue (SGnRHa) - Ovaplant ® S 150 Syndel Laboratories Ltd.; and, (3) EVAC-based implant containing 75 ug (males), or 150 ug (females) of LHRHa - Reproboost ® VeriPharm LLC.

Normandeau Associates, Inc. collected adult American shad at the West lift of the Conowingo Dam and held the brood stock overnight. Subsequently, the 4-5 hour transport employed a 3,800 L (2.5 m diameter) tank with recirculated flow, ambient temperature water, and salt added to 5 ppt salinity. Brood stock were received at NEFC on five occasions from May 3 to May 29, 2001 for the hormone trials. Between 75 to 100 shad per shipment were available for the test.

Upon arrival, shad received implants into the dorsal musculature with one of three hormones and were placed into separate tanks at a ratio of 3 males : 2 females. For a particular shipping date either 5,500 L (3 m diameter) or 11,000 L (3.7 m diameter) circular tanks in a recirculating system were used. The system employed 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 ppm dissolved oxygen.

Daily mortality records were maintained. Spawned eggs were collected each morning from saran filter socks, enumerated by volume (L) and Von Bauer trough count, and then transported for incubation to either Van Dyke Shad Hatchery or NEFC Hatchery Building. Spawning data was evaluated by anova (alpha 0.05).

2. *Water salinity evaluations*

Brood stock collection and transport was similar to that described above. For the salinity trial, however, all shad were implanted just prior to transport to NEFC with VeriPharm LHRHa pellets at 75 ug (males), or 150 ug (females). Upon arrival blood plasma was collected from eight shad of each sex to determine levels of cortisol, lactate, glucose, sodium, potassium and chloride. Shad were anesthetized with MS-222 prior to collection of blood. All blood chemistry analyses were provided by Dr. Steve McCormick at the Conte Anadromous Fish Research Center (USGS). Three shipments (May 5, 19 and 29) of 100 shad were stocked into two 22,000 L (6 m diameter) tanks at a 3:2 male to female ratio, 50 shad per tank. One tank was maintained as described above with 3 ppt salinity while the second was operated as a fresh water recirculation system with similar exchange rate, dissolved oxygen and temperature profiles. Data collection and egg processing was conducted as described above. For the second and third shipments blood plasma was collected 96 hours post-spawn from eight males and females from each treatment. Spawning data was evaluated by anova at an alpha of 0.1, while blood chemistry measurements were examined by Dunnett's t test at an alpha of 0.05.

3. *Tank spawning of American shad at Conowingo Dam*

Hormone-induced spawning trials with American shad at Conowingo Dam during the spring of 2001 is reported in Job II - Part 3 (Normandeau Associates) of this annual report. It provides detailed information concerning river side tank spawning methodology. VeriPharm LHRHa implants were employed on 10 spawning trials with 36 males and 24 females (3:2) per event. On three occasions (early, mid and late season) blood plasma was collected prior to hormone implantation and again at post spawning from ten female shad in each sample. Plasma was examined as indicated in the trial above.

Results and Conclusions

1. Hormone evaluations

A significant difference was not determined for hormone treatment in terms of eggs produced per available female per spawning day - a day when > 25 ml eggs were collected per tank. Also a temporal shipment difference was not demonstrated for production performance over the five week period.

Overall 86% of eggs were spawned on day three or four after hormone implant (Fig. 1). Average egg production per female (days three and four) was 27, 269 (VeriPharm), 25,086 (Syndel - SGnRHa), and 23,134 (Syndel - LHRHa). An examination of egg take occurring on days three and four by hormone treatment found that a lower percentage were spawned in this time frame by shad implanted with VeriPharm (79%) **A**, than with Syndel - LHRHa **B** (99%). American shad implanted with Syndel- SGnRHa **A, B** (91%) did not differ from the other treatments (Fig. 2). The prolonged egg release of VeriPharm implanted fish may correlate with the reported uniformity of hormone release from the EVAC implant over a 20-day period. Communication with the manufacturer of the cellulose/cholesterol implants indicated that this carrier type produces an initial larger pulse followed by a lower but continued hormone release. A better egg quality was indicated for days three and four as a group since 86% of the total spawn and 92% of viable eggs from the 3 ppt system occurred on these days

2. *Water salinity evaluations*

Freshwater brood stock survival to five days post shipment was lower (84 %) than that observed for the 3 ppt tank (98 %). Significant differences were found for egg production per female in the freshwater system (10,429) compared to the low salinity environment (29,933). Likewise the production level of viable eggs were found to be different with averages of 6% for freshwater spawned eggs compared to 28% for eggs from the 3 ppt trial tank (Fig 3). A significant temporal effect across shipment dates was not observed. Egg size in response to the osmotic gradient was determined to be significantly different between the two salinity levels - freshwater 2.9 mm vs. 2.5 mm in low salinity (Von Bauer counts - 107 and 120 respectively).

Blood chemistry analyses (Figs. 4, 5, 6) were based upon results obtained from the second and third shipments, since post spawn data was not available for the May 5 group. When compared to blood plasma levels sampled at arrival at the NEFC, American shad maintained in the freshwater system produced significant post-spawn elevations for glucose (9.4 to 15.2 mM) and cortisol (671 to 2079 ng/ml); and significant declines for sodium (173 to 145 mM) and chloride (96 to 72 mM). No differences were determined between arrival and post-spawn levels of lactate and potassium for the freshwater samples. There were no significant changes in blood plasma parameters for post spawn low salinity American shad when compared to levels at arrival. Those changes evidenced for shad maintained in the freshwater recirculation system are consistent with observations by Millard et al. (2001) and are indicative that shad in this system were subject to stressors that they were not able to compensate for. The elevated cortisol levels may have contributed to the poor reproductive performance of the freshwater group in that cortisol competes for gonadotrophic hormones receptor sites. Failure to maintain osmotic homeostasis may have induced elevated mortality levels in the freshwater replicates.

Additionally behavioral differences were observed between the groups. Those fish maintained at 3 ppt were active, alert and exhibited strong swimming and schooling behavior. In contrast, their counterparts in the freshwater tank were listless, schooled to a much lesser degree, and offered little reaction to external stimuli.

3. *Tank spawning of American shad at Conowingo Dam*

At Conowingo, shad egg production totaled about 24,000 per female with approximately 34% viability. These values indicate better egg survival than that obtained for shad spawned in trials using 3 ppt at NEFC - 24,000 and 22 % respectively. Blood plasma profile changes (Figs. 7, 8, 9) between capture and post-spawn at Conowingo revealed a significant increase of potassium (2 to 2.9 mM) and significant decreases in sodium (166 to 157 mM) and chloride (115 to 90 mM). Levels of glucose, lactate and cortisol, when pooled across the three sample dates, did not yield significant differences pre- and post-spawn.

4. *Other observations*

Hand stripping of eggs and dry method fertilization was attempted with approximately 200 shad four days post-arrival at NEFC. No viable eggs were produced. Similar results were noted at Conowingo Dam. Also, approximately 75 American shad were used in two trials employing an experimental VeriPharm Inc., intermuscular injection and one trial using an interperitoneal injection of Ovaprim® Syndel Laboratories Ltd. The presence of many small immature eggs in spawns from these groups indicated that injection rates may have exceeded required hormone level.

Summary

Trials were conducted in a 3 ppt salinity recirculation system to assess the effectiveness of three hormone implants for inducing tank spawning of American shad. The implants were: 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. No differences in egg production per female per spawning day between hormone treatments were detected. A difference in spawning peaks for the two LHRHa delivery types was found. The EVAC implant produced a lower peak spawning pulse on days three and four than did the cholesterol/cellulose pellet. As a group, better egg quality was indicated for days three and four with 86% of the total spawn and 92% of viable eggs from the 3 ppt system having occurred on those days.

Brood stock survival, egg production per female, and egg viability rates were greater for tank-spawn operations using 3 ppt salinity relative to a similar freshwater system. Adults held in fresh water exhibited significant post-spawn increases in cortisol and glucose and decreases in sodium and chloride when compared to pre-spawn levels.

Approximately 8.5 million eggs were collected from 965 American shad brood stock of which 1.6 million were viable. Egg viability across all trials was 19%. Egg incubation was conducted at both Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Shad Hatchery - 5 million eggs; and at the U.S. Fish and Wildlife Service Northeast Fishery Center (NEFC) - 3.5 million. The NEFC stocked 307,000 fry into Bald Eagle Creek, a tributary to the West Branch Susquehanna River, with OTC marks at days 3, 6, 9, and 15.

Literature Cited

Millard, M., J. Fletcher and J. Mohler. 2001. Evaluating sedation as a means to suppress the stress response associated with handling and transport of American shad. Job V, Task 4 In Restoration of American Shad to the Susquehanna River. 2000 Annual Progress Report to Susquehanna River Anadromous Fish Restoration Committee. U.S. Fish and Wildlife Service, Harrisburg, PA.

Fletcher, J., M. Millard, J. Mohler and K. King. 2001. Tank spawning techniques: Relative efficacy of two hormones for inducing spawning in American shad. Job V, Task 3 In Restoration of American Shad to the Susquehanna River. 2000 Annual Progress Report to Susquehanna River Anadromous Fish Restoration Committee. U.S. Fish and Wildlife Service, Harrisburg, PA.

Fig. 1 Comparison of Hormone Implants

Day 3 and 4 Egg Production per Female (86 %)

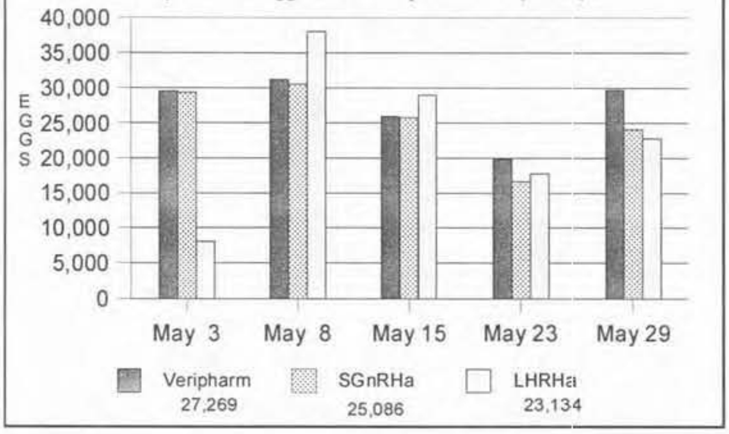
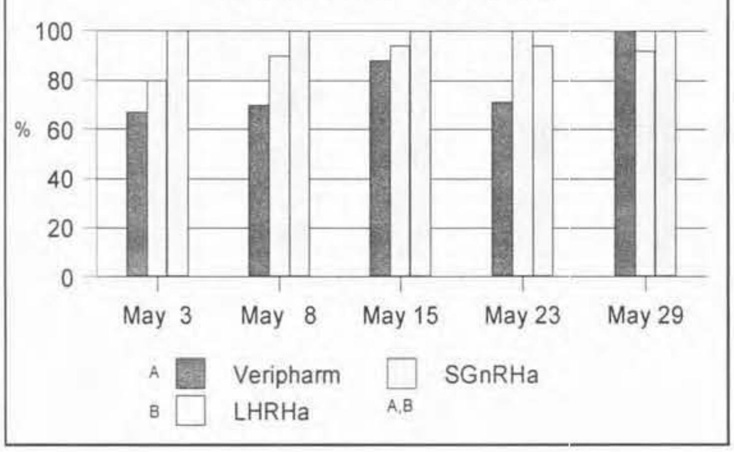


Fig. 2 Percent Egg Take on Days 3 and 4

Effect of Hormone Treatment



Fi g. 3 Effect of Water Salinity - Fresh vs. 3 ppt

Egg Production and Viability per Female

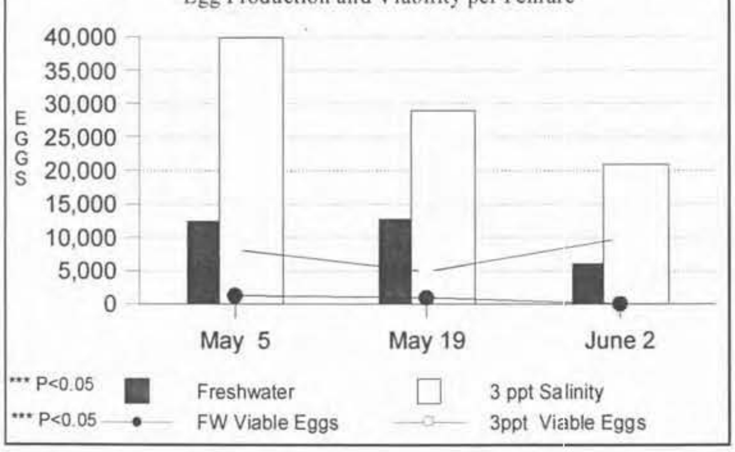


Fig. 4 Effect of Water Salinity - Fresh vs. 3 ppt

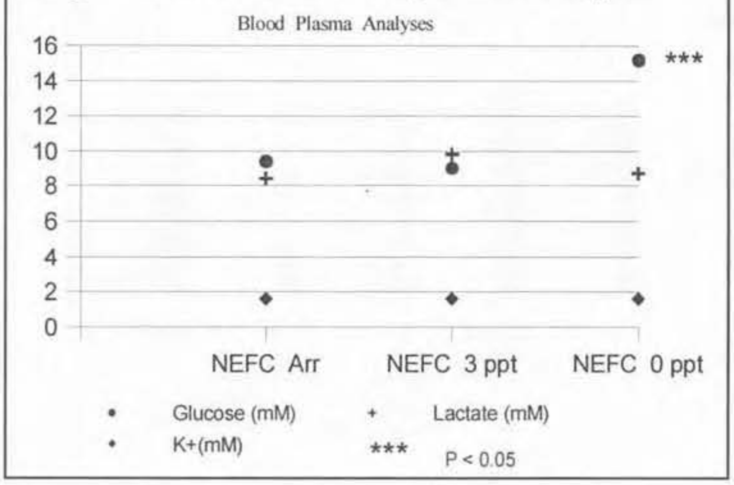


Fig. 5 Effect of Water Salinity - Fresh vs. 3 ppt

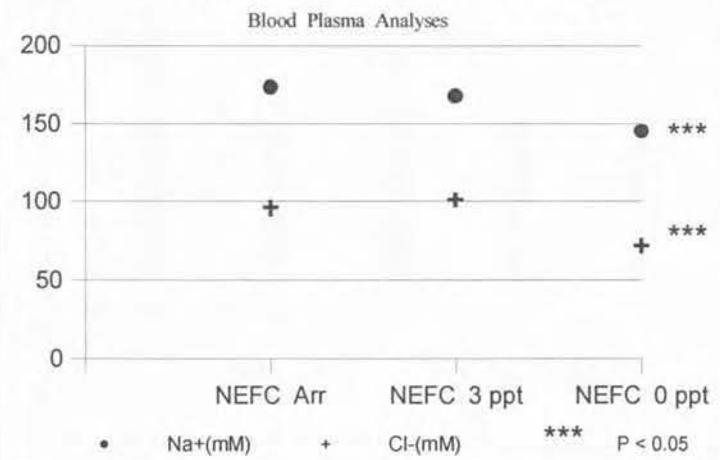


Fig. 6 Effect of Water Salinity - Fresh vs. 3 ppt

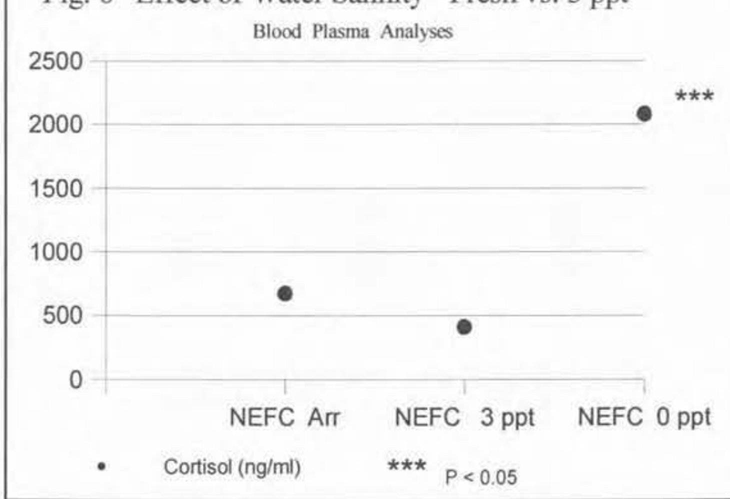


Fig. 7 Conowingo Dam - Pre and Post Spawn

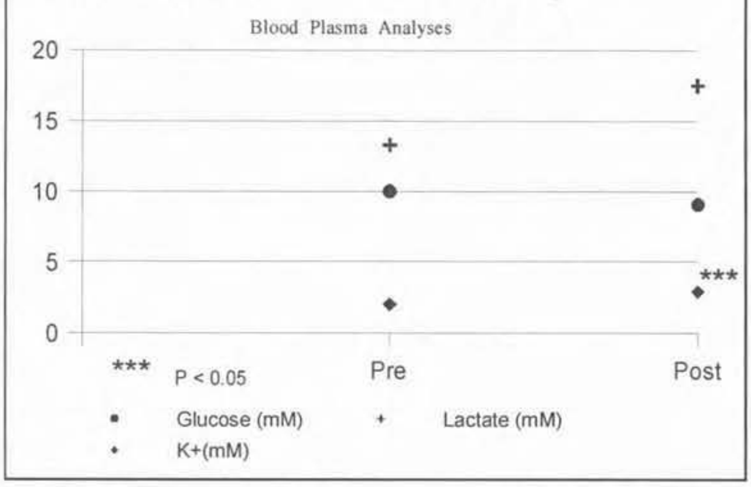


Fig. 8 Conowingo Dam - Pre and Post Spawn

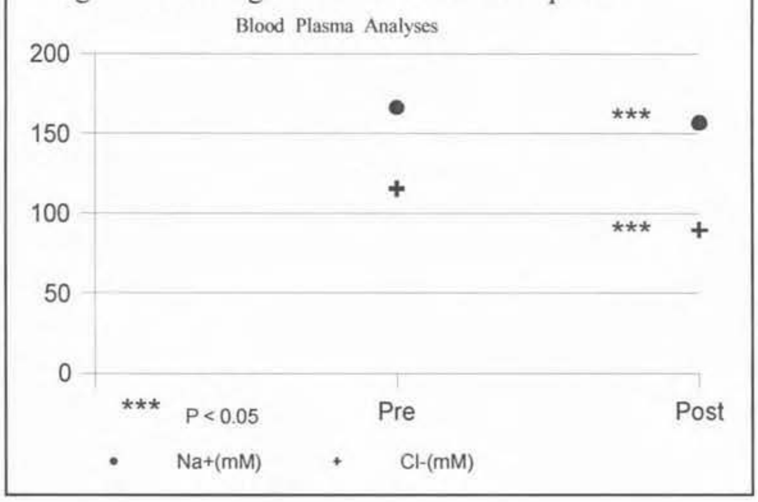
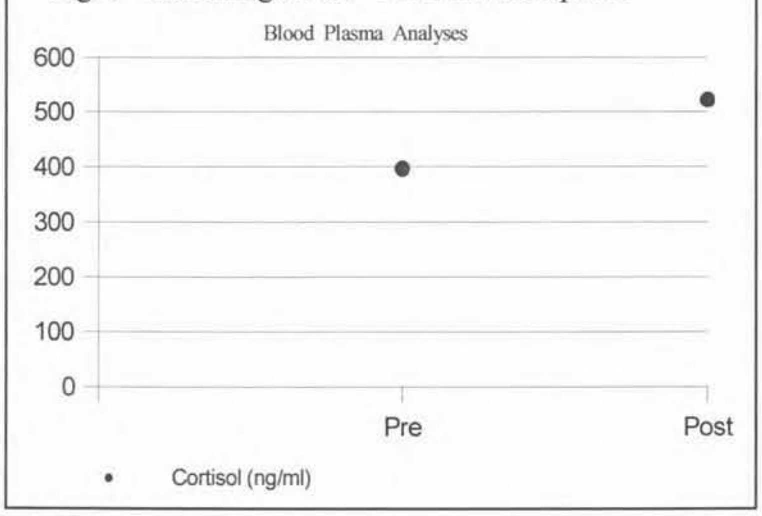


Fig. 9 Conowingo Dam - Pre and Post Spawn



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

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Resources 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 index 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 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 2001 differed slightly to those of 2000 as only one pound net, Rocky Point, was fished (Figure 1). Hook and line sampling in the Conowingo tailrace, however, remained unchanged from 2000. Tagging procedures in 2001 were also unchanged from 2000 in that both pound net and hook and line captured fish were marked with different colored tags in order to differentiate between gear types and tagging locations. All other adult data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Results

Pound net tagging at the Rocky Point pound net began on 24 March and continued until 5 May, while hook and line effort commenced on 26 March and ended 23 May. Of the 2,992 adult American shad captured, 1,297(43%) were tagged and 363 (28%) subsequently recaptured (Table 1). Recapture data for the 2001 season is summarized as follows:

364 fish recaptured by the Conowingo East Fish Lift
52 fish recaptured by the Conowing West Fish Lift
2 fish recaptured by pound net
6 fish recaptured by anglers from Conowingo tailrace
4 fish recaptured by anglers above Conowingo Dam
2 pre-spawned fish recaptured outside the system
19 2000 marked fish recaptured

Only those fish initially captured by pound net, hook and line, and the east fish lift and subsequently recaptured by these same gears are utilized to calculate the two population indicies. Since color was not noted in the west lift catch and numbers may have duplicated previous year's tags east lift data was not utilized for 2001. The recapture value also does not reflect the 10 fish recaptured by sport anglers and the two fish taken from the Delaware River.

The 2001 adult American shad Petersen population index for the upper Chesapeake Bay was 693,033 (Table 2, Figure 2), and has been increasing exponentially since 1980 (r^2=0.99, P=<0.01). The Conowingo tailrace population index for 2001 was 560,912 (Table 3, Figure 3), and has also been increasing exponentially since 1984

(r^2=0.90, P=<0.001). A 3% adjustment for tag loss was included in both calculations as was an immigration factor for the two pre-spawned fish recaptured outside the upper Bay (upper Bay index only).

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 population indices.

Effort, catch, and catch-per-unit-effort (CPUE) by gear type in the upper Bay during 2001 and previous years (expressed as arithmetic means) is presented in Table 4. Relative abundance of American shad can also be estimated and associated trends noted by examining the annual CPUE's of these three collecting gears. Measures of relative abundance from pound nets, hook and line, and the Conowingo fish lifts were calculated as the geometric means (based on log e transformations) of fish caught per pound net day, 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 these CPUE estimates indicates that the catch of adult American shad has been linearly increasing in all three gear types over time: pound net (1980-2001) r^2 = 0.37, P = <0.001; hook and line (1984-2001) r^2 = 0.70, P = <0.001; fish lifts (1980-2001) r^2 = 0.65, P = <0.001 (Figure 4). Comparisons of these CPUE estimates to both the upper Bay and tailrace Petersen indices for these respective years indicate that:

* pound net, hook and line, and fish lift CPUE's were correlated with log e transformed upper Bay indices (r^2=0.54 P=<0.13, r^2=0.82 P=<0.0001, r^2=0.78 P=<0.0001, respectively; Table 5);
* hook and line and fish lift CPUE's were correlated with log e transformed tailrace indices (r^2=0.85 P=<0.0001, r^2=0.77 P=<0.0002, respectively; Table 5).

The increases in pound net, hook and line, and fish lift CPUE's over time and their associated positive correlations with both Petersen indices continued in 2001 indicating that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay also continued in 2001.

A total of 652 adult American shad (273 pound net, 379 hook and line) were examined for physical characteristics by DNR biologists in 2001 (Table 6). The 1996 year-class (age V, sexes combined) was the most abundant age group sampled in the upper Bay (gears combined), accounting for 39% of the total catch (Table 6). Age frequency modes occurred at age 5 for both pound net and hook and line males. Age frequency modes for females occurred at ages 6 for pound net and age 5 for hook and line catches. Males (gears combined) were present in age groups 3-7 while females were found in age groups 3-8. The overall incidence of repeat spawning in male American shad increased from 4.7 % in 2000 to 25.6 % in 2001 while female American shad repeat spawning increased from 13.7% in 2000 to 27.1% in 2001.

Otoliths from 53 expired adult American shad collected from the upper Bay pound net during spring 2001 sampling were extracted by DNR personnel for analysis. Of the 51 readable pairs, 34 fish (67%) were determined to be of wild origin and 17 (33%) from hatchery production. All but one of the hatchery fish were from Pennsylvania stockings in the Susquehanna River (mostly single marked). The remaining fish was originally stocked in the Potomac River by USFWS.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 2001.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Rocky Point	2,020	367
Hook and Line	Conowingo Tailrace	972	930
Fish Lifts	Conowingo Tailrace	193,574	
	TOTALS	195,566	1,297

Table 2. Upper Chesapeake Bay relative population index of adult American shad in 2001 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 2001 survey -

C = 196,556
R = 348
M = 1,226*

Therefore -

$$N = \frac{(196{,}556 + 1)\ (1{,}226 + 1)}{(348 + 1)}$$

= **693,033**

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)

Upper $N^* = \frac{(196{,}556 + 1)\ (1{,}226 + 1)}{312.36 + 1}$ = 769,643 @ .95 confidence limits

Lower $N^* = \frac{(196{,}556 + 1)\ (1{,}226 + 1)}{385.48 = 1}$ = 624,031 @ .95 confidence limits

M* adjusted for 3% tag loss and emmigration

Table 3. Conowingo Dam tailrace relative population index of adult American shad in 2001 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 2001 survey -

C = 191,939
R = 308
M = 902*

Therefore -

$$N = \frac{(191{,}939 + 1)\ (902 + 1)}{(308 + 1)}$$

= **560,912**

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)

$$\text{Upper } N^* = \frac{(191{,}939 + 1)\ (902 + 1)}{275.39 + 1} = 629{,}346$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(191{,}939 + 1)\ (902 + 1)}{344.45 + 1} = 501{,}728$$ @ .95 confidence limits

M* adjusted for 3% tag loss

Table 4. Arithmetic means of catch, effort, and catch-per-unit-effort (CPUE) for adult American shad collected by pound net and hook and line during the 1980-2001 tagging program in the upper Chesapeake Bay.

A. Pound Net

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POPULATION ESTIMATES*
1980	Rocky Pt.	26	50	1.92	5,531
1981	Rocky Pt.	38	50	0.86	9,357
1982	Rocky Pt.	27	62	2.29	37,551
1985	Rocky Pt.	10	30	3.00	14,283
					7,876
1988	Rocky Pt.	33	87	2.64	
	Cherry Tr.	41	75	1.83	
	Romney Cr.	41	8	0.20	38,386
	TOTALS	115	170	1.48	28,714
1989	Rocky Pt.	32	91	2.84	
	Cherry Tr.	62	295	1.83	
	Beaver Dam	11	14	1.27	75,820
	TOTALS	105	400	3.81	*43,650*
1990	Rocky Pt.	38	221	5.82	
	Cherry Tr.	71	178	2.50	123,830
	TOTALS	109	399	3.66	*59,420*
1991	Rocky Pt.	38	251	6.61	
	Cherry Tr.	56	594	10.61	
	Bohemia R.	54	209	3.87	139,862
	TOTALS	148	1054	7.12	*84,122*
1992	Cherry Tr.	56	147	2.63	
	Bohemia R.	47	43	0.87	105,255
	TOTALS	103	190	1.80	*84,416*
1993	Cherry Tr.	48	255	5.31	
	Cara Cove	45	26	0.58	47,563
	TOTALS	93	281	3.02	*32,529*
1994	Cherry Tr.	48	320	6.67	
	Cara Cove	46	26	0.57	129,482
	TOTALS	94	346	0.57	*94,770*

Table 4, continued.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POPULATION ESTIMATES*
1995	Rocky Pt	48	425	8.85	
	Cherry Tr.	57	472	8.28	
	Beaver Dam	23	262	11.39	333,891
	TOTALS	128	1159	9.05	*210,546*
1996	Rocky Pt.	60	315	5.25	
	Cherry Tr.	58	330	5.69	
	White Pt.	40	311	7.76	203,216
	TOTALS	158	956	6.05	*112,217*
1997	Rocky Pt.	56	658	11.25	
	Cherry Tr.	55	510	9.27	708,628
	TOTALS	111	1168	10.52	*423,324*
1998	Cherry Tr.	48	215	4.50	487,810 *314,904*
1999	Cherry Tr.	52	343	6.60	
	Gateway	51	58	0.90	685,058
	TOTALS	103	401	3.89	*583,198*
2000	Cherry Tr.	36	1041	28.92	
	Gateway	39	90	2.31	1,357,400
	TOTALS	75	1137	15.16	*957,249*
2001	Rocky Pt.	43	2020	46.98	693,033 *560,912*

* tailrace estimates in *italics*

Table 4, continued.

B. Hook and Line

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPBH**	CPUE HTC***	POPULATION ESTIMATES*
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*

* Tailrace estimates in *italics*
** Catch-per-boat-hour
*** Hours to catch one American shad
**** Hours fished not recorded

Table 4, continued

C. Conowingo Fish Lifts

YEAR	HOURS FISHED	TOTAL CATCH	CATCH PER LIFT HOUR	POPULATION ESTIMATES*
1980**	117	139	1.18	5,531
1981	178	328	1.84	9,357
1982	336	2,039	6.07	37,551
1983	262	437	1.67	12,059
1984	192	167	0.87	8,074 *3,516*
1985	421	1,546	3.67	14,283 *7,876*
1986	449	5,195	11.57	22,902 *18,134*
1987	532	7,667	14.41	27,354 *21,823*
1988	529	5,169	9.77	38,386 *28,714*
1989	480	8,311	17.31	75,820 *43,650*
1990	617	15,964	25.87	123,830 *59,420*
1991***	1,108	27,227	24.57	139,862 *84,122*
1992	1,236	25,721	20.81	105,255 *86,416*
1993	839	13,546	16.15	47,563 *32,529*
1994	959	32,330	33.71	129,482 *94,770*
1995	306	61,650	47.21	333,891 *210,546*
1996	680	37,513	55.17	203,216 *112,217*
1997	947	103,945	109.76	708,628 *423,324*
1998	866	46,481	53.68	487,810 *314,904*
1999	739	79,370	107.40	685,058 *583,198*
2000	573	163,331	285.05	1,357,400 *957,249*
2001	743	204,514	275.25	693,033 *560,912*

* tailrace estimates in *italics*
** 1980 - 1990 west lift only
*** 1991 - 2000 both lifts combined

Table 5. Pearson Product Moment Correlation (r_p) for the annual upper Chesapeake Bay Petersen population indices, annual geometric mean CPUE's for three gear types (1980-2001), annual Conowingo tailrace Petersen population indices, and geometric mean CPUE's for two gear types (1984-2001) where N = number of years.

GEAR TYPE	PETERSEN POPULATION INDICES UPPER BAY	TAILRACE
Pound Net		
r_p	0.54	NA
N	9	
P	0.13	
Hook & Line		
r_p	0.82	0.85
N	18	18
P	<0.0001	<0.0001
Fish Lifts		
r_p	0.78	0.77
N	21	18
P	<0.0001	<0.0002

Table 6. Catch (N), age composition, number and percent repeat spawners, mean fork length and length ranges by sex, age group, and gear for adult American shad collected during 2001.

Males					Females			
Age Group	N	Number of Repeats	Mean Length	Length Range	N	Number of Repeats	Mean Length	Length Range
POUND NET								
III	22	0	350	320-385	3	0	359	330-378
IV	39	1	394	345-435	76	1	421	375-445
V	53	22	421	375-465	119	15	449	405-495
VI	16	10	462	430-495	122	61	479	400-517
VII	1	1	475	--	18	13	502	462-525
VIII	0	--	--	--	2	2	5230	500-545
HOOK AND LINE								
III	26	0	351	320-395	1	0	378	--
IV	60	0	393	360-430	46	0	422	395-443
V	82	36	418	390-464	71	7	450	405-485
VI	12	9	449	425-471	70	35	479	400-517
VII	0	--	--	--	10	8	501	462-525
GEARS COMBINED								
III	48	0	350	320-395	3	--	359	330-378
IV	99	1	394	345-435	76	1	421	375-445
V	125	58	419	375-465	119	15	449	405-495
VI	28	19	456	425-495	122	61	479	400-517
VII	2	2	476	475-477	18	13	502	462-525
VIII	0	--	--	--	2	2	523	500-545

Figure 1. Gear and locations utilized in capturing adult American Shad for tagging in the upper Chesapeake Bay in Spring 2001.

Capture Locations:

- Hook and Line
- Rocky Point

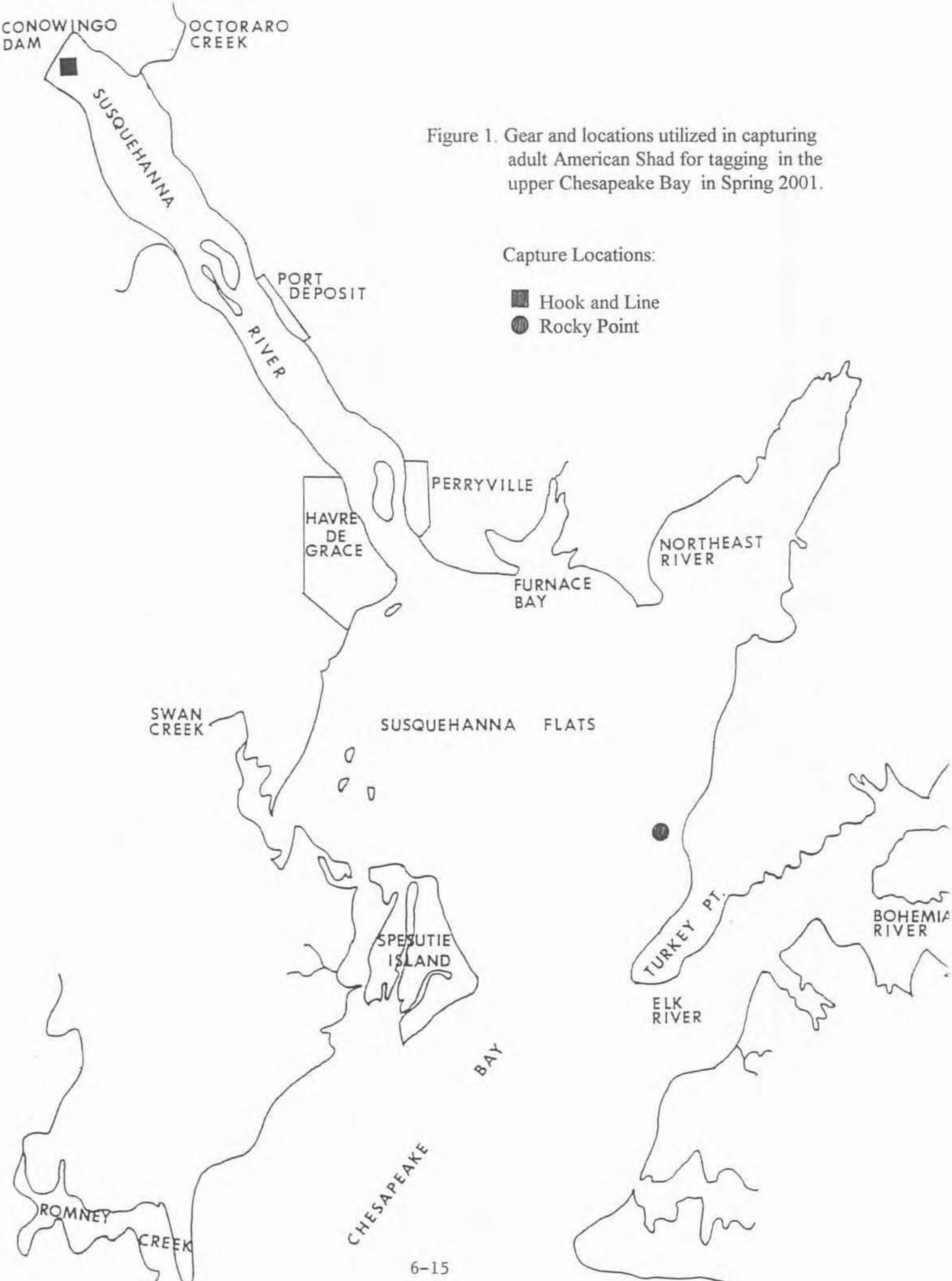


Figure 2. Upper Chesapeake Bay population estimate of American shad, 1980-2001. Bars indicate 95% confidence intervals and numbers above indicate the yearly population estimate.

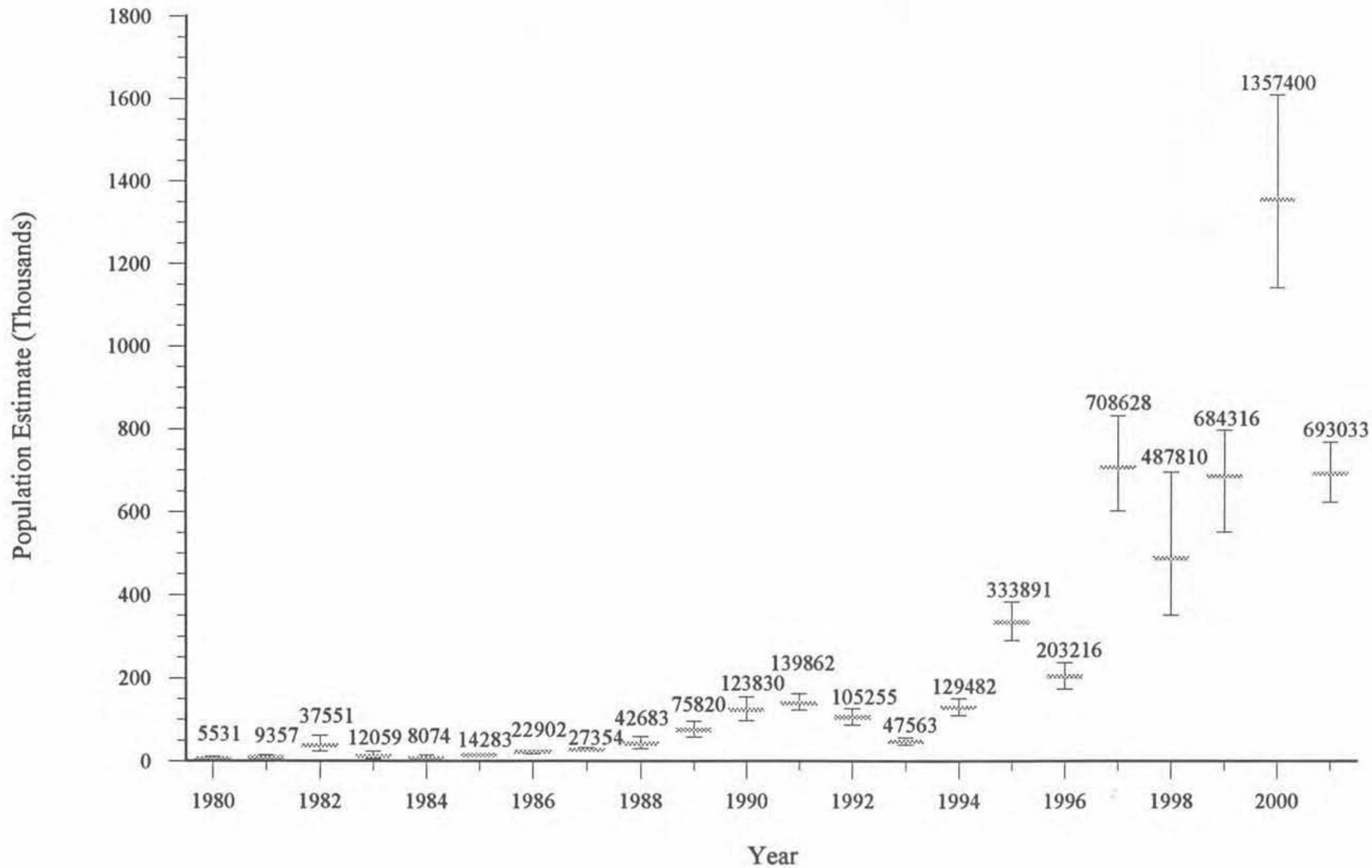


Figure 3. Conowingo Dam tailrace population estimates of American shad, 1984-2001. Bars indicate 95% confidence ranges and numbers above indicate the yearly population estimate.

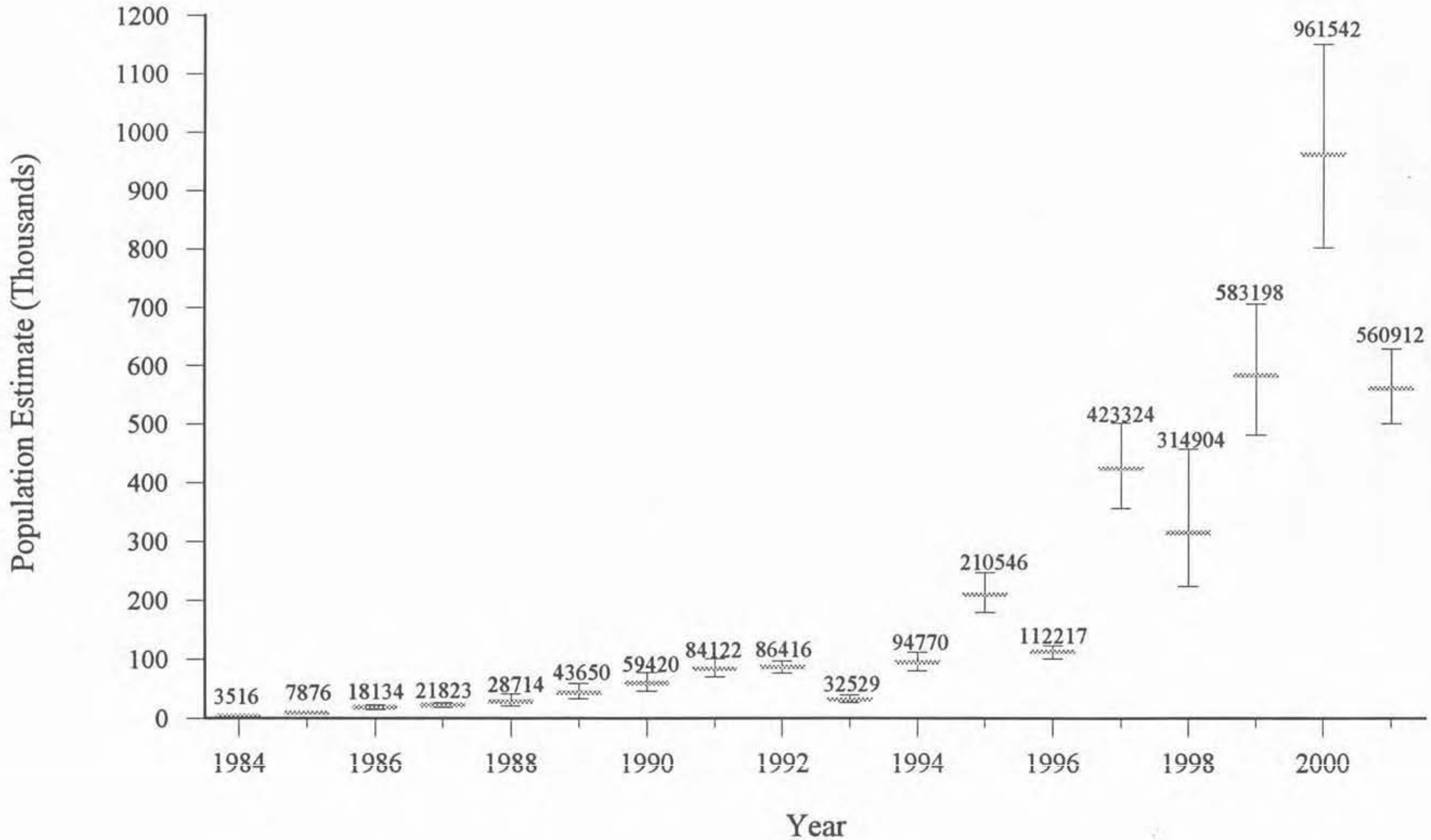
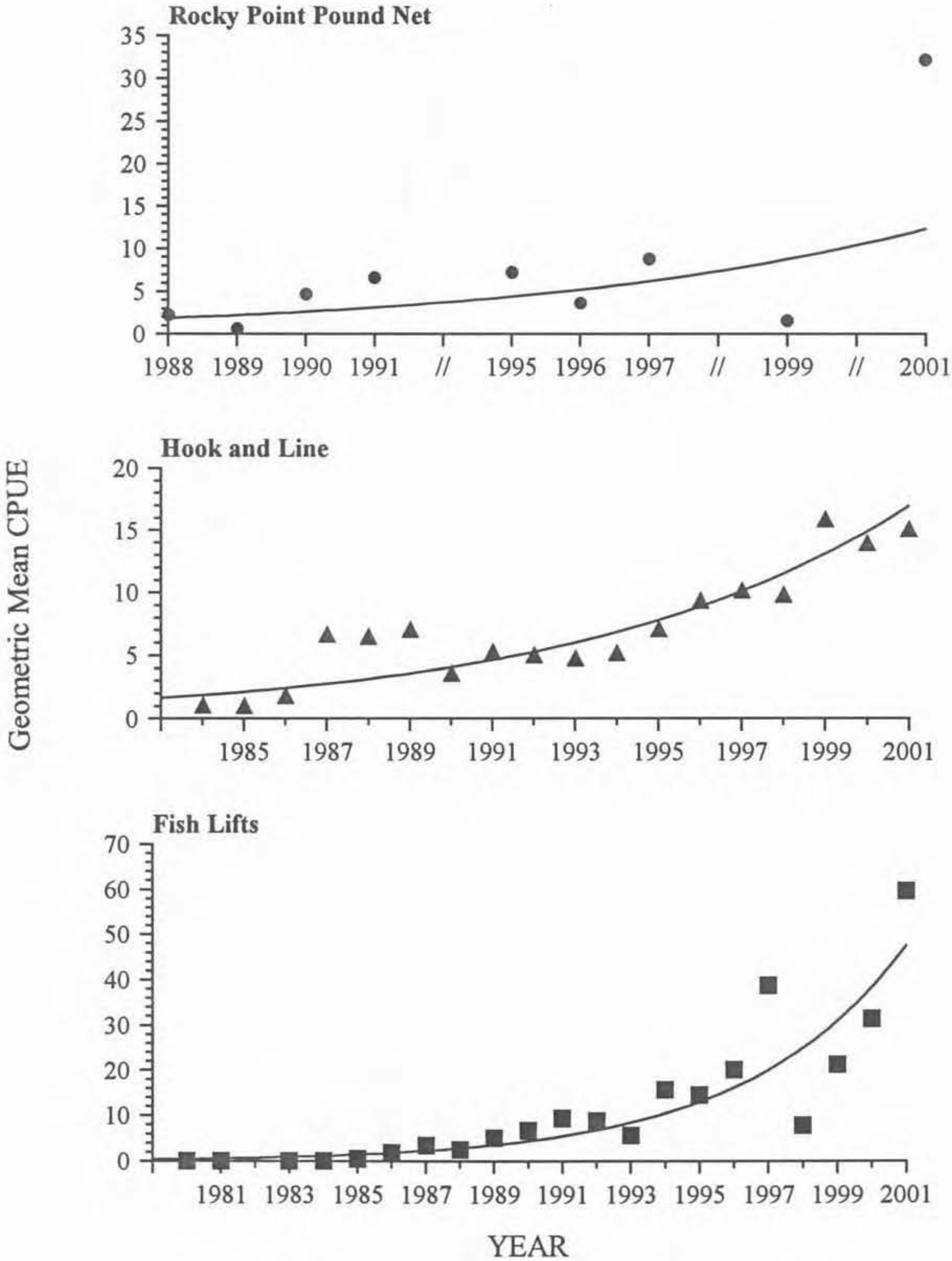


Figure 4. Regression analysis of geometric mean catch-per-unit-efforts (CPUEs) of American shad sampled by pound net, hook and line, and Conowingo fish lifts in the upper Chesapeake Bay, 1980-2001.



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