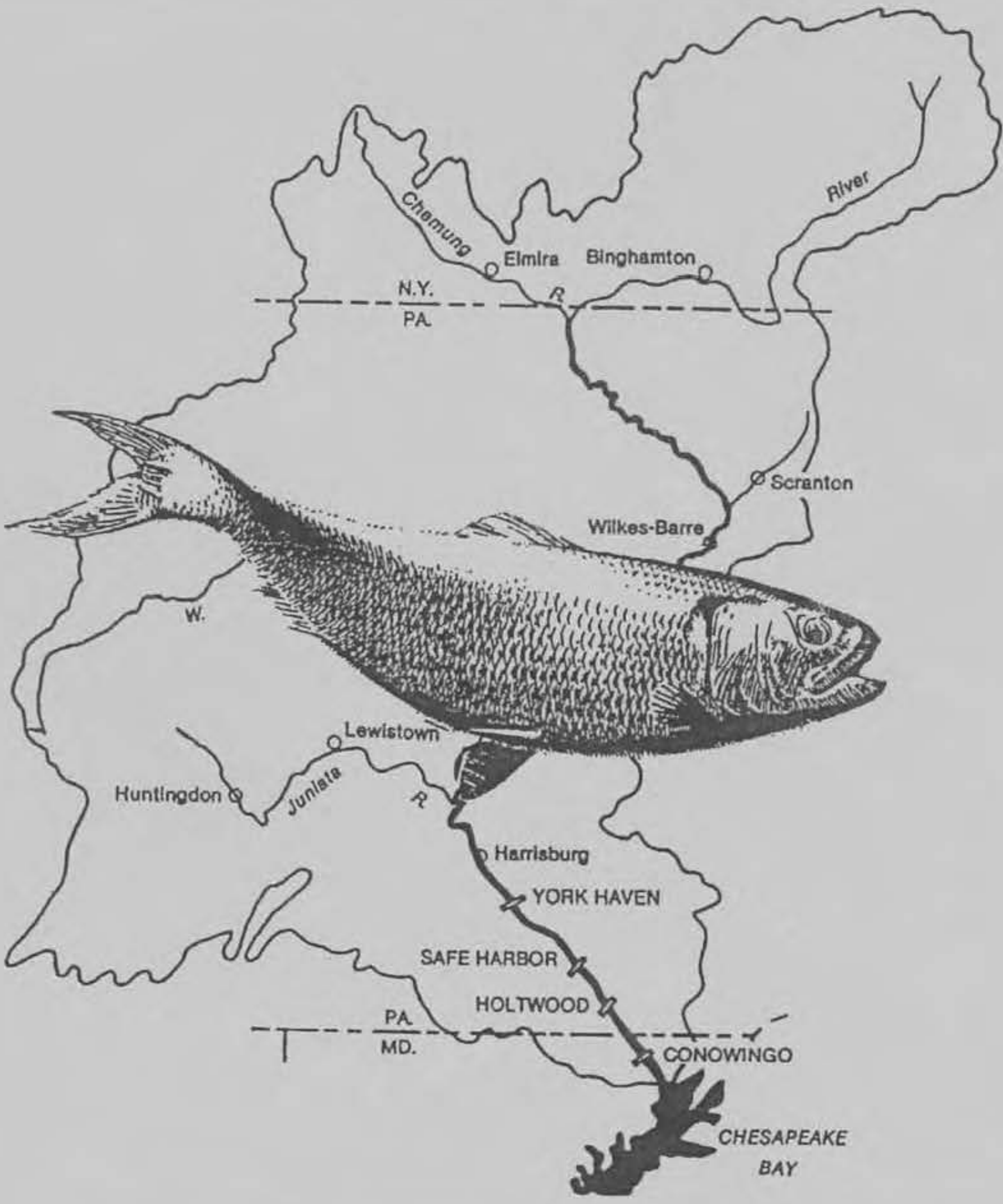
Restoration of American Shad to the Susquehanna River

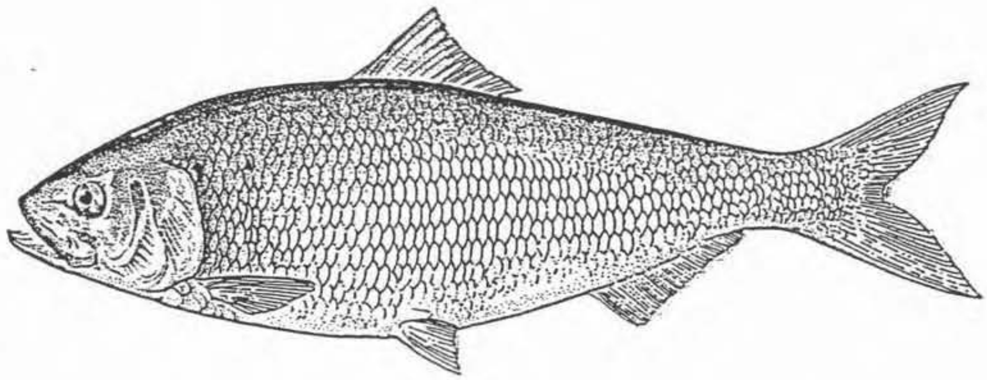
Annual Progress Report
2000



Susquehanna River
Anadromous Fish Restoration Committee

February 2001

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2000

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

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EXECUTIVE SUMMARY

This 2000 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 shad and herring stocks based on hatchery releases and natural reproduction of adult fish collected for transport or directly passed at fish lifts at Conowingo, Holtwood, Safe Harbor and York Haven dams. The restoration program represents a continuing commitment among all parties to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

Spring 2000 was characterized by relatively high river flows in April which, along with a serious debris problem at Conowingo, delayed startup of operations at the East lift until April 18. Another flow event shut down operation during April 23 - May 3, and daily operations commenced thereafter. Record numbers of shad occurred from May 4-13 (127,768 fish). As flows dropped and water temperature increased to the mid-70s, catch dropped off to an average 1000 shad/day (range 75-3300) until operations terminated on June 9. For the season the East lift operated 45 days, made 570 lifts and passed 493,955 fish. These included 317,753 gizzard shad, a new record 153,546 American shad, 14,963 bluebacks, and two alewives. Other then the high flow event in late April (>100,000 cfs), the lift shutdown on May 27-29 due to a hoist motor failure. Maryland DNR tags observed here totaled 111, most of which were year 2000 fish tagged in the tailrace.

The Conowingo West lift operated on 34 days between late April through early June, fishing for 206.5 fishing hours and making 424 separate lifts. Total catch amounted to 458,349 fish including 366,099 gizzard shad, 9,785 American shad, 14,326 blueback herring, 1 hickory shad, 9,189 alewives, and 2,453 striped bass. Sex ratio in the American shad run was 2:1 favoring males. Every 50th shad collected throughout the season was killed for otolith analysis and a scale sample.

A total of 1,351 shad were stocked at Columbia, Conestoga River and Muddy Creek and 4,783 bluebacks were stocked in the Conestoga River, Little Conestoga Creek, and Muddy Creek with very low mortality. Little Conestoga also received 2,026 alewives. Other transfers from the West lift included 1,726 shad provided to Maryland DNR, 1,179 delivered to or hauled by USFWS-Lamar for tank spawning, and 447 shad delivered to PFBC's Benner Spring Research Station.

The tailrace lift at Holtwood operated on 36 days during May 6 through June 14, fishing for 295 hours and making 363 lifts. Because of low May flows and the placement and replacement of flashboards, the spillway lift only operated on 23 days making 208 lifts in 182 hours. A total of 29,421 American shad were passed - 21,110 at the tailrace and 8,311 at the spillway. Other fish in combined Holtwood collections included 27 blueback herring, 141,176 gizzard shad, and 10,810 others. Peak passage day for American shad was May 15 (2,880 fish). Thirteen DNR tags were observed. Shad passage rate at Holtwood in 2000 was only 19.2% of shad at Conowingo East lift, a substantial decline from 1999 when about 50% of the East lift count passed this site.

The Safe Harbor fish lift operated for 269 hours during 35 days between May 8 and June 15 and made 585 lifts. Total fish passage was 169,942 fish including 21,079 American shad, 159 blueback herring, 657 alewives (from tributary stockings) and 120,696 gizzard shad. Peak day of American shad passage was May 8 (1,651). Safe Harbor passed 72% of the shad passing Holtwood. Six DNR tags were observed.

Fish ladder operations began at York Haven's East Channel Dam on May 12 and continued for 39 days until June 19. Shad were observed passing this site every day and peak passage occurred on May 19 (425 fish). For the season, total fish passage amounted to 134,279 fish including 4,687 American shad and about 74,000 gizzard shad. No DNR tags were observed. High velocities may have precluded use of the open weir and flow control gates as passage avenues for shad. Poor visibility at the counting window will result in modification in 2001 to narrow the depth of view.

Maryland DNR collected shad for tag and release from pound nets at Cherry Tree Point and Gateway off Aberdeen during March 30 through May 11 and angling in the Conowingo tailrace during May 1-22. Total catch from both gears was 1,861 shad of which 1,092 were tagged and released. Overall catch per effort from pound nets was the highest recorded since 1980 and catch per boat hour in the tailrace equaled the previous best year (1998).

Total recaptures of 2000 tags at the Conowingo lifts was 128 fish. Using Peterson techniques, shad population indices were calculated for the upper Bay (1,357,400 fish) and Conowingo tailrace (957,249), both new highs. Scale analysis from combined pound net and angling samples showed that most males were ages 4-5 with 4.7% repeat spawners and females were 4-6 with 13.7% repeats.

Based on analysis of 193 readable otoliths from adult shad taken at Conowingo West lift in 2000, 89 (46%) were of hatchery origin and 104 (54%) were wild. This compares to 53% hatchery and 47% wild in 1999. The majority of hatchery fish (73%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River. Most others were either double or triple marked with three fish (3%) carrying four marks. Six of eight adult shad taken at upstream or tributary locations were also marked. DNR examined 61 adult shad from pound nets and found that 50 (82%) were wild and 11 (18%) were of hatchery origin of which 8 carried the double TC mark used by DNR for stocking below Conowingo in past years. Based on the annual analysis of hatchery vs. wild shad at Conowingo (1986-1995 year classes), age of fish, and known stocking numbers, PFBC researchers calculated that, on average for the 10- year period, it took 318 larvae, 134 fingerlings, or 0.86 transplanted adults to produce each adult return to Conowingo Dam.

In 2000 the Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River and PFBC completed Delaware River egg collections. During the month of May, the Hudson produced 14.882 million eggs (71.3% viable) and the Delaware produced 3.827 million (39.6% viable). Total eggs delivered to Van Dyke was 18.71 million with an average viability of 65%. Tank spawning of Susquehanna River broodfish at USFWS-Lamar produced about 3 million eggs of which 2 million were incubated in 2000.

Van Dyke Hatchery produced a total of about 10.35 million fry of which 9.46 million were stocked in the Susquehanna drainage as follows: 6.25 M in the Juniata River; 1.12 M in the mainstem above Clarks Ferry: 0.97 M in the North Branch; 0.63 M in the West Branch; and 0.49 M in four lower river tributaries. The PFBC also reared and stocked 447,000 shad fry for the Lehigh River and 536,000 for the Schuylkill River, and they provided 91,000 fry to the State of Delaware for stocking the upper Nanticoke River. Lamar stocked about 328,000 shad fry in the West Branch. All fish from both sites were distinctively marked with tetracycline.

Relatively low river levels, clear water conditions and small numbers of spawners above Safe Harbor contributed to poor summer-fall net collections at most locations. A total of only 31 juvenile shad were taken at Columbia with haul seines on 15 sampling dates. CPUE here was one of the lowest on record. No juveniles were taken by seine in tributaries (288 hauls), by electrofishing in the Juniata and upper Susquehanna, or by push nets in Conowingo Pond (13 surveys). Lift netting at Holtwood produced 406 juvenile shad in 300 lifts (comparable to 1999) with most fish passing this site during the 4-week period October 30 - November 26. Over 200 juveniles were collected with electrofishing gear at York Haven and Muddy Run. Peach Bottom screens produced 100 shad, six bluebacks and two alewives, while intake strainers at Conowingo provided 63 shad and one blueback. Electrofishing for adult shad produced two males at the base of the City of Lancaster Water Supply Dam on the Conestoga River; a single male at Detters Mill Dam on West Conewago Creek; and four adults at the base of the inflatable dam at Sunbury.

During July-September sampling in the upper Chesapeake Bay, Maryland DNR collected 409 juvenile shad in 42 seine hauls at 5 of 7 permanent sampling sites and another 142 fish in 15 hauls at 4 of 5 auxiliary sites. Catch per effort here in 2000 (9.67 shad/haul) was among the highest recorded in the past 40 years.

Otoliths from a total of 536 juvenile shad were examined for hatchery marks from combined collections made at and above Conowingo Dam. Of these, 523 (98%) were hatchery marked (compared to 95% in 1998-1999) of which the majority (423 fish - 81%) carried the single day mark indicating that they were stocked at various locations in the Juniata and mainstem Susquehanna rivers. Of the remaining hatchery fish examined, 75 fish (14.3%) were stocked in the North Branch; 11 fish (2%) were stocked in the West Branch; 8 fish (1.5%) were from W. Conewago Creek; and the remaining 6 fish (3 each) were from Conodoguinet Creek and Conestoga River. Of 307 juvenile shad otoliths successfully examined from Maryland DNR's upper Bay samples only one fish was hatchery origin carrying a single day 3 mark.

In terms of relative survival from stocking site to recovery, Juniata and mainstem Susquehanna produced the best results followed by Conewago Creek, Conodoguinet Creek, and the North Branch. Relatively poor recovery rates were measured from the West Branch and Conestoga River, and, no fish were recovered from the small stocking made in Swatara Creek.

In an effort to reduce stress and improve survival, two light sedatives, salts and improved handling methods were tested in hauling adult shad from Conowingo to Lamar in 2000. Based on statistical analysis with controls, neither clove oil (eugenol) nor metomidate treatments improved fish survival. Blood chemistry analysis indicated increased levels of glucose and cortisol, decreased levels of sodium, chloride and lactate. Rather than stabilizing post-hauling, stress response indicators continued to degrade in the freshwater recirculating system at Lamar.

In a second experiment conducted by USFWS-Lamar, two hormones (synthetic LHRHa and salmonid GnRHa) were compared for tank spawning. Reproductive performance in terms of average number of viable eggs per female was statistically the same for both treatments. However, when salt (2-4 ppt) was added to the system, survival to 7 days improved substantially

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, 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 and juvenile shad seining in the upper Chesapeake Bay. USFWS and USGS covered most costs associated with adult shad stress studies, hormone trials and tank spawning. Costs related to Conowingo West fish lift operations including collection, sorting, and trucking of shad and herring, as well as purchase of hormones and special transport tanks (Lamar) were paid from a contributed funds account administered by the U. S. Fish and Wildlife Service and a grant from EPA (Chesapeake Bay Program). Contributions to the special account came from upstream utilities (balance from 1984 agreement), PECO Energy's 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 the address below.

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JOB I - Part 1

SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY IN SPRING 2000

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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 2000 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 10 to 30 April, 1 to 31 May, and 1 to 9 June, respectively.

Fishway Operation

East lift operation began on 10 April and generally operated on an every other day basis through 28 April. Operations were suspended from 29 April to 3 May due to a hopper hoist motor failure. Lift operation resumed on a daily basis on 4 May. Operations were suspended from 27 May to 29 May due to the onset of a high flow event in excess of 100,000 cfs and a poor shad catch on 26 May. Operations resumed 30 May with continuous operation until season end, 9 June. In all, the lift was operated a total of 45 days during the 2000 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 2000 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 2000 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.

Each day a permanent record (video tape) of daily fish passage was made. The video system was comprised of the following Panasonic equipment: (1) a black and white camera (Model # WV-BP310 Series 1/3" CCD); (2) a super wide angle lens (Model # WV-LD2.8); (3) a time-lapse Super VHS recorder/player (Model # 6-6730S-VHS/VSS); and (4) a color monitor (Model # CT-20611). The recorded tapes were reviewed using a video cassette recorder/player equipped with a jog/shuttle control. This feature allowed a day's tape to be reviewed at different speeds during playback, including slow motions and frame by frame. Selected segments of tape were reviewed by a biotechnician who counted the number of shad passing the window during the selected time period.

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 493,955 fish of 30 species and one hybrid was passed upstream into Conowingo Pond. Gizzard shad (317,753) and American shad (153,546) were the dominant species passed, comprising 64% and 31% respectively of the season total; the two species together thus accounted for 95% of the total fish passed. Other common fishes included blueback herring (14,963), white perch (4,387), striped bass (802), and channel catfish (677). Alosids (American shad, blueback herring, and alewife) comprised over 34% of the total catch. Peak passage occurred on 7 May when 49,772 fish, or 10% of the season total, were passed.

American Shad Passage

The East lift captured and passed 153,546 American shad (Table 1). The first shad was passed on 18 April. Collection and passage of shad varied daily with nearly 83% (127,768) of the shad captured and passed during the ten day period between 4 May and 13 May. The lift captured and passed over 10,000 American shad on seven separate days. On 20 of the 45 days of operation the American shad passage exceeded 1,000 fish. Peak passage occurred on 5 May when 22,565 American shad were passed.

American shad were collected at water temperatures of 52.3°F to 75.9°F and at natural river flows of 22,900 to 114,500 cfs (Table 2 and Figure 1). While the average daily river flow during the operational season was 56,687 cfs, over 85% of the American shad were collected at river flows of less than 40,000 cfs (Table 2 and Figure 1). The hourly passage of American shad in the East lift is given in Table 3. Most shad passed (144,351) through the fishway from 0900 to 1859 h. Peak hourly passage of shad (17,705) occurred between 1100 to 1159 h. Generally shad passage was steady over the hours of viewing, all the hour periods from 0900 to 1859 h had passage greater that 11,000 but less than 18,000 shad.

Other Alosids

Only two alewife were captured and passed, both on 18 April. A total of 14,963 blueback herring were captured and passed (Table 1). Most blueback herring (74%) were passed on 8 May at a water temperature of 72.0°F and river flow of 29,700 cfs. No hickory shad were captured.

Video Record

A limited review of the video records showed that generally, fish passage was adequately captured on the tape record in 2000. Data in Table 4 lists by date and time the shad count, the number of shad visually estimated from the video count, and the difference between the two counts. The differences between visual counts and tape counts varied from 0 to 68 shad or from 0.0 to 4.8%. These video counts were derived via a frame by frame review of the time period.

High river flows in spring 2000 resulted in poorer water clarity than that observed in 1999. This hampered video tape quality and subsequent review from 4 May when more than 3000 shad were passed in an hour. The visual estimates made by technicians, however, accurately reflected the number of fish that passed through the East lift based on better quality tapes reviewed. To further maximize the visual count accuracy, two people were utilized during periods of increased fish passage and/or reduced water clarity.

SUMMARY

Despite a delayed start, as the result of high river flows and a low American shad catch during the beginning of the 2000 season, the East lift successfully passed 153,546 American shad by the season's end. The total of American shad passed during the 2000 season surpassed all previous years of operation since the first use of the trough in 1997 (Table 5).

Modifications that were made at the end of the 1999 and beginning of the 2000 season proved to be effective. Namely, the slanted grating, covering the butterfly valve successfully prevented clogging of the valve, and thus maintained an adequate flow of water in the trough during the 2000 season. Other modifications including a curved hopper chute to direct fish upstream in the trough and plastic sheets covering the top section of slanted grating to prevent injury during low flow periods, also contributed to the successful operation of the lift. A total of 517 American shad lift mortalities (0.3% of the total shad passed), were observed this season as compared to the 2,000 shad mortalities (nearly 3% of the total passed) in 1999. These modifications will continue to be evaluated and improved upon if necessary for future operation.

Fish viewing conditions were poorer than those encountered in 1999 due to reduced water clarity as a result of high river flows. Differences between visual counts and tape derived counts were small (0.0 to 4.8%) where most American shad positively identified were verified on the videotapes when tape visual clarity was adequate. 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.

- Discontinue video tape recording based on the low number of annual count discrepancies since1997.

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2000.

Date	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*
Hours Of Operation	*4.00*		*4.25*		*5.00*		*7.00*	
Numbers Of Lifts	*4*		*4*		*5*		*8*	
Water Temperature	*48.6*		*48.2*		*48.0*		*50.8*	
American shad								
Blueback herring								
Alewife								
Gizzard shad	121		1,470		836		1,447	
Sea lamprey								
Rainbow trout								
Brown trout								
Muskellunge								
Carp			1					
Quillback								
White sucker	1		1					
Shorthead redhorse							2	
White catfish								
Yellow bullhead								
Brown bullhead								
Channel catfish	3		4		1			
Margined madtom								
White perch								
striped bass								
Hybrid striped bass					1			
Redbreast sunfish								
Green sunfish								
Pumpkinseed								
Bluegill	1				1			
Rock bass								
Smallmouth bass								
Largemouth bass								
White crappie								
Black crappie								
Yellow perch	1							
Walleye					1			
TOTAL	***127***		***1,476***		***840***		***1,449***	***0***

Table 1

Continued.

Date	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*
Hours Of Operation	*7.75*	*6.75*	*6.25*		*5.75*		*3.00*	
Numbers Of Lifts	*8*	*8*	*8*		*11*		*5*	
Water Temperature	*53.8*	*52.3*	*53.4*		*52.4*		*51.3*	
American shad	71	24	9		39			
Blueback herring					4			
Alewife	2							
Gizzard shad	3,514	13,740	17,585		12,250		4,100	
Sea lamprey								
Rainbow trout					1			
Brown trout								
Muskellunge								
Carp		1	1				1	
Quillback			2					
White sucker			1					
Shorthead redhorse	10	21	9		5			
White catfish								
Yellow bullhead								
Brown bullhead								
Channel catfish	2		3		14		16	
Margined madtom								
White perch		1						
striped bass					1			
Hybrid striped bass			1					
Redbreast sunfish								
Green sunfish								
Pumpkinseed								
Bluegill	3	1						
Rock bass								
Smallmouth bass	3	5	4		6		1	
Largemouth bass		1						
White crappie								
Black crappie								
Yellow perch	2							
Walleye	4	2	2		13		3	
TOTAL	***3,611***	***13,796***	***17,617***		***12,333***		***4,121***	

Table 1

Continued.

Date	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*
Hours Of Operation	*4.83*		*2.50*					
Numbers Of Lifts	*7*		*3*					
Water Temperature	*53.0*		*52.5*					
American shad								
Blueback herring								
Alewife								
Gizzard shad	9,520		6,468					
Sea lamprey	1							
Rainbow trout								
Brown trout			1					
Muskellunge								
Carp								
Quillback								
White sucker								
Shorthead redhorse								
White catfish								
Yellow bullhead								
Brown bullhead								
Channel catfish	41		3					
Margined madtom								
White perch								
striped bass								
Hybrid striped bass								
Redbreast sunfish								
Green sunfish								
Pumpkinseed								
Bluegill								
Rock bass								
Smallmouth bass	3		1					
Largemouth bass								
White crappie								
Black crappie								
Yellow perch								
Walleye	4							
TOTAL	***9,569***		***6,473***					

Table 1

Continued.

Date	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*
Hours Of Operation	*4.50*	*11.00*	*10.75*	*11.25*	*10.50*	*10.25*	*10.75*	*10.75*
Numbers Of Lifts	*15*	*22*	*23*	*26*	*27*	*23*	*26*	*25*
Water Temperature	*62.5*	*64.5*	*66.7*	*69.4*	*72.0*	*74.0*	*75.9*	*75.6*
American shad	18,181	22,565	13,557	13,068	11,166	12,199	12,448	9,715
Blueback herring	2	30	37	2,447	11,020	638	162	53
Alewife								
Gizzard shad	4,550	14,270	11,990	33,200	7,615	12,077	10,357	7,060
Sea lamprey	1		1	2	3	4		
Rainbow trout								
Brown trout						3		1
Muskellunge								
Carp	9	5	62	21	33	19	2	16
Quillback	4	12	1	135	66	15	21	23
White sucker		3		1	2	4	1	4
Shorthead redhorse	3	4	1	2	6	1	2	5
White catfish								
Yellow bullhead							1	
Brown bullhead				3		1		
Channel catfish	1	3	1	13	8	3	5	3
Margined madtom				6				
White perch	1	2280	587	809	332	164	21	12
striped bass				6		7	1	3
Hybrid striped bass								
Redbreast sunfish				1				1
Green sunfish								1
Pumpkinseed							1	
Bluegill	2	1	4	10	2	5	2	3
Rock bass		1	3	4	1	1	3	1
Smallmouth bass	15	77	46	37	27	34	10	19
Largemouth bass		1	2	1	1	2		
White crappie								
Black crappie			1					
Yellow perch		4	4	3	3	4	2	3
Walleye	5	13	5	3	2	4	3	1
TOTAL	***22,774***	***39,269***	***26,302***	***49,772***	***30,287***	***25,185***	***23,042***	***16,924***

Table 1

Continued.

	12 May	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
Hours Of Operation	*11.00*	*10.50*	*10.92*	*9.75*	*10.75*	*11.00*	*10.75*	*9.75*
Numbers Of Lifts	*23*	*16*	*15*	*19*	*23*	*20*	*21*	*13*
Water Temperature	*75.6*	*75.3*	*73.9*	*72.5*	*69.6*	*67.9*	*67.3*	*67.6*
American shad	6,956	7,913	2,950	3,355	3,600	2,348	2,318	1,246
Blueback herring	187	20	83	89	14	3	126	17
Alewife								
Gizzard shad	5,465	7,546	8,929	10,224	8,085	13,031	7,295	2,983
Sea lamprey	1		1	4	1		3	1
Rainbow trout								
Brown trout	2							
Muskellunge								
Carp	4	122	49	3	3	3	1	
Quillback	12	15	48	2	9	11	5	2
White sucker		2	5			1	1	
Shorthead redhorse	1		1		5	2	4	
White catfish								
Yellow bullhead								
Brown bullhead								1
Channel catfish	1	1	4	5	4	20	18	17
Margined madtom			1					
White perch	2	1	10	6	14	1	8	11
striped bass	2	62	23	9	13	46	57	116
Hybrid striped bass								
Redbreast sunfish		3	6					
Green sunfish		1						
Pumpkinseed			1					
Bluegill	2	7	4	3	1		2	2
Rock bass	1	4					2	2
Smallmouth bass	18	15	10	2	10	7	5	5
Largemouth bass			3			1		1
White crappie								
Black crappie								1
Yellow perch	1	2		1				
Walleye	3		4	4	11	8	15	6
TOTAL	***12,658***	***15,714***	***12,132***	***13,707***	***11,770***	***15,482***	***9,860***	***4,411***

Table 1

Continued.

Date	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours Of Operation	*10.68*	*10.50*	*10.75*	*10.50*	*8.75*	*8.83*	*6.00*	
Numbers Of Lifts	*14*	*14*	*12*	*11*	*9*	*9*	*6*	
Water Temperature	*67.2*	*65.4*	*62.3*	*61.3*	*61.0*	*62.1*	*63.4*	
American shad	963	1,368	603	301	1,042	1,018	14	
Blueback herring	1	4				5		
Alewife								
Gizzard shad	5,115	2,555	6,905	2,713	3,395	5,111	2,600	
Sea lamprey								
Rainbow trout								
Brown trout	1							
Muskellunge								
Carp		1		4		3		
Quillback	5		3					
White sucker	1							
Shorthead redhorse	1	1	3	1			1	
White catfish							1	
Yellow bullhead			1	11				
Brown bullhead	7		1	16		1		
Channel catfish	13	37	137	96	2	126	31	
Margined madtom								
White perch	28	17	10	4		5		
striped bass	140	68	46	27	24	34	18	
Hybrid striped bass								
Redbreast sunfish				1				
Green sunfish								
Pumpkinseed								
Bluegill	1		1					
Rock bass	2							
Smallmouth bass	1	3	2	2	5	8	1	
Largemouth bass			1	1	1			
White crappie								
Black crappie								
Yellow perch							1	
Walleye	5	8	11	7		6	5	
TOTAL	***6,284***	***4,062***	***7,724***	***3,184***	***4,469***	***6,317***	***2,672***	

Table 1

Continued.

Date	28 May	29 May	30 May	31 May	1 Jun	2 Jun	3 Jun	4 Jun
Hours Of Operation			*6.50*	*7.25*	*7.75*	*7.33*	*7.50*	*7.25*
Numbers Of Lifts			*10*	*8*	*8*	*8*	*7*	*8*
Water Temperature			*61.8*	*62.6*	*64.4*	*67.2*	*69.8*	*72.0*
American shad			74	145	208	347	280	1,089
Blueback herring					17			
Alewife								
Gizzard shad			7,540	3,928	6,753	6,840	2,677	2,019
Sea lamprey								
Rainbow trout								
Brown trout								
Muskellunge							1	
Carp					1	1	8	1
Quillback							1	6
White sucker								
Shorthead redhorse								
White catfish								
Yellow bullhead								
Brown bullhead						1		
Channel catfish			25	1	1		7	
Margined madtom								
White perch			2		17	3	6	2
striped bass			13	9	12	6	10	4
Hybrid striped bass								
Redbreast sunfish								
Green sunfish								
Pumpkinseed								
Bluegill			1		1		1	8
Rock bass								
Smallmouth bass					2	1	7	5
Largemouth bass						5	1	
White crappie								
Black crappie								
Yellow perch								
Walleye			1	1	2	1	2	3
TOTAL			***7,656***	***4,084***	***7,014***	***7,205***	***3,001***	***3,137***

Table 1

Continued.

Date	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*TOTAL*
Hours Of Operation	*7.50*	*7.50*	*7.17*	*7.67*	*7.08*	*367.76*
Numbers Of Lifts	*8*	*8*	*8*	*7*	*7*	*570*
Water Temperature	*72.3*	*71.0*	*68.5*	*67.4*	*68.0*	
American shad	708	572	591	291	204	*153,546*
Blueback herring	4	2				*14,963*
Alewife						*2*
Gizzard shad	6,471	3,610	4,360	5,098	4,335	*317,753*
Sea lamprey						*23*
Rainbow trout	1					*2*
Brown trout						*8*
Muskellunge						*1*
Carp	1	1	1	10		*388*
Quillback	1		1		8	*408*
White sucker		1				*29*
Shorthead redhorse						*91*
White catfish						*1*
Yellow bullhead						*13*
Brown bullhead					1	*32*
Channel catfish	1	1	1	2	2	*677*
Margined madtom						*7*
White perch	1	3		3	26	*4,387*
striped bass		6	2	18	19	*802*
Hybrid striped bass						*2*
Redbreast sunfish	1			7		*20*
Green sunfish						*2*
Pumpkinseed				1		*3*
Bluegill	13	4		8	2	*96*
Rock bass						*25*
Smallmouth bass	7	4	2	15	2	*427*
Largemouth bass	2	3	1	4	1	*33*
White crappie	2					*2*
Black crappie						*2*
Yellow perch						*31*
Walleye		5		2	2	*177*
TOTAL	*7,213*	*4,212*	*4,959*	*5,459*	*4,602*	*493,955*

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 2000.

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
10 Apr	0	0	112,000	48.6	0	11	C	310	25.0	108.6	4
11 Apr	-	-	123,700	49.1							
12 Apr	0	0	111,400	48.2		11	C	310	25.0	108.7	4
13 Apr	-	-	94,700	47.7							
14 Apr	0	0	80,400	48.0		11	C	310	22.5 - 24.5	108.8	2
15 Apr	-	-	70,400	49.4							
16 Apr	0	0	62,300	50.8	18	11	C	310	22.0	108.0	0
17 Apr	-	-	59,100	53.1							
18 Apr	71	0	58,400	53.8	18	11	C	310	22.0	106.7	0
19 Apr	24	0	69,000	52.3	18	11	C	310	23.0	105.6	0
20 Apr	9	0	94,100	53.4	18	11	C	310	23.0	106.7	0
21 Apr	-	-	98,600	54.7							
22 Apr	39	0	94,100	52.4	18	11	C	310	24.0	109.0	1
23 Apr	-	-	103,000	51.5							
24 Apr	0	0	125,600	51.3	8	11	C	310	25.0	108.7	3,4
25 Apr	-	-	127,000	52.3							
26 Apr	0	0	109,600	53.0	8	11	C	310	23.5 - 25.5	108.6	2,3,4
27 Apr	-	-	91,200	53.2							
28 Apr	0	0	74,900	52.5	16	11	C	310	22.0	108.0	0
29 Apr	-	-	65,700	53.4							
30 Apr	-	-	56,300	55.9							
1 May	-	-	51,800	58.1							
2 May	-	-	46,600	59.8							
3 May	-	-	42,200	60.9							
4 May	18,181	0	38,800	62.5	20	8	C	310	22.0	107.0	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
5 May	22,565	*2YL ,1OR*	35,800	64.5	18	8	C	310	22.0	106.7	0
6 May	13,557	*2YL ,5OR, 1GR*	33,600	66.7	18	8	C	310	18.0 - 23.0	107.8	0
7 May	13,068	*7OR*	31,700	69.4	24	11	C	310	18.0 - 22.5	107.7	0
8 May	11,166	*2YL ,7OR ,2GR*	29,700	72.0	24	11	C	310	16.5 - 23.0	108.4	0
9 May	12,199	*1YL ,21OR*	27,700	74.0	24	11	C	310	17.0 - 23.0	107.7	0
10 May	12,448	*1YL ,12OR, 1GR*	25,800	75.9	24	11	C	310	17.5 - 23.0	107.5	0
11 May	9,715	*17OR ,1GR*	23,400	75.6	24	7	C	310	17.5 -22.5	106.7	0
12 May	6,956	*9OR*	22,900	75.6	24	10	C	310	17.0 - 23.0	107.8	0
13 May	7,913	0	37,700	75.3	24	7	C	310	18.0 - 22.0	106.9	0
14 May	2,950	0	46,500	73.9	24	9	C	310	18.0 - 23.0	108.2	0
15 May	3,355	*7OR*	47,700	72.5	18	9	C	310	21.0	107.5	0
16 May	3,600	*1OR*	55,400	69.6	16	9	C	310	22.5	107.1	0
17 May	2,348	0	56,200	67.9	18+	9	C	310	22.0	170.1	0
18 May	2,318	*1OR*	54,300	67.3	16+	9	C	310	22.0	105.4	0
19 May	1,246	0	48,300	67.6	12+	8	C	310	21.0	106.5	0
20 May	963	*2OR*	42,900	67.2	4+	8	C	310	22.5	107.2	0
21 May	1,368	*1OR*	50,100	65.4	4+	8	C	310	20.0 - 22.5	107.3	0
22 May	603	0	73,600	62.3	4+	10	C	310	21.5	105.6	0
23 May	301	0	68,400	61.3	4+	10	C	310	22.0	106.3	0
24 May	1,042	*2OR*	69,000	61.0	10	10	C	310	21.5	104.9	0
25 May	1,018	0	83,100	62.1	12	9	C	310	22.0	105.3	3
26 May	14	0	114,500	63.4	12	10	C	310	23.0 - 25.5	109.0	4
27 May	-	-	108,200	63.3							
28 May	-	-	89,600	62.4							
29 May	-	-	71,700	62.5							
30 May	74	0	60,400	61.8	9	10	C	310	21.5	107.3	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
31 May	145	1*OR*	54,400	62.6	12	10	C	310	21.5	106.9	0
1 Jun	208	1*OR*	46,600	64.4	18+	10	C	310	21.5	106.5	0
2 Jun	347	0	41,000	67.2	18+	10	C	310	22.5	107.8	0
3 Jun	280	0	35,200	69.8	16	9	C	310	19.0 - 22.0	108.0	0
4 Jun	1,089	2*OR*	31,900	72.0	12+	7	C	310	20.0 - 22.0	108.6	0
5 Jun	708	0	28,000	72.3	18+	8	C	310	19.5 - 22.0	107.6	0
6 Jun	572	1*BL*	29,000	71.0	20	9	C	310	19.5 - 21.5	107.6	0
7 Jun	591	0	35,100	68.5	12	7	C	310	19.5 - 22.0	108.2	0
8 Jun	291	0	42,100	67.4	24	9	C	310	22.0	107.9	0
9 Jun	204	0	38,300	68.0	12	10	C	310	18.0 - 23.5	107.4	0

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2000.

Date	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*
Observation Time - Start	*12:15*		*12:00*		*11:10*		*11:20*		*11:15*	*11:00*	*11:30*		*11:30*
Observation Time - End	*16:00*		*15:30*		*16:20*		*18:30*		*19:15*	*18:15*	*18:00*		*18:00*
Military Time (hrs)													
0700 to 0759													
0800 to 0859													
0900 to 0959													
1000 to 1059													
1100 to 1159										8			
1200 to 1259									1	3	2		
1300 to 1359									1	5	1		
1400 to 1459									4		2		
1500 to 1559									3	5	1		15
1600 to 1659									16	3			9
1700 to 1759									30		3		15
1800 to 1859									10				
1900 to 1959									6				
Total	*0*		*0*		*0*		*0*		*71*	*24*	*9*		*39*

Table 3

Continued.

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		*12:00*		*11:15*		*11:15*						*12:30*	*8:10*
Observation Time - End		*15:30*		*16:15*		*13:30*						*17:15*	*19:25*
Military Time (hrs)													
0700 to 0759													
0800 to 0859													1,335
0900 to 0959													2,345
1000 to 1059													2,495
1100 to 1159													1,980
1200 to 1259												212	1,260
1300 to 1359												1,969	1,550
1400 to 1459												3,800	2,350
1500 to 1559												3,055	2,440
1600 to 1659												2,629	2,080
1700 to 1759												2,447	2,410
1800 to 1859												2,974	1,740
1900 to 1959												1,095	580
Total		***0***		***0***		***0***						***18,181***	***22,565***

Table 3

Continued.

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	*8:20*	*8:05*	*8:15*	*7:45*	*8:03*	*7:45*	*8:00*	*8:45*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*
Observation Time - End	*19:30*	*19:20*	*19:30*	*19:15*	*19:15*	*19:15*	*19:20*	*19:00*	*19:30*	*19:10*	*19:15*	*19:00*	*19:00*
Military Time (hrs)													
0700 to 0759				22		80							
0800 to 0859	330	718	125	309	272	443	353	16	225	9	71	7	31
0900 to 0959	767	749	813	1,367	1,580	1,325	961	509	344	75	136	145	93
1000 to 1059	969	1,294	919	1,632	1,864	1,396	803	1,190	255	185	144	206	228
1100 to 1159	1,070	2,275	955	2,136	2,783	1,031	742	2,720	234	178	140	224	259
1200 to 1259	910	2,237	876	1,860	2,124	699	484	812	171	225	373	207	277
1300 to 1359	1,623	1,733	1,106	1,280	2,003	471	543	623	196	316	504	316	286
1400 to 1459	1,514	1,332	937	914	712	709	549	778	358	265	554	257	277
1500 to 1559	1,436	718	1,160	707	406	520	795	458	296	442	555	254	256
1600 to 1659	1,378	534	1,417	732	240	506	658	324	242	491	458	301	196
1700 to 1759	1,238	643	1,052	541	181	1,001	581	253	253	570	302	242	199
1800 to 1859	1,275	580	1,100	652	222	1,083	313	230	205	519	285	189	216
1900 to 1959	1,047	255	706	47	61	451	174		171	80	78		
Total	*13,557*	*13,068*	*11,166*	*12,199*	*12,448*	*9,715*	*6,956*	*7,913*	*2,950*	*3,275*	*3,600*	*2,348*	*2,318*

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*	*8:41*	*8:00*	*8:00*	*8:00*	*8:00*	*9:45*	*8:00*				*12:00*	*11:30*
Observation Time - End	*19:15*	*19:15*	*18:55*	*19:15*	*18:40*	*17:30*	*18:55*	*15:20*				*18:15*	*18:10*
Military Time (hrs)													
0700 to 0759													
0800 to 0859	3	14	10	1		1		5					
0900 to 0959		43	53	33		21	4	3					
1000 to 1059	72	109	58	28	3	48	25						
1100 to 1159	124	137	152	46	2	114	80	1					4
1200 to 1259	221	124	155	80	20	197	140	1				2	7
1300 to 1359	182	140	186	103	28	189	100					5	13
1400 to 1459	194	107	236	76	29	211	162	3				11	23
1500 to 1559	144	74	236	55	58	100	124	1				10	34
1600 to 1659	80	56	116	62	71	120	141					22	25
1700 to 1759	112	84	114	48	51	41	150					11	35
1800 to 1859	85	48	52	63	39		92					13	4
1900 to 1959	29	27		8									
Total	***4,573***	***963***	***1,368***	***603***	***301***	***1,042***	***1,018***	***14***				***74***	***145***

Table 3

Continued.

Date	_1 Jun_	_2 Jun_	_3 Jun_	_4 Jun_	_5 Jun_	_6 Jun_	_7 Jun_	_8 Jun_	_9 Jun_	
Observation Time - Start	_10:20_	_10:25_	_10:20_	_11:00_	_11:00_	_11:00_	_11:00_	_10:30_	_10:15_	
Observation Time - End	_18:20_	_18:20_	_18:15_	_18:15_	_18:15_	_18:15_	_18:10_	_17:58_	_18:00_	**_TOTAL_**
Military Time (hrs)										
0700 to 0759										**_102_**
0800 to 0859										**_4,278_**
0900 to 0959										**_11,366_**
1000 to 1059	2	5							9	**_13,939_**
1100 to 1159	4	13	11	94	94	29	10		55	**_17,705_**
1200 to 1259	11	47	36	129	90	22	45	15	29	**_14,104_**
1300 to 1359	26	37	30	280	145	182	91	70	45	**_16,378_**
1400 to 1459	44	62	46	106	79	88	126	46	31	**_16,992_**
1500 to 1559	20	60	35	153	122	95	112	54	17	**_15,026_**
1600 to 1659	47	72	32	147	107	68	103	43	13	**_13,539_**
1700 to 1759	37	39	53	115	48	48	87	63	5	**_13,102_**
1800 to 1859	17	12	37	65	23	40	17			**_12,200_**
1900 to 1959										**_4,815_**
Total	**_208_**	_347_	**_280_**	_1,089_	_708_	_572_	_591_	**_291_**	**_204_**	**_153,546_**

Table 4

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods at the Conowingo Dam East Fish Passage Facilty in 2000.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
5 May	18	1000 - 1059	2,495	2,427	-68 (2.7%)
5 May	18	1200 - 1259	1,260	1,200	-60 (4.8%)
5 May	18	1300 - 1359	1,550	1,489	-61 (3.9%)
9 May	24	0900 - 0959	1,367	1,357	-10 (0.7%)
9 May	24	1200 - 1259	1,860	1,845	-15 (0.8%)
12 May	24	1600 - 1659	658	658	0 (0.0%)

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Table 5

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2000.

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**

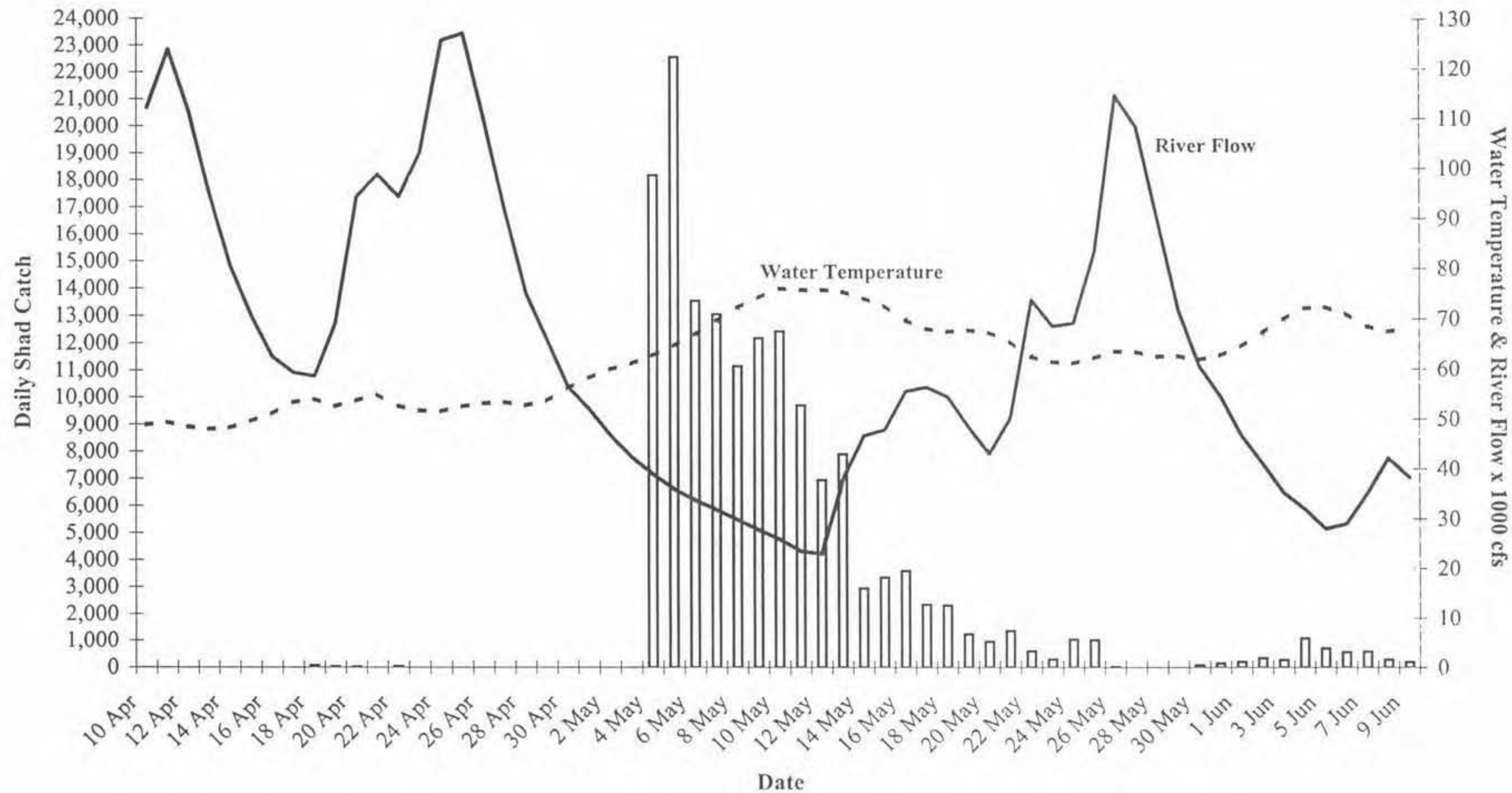

Figure 1

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 2000.

Job I - Part 2
Summary of Conowingo Dam West Fish Lift Operations - 2000

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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 same primary 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 2000 (see Job I, 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 through 2001, 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 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, the EPA Chesapeake Bay Program, PA Fish and Boat Commission, and Maryland DNR. These contributed funds are administered by the U.S. Fish and Wildlife Service's Susquehanna River Coordinator.

The objectives of Conowingo West lift operations in 2000 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, delivery of live shad to PFBC's Benner Spring Research Station for schooling studies. Shad from this site are 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 and to arrange for appropriate transport and stocking from the West lift.

River flows were unusually high during most of April and daily trapping did not begin at the West lift until April 28. Operations proceeded every day (except May 28) through May 31, discontinued during June 1-3 and concluded on June 4. Total fishing effort over 34 operating days in 2000 included 424 lifts and a fishing time of 206.3 hours.

Shad and herring collected in the trap were counted and either placed into trapside holding tanks or, in the case of Lamar broodfish, directly into the USFWS four-compartment transport system. When sufficient herring numbers or excess American shad were available, these were loaded into truck-mounted 1,000 gallon circular transport tanks and hauled to stocking sites. Shad were stocked in the Conestoga River and at the Columbia, PA boat launch and herring were stocked into the Conestoga River, Little Conestoga Creek, and Muddy Creek. Live shad were also delivered to PFBC's Benner Spring Research Station at State College and provided to USFWS Northeast Fishery Center and 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 2000 season. Total catch at the West lift amounted to 458,349 fish of 37 taxa (Table 1). Gizzard shad and white perch comprised 87% of this total. Alosid catch included 9,785 American shad, 14,326 blueback herring, 9,189 alewives, and one hickory shad. Most American shad (90%) were taken during the three-week period May 3-24 with a peak day catch of 1,002 fish on May 15. All alewives were caught on May 1-7 and most blueback herring were collected during May 7-10 and May 25-26 (Table 2).

American shad transfers from the West lift included 1,351 fish stocked at Conestoga River (495), Columbia (797), and Muddy Creek (59); 1,179 provided directly to USFWS-Lamar (889) or hauled there by NAI (290); and, 447 taken to Benner Spring (Table 3). Total observed mortalities for shad transported by NAI was 2 fish. Another 1,726 shad were provided on eight dates to Maryland DNR for tank spawning (Table 4). As shown in Table 5, a total of 4,783 blueback herring were stocked in Little Conestoga Creek (502), Conestoga River (2,481) and Muddy Creek (1,800). Alewife stocking (also Table 5) amounted to 2,026 fish placed in the Little Conestoga.

A total of 197 shad were sacrificed and provided to PFBC for otolith analysis and 23 Maryland DNR tags were recovered. Overall sex ratio of shad in the West lift in 2000 was 2 to 1 favoring males. Males averaged 410 mm fork length and 862 g, while females averaged 462 mm and 1402 g.

Discussion

In 2000, high river flows in April 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 May 4 and continuing to the first week of June. Of the total American shad collected here in 2000, about one-half (4,993) were either hauled to upstream spawning waters or provided to hatcheries for tank spawning or research. Most remaining shad were released alive back to the tailrace.

West lift catch per effort of about 51.4 shad per fishing hour and 26 shad per lift were the highest capture rates ever recorded at this facility. Shad catch per operating day (316) was exceeded only in 1996 (Table 6). Operations and fish catch at the West lift during 1985-2000 are summarized in Table 7. Based on analysis of 193 adult shad otolith samples from Conowingo, hatchery-marked fish comprised 46% of the 2000 run, a decrease from 53% the previous year. Most marked fish carried the single day tag indicating they were stocked into the Juniata River.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 2000.

Number of days	*34*
Number of lifts	*424*
Fishing time (hours : minutes)	*206:32*
Number of taxa	*37*
AMERICAN SHAD	9,785
ALEWIFE	9,189
BLUEBACK HERRING	14,326
GIZZARD SHAD	366,099
HICKORY SHAD	1
STRIPED BASS	2,453
White perch	40,318
American eel	735
Rainbow trout	5
Brown trout	8
Carp	3,236
Comely shiner	1
Spotfin shiner	32
Quillback	154
White sucker	44
Shorthead redhorse	1,317
White catfish	351
Yellow bullhead	16
Brown bullhead	94
Channel catfish	8,394
Rock bass	119
Redbreast Sunfish	123
Green Sunfish	17
Pumpkinseed	13
Bluegill	292
Smallmouth bass	764
Largemouth bass	63
White crappie	30
Black crappie	8
Yellow perch	161
Walleye	177
Atlantic needlefish	7
Sea lamprey	11
Greenside darter	1
Hybrid striped bass	1
Northern hogsucker	2
Splake	2
TOTAL	***458,349***

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 2000.

Date	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*
Number of lifts	*15*	*19*	*15*	*12*	*23*	*13*	*11*	*5*	*18*	*9*
Time of first lift	*10:45*	*8:36*	*12:00*	*11:00*	*8:20*	*11:20*	*11:05*	*11:00*	*8:45*	*10:55*
Time of last lift	*16:15*	*16:00*	*15:35*	*17:15*	*17:10*	*16:15*	*14:55*	*16:15*	*15:30*	*18:17*
Fishing time (hours)	*5:30*	*7:24*	*3:35*	*6:15*	*8:50*	*4:55*	*3:50*	*5:15*	*6:45*	*7:22*
Average water temperature (°F)	*54.1*	*54.9*	*55.8*	*57.6*	*60.8*	*61.7*	*62.2*	*63.4*	*64.9*	*63.0*
American shad	1	0	0	23	99	644	402	615	264	406
Alewife	0	2	0	3286	3025	1145	68	453	190	1020
Blueback herring	2	0	0	650	0	0	2	0	0	1295
Gizzard shad	37600	42400	42400	33200	16400	21700	22095	13600	23000	15620
Hickory shad	0	0	0	0	0	1	0	0	0	0
Striped bass	4	2	0	0	0	1	0	0	7	18
Carp	10	37	9	1	1	4	0	0	0	0
Other species	417	560	157	675	869	810	1,248	1,072	17,380	1,968
TOTAL	**38,034**	**43,001**	**42,566**	**37,835**	**20,394**	**24,305**	**23,815**	**15,740**	**40,841**	**20,327**

Date	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Number of lifts	*7*	*10*	*14*	*15*	*14*	*17*	*17*	*11*	*12*	*11*
Time of first lift	*11:00*	*10:58*	*10:58*	*10:55*	*11:25*	*8:45*	*11:00*	*11:00*	*11:00*	*10:55*
Time of last lift	*15:25*	*15:45*	*17:30*	*18:05*	*16:30*	*16:23*	*17:40*	*16:20*	*16:30*	*16:15*
Fishing time (hours)	*4:25*	*4:47*	*6:32*	*7:10*	*5:05*	*7:38*	*6:40*	*5:20*	*5:30*	*5:20*
Average water temperature (°F)	*69.9*	*71.6*	*72.5*	*75.2*	*76.6*	*74.5*	*75.5*	*74.3*	*74.3*	*72.4*
American shad	76	4	17	694	246	393	621	1002	946	269
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback herring	2750	5240	422	0	0	220	14	0	0	91
Gizzard shad	6850	241	12675	14375	3815	9400	2148	2015	2225	1290
Hickory shad	0	0	0	0	0	0	0	0	0	0
Striped bass	20	4	305	435	34	355	104	75	73	95
Carp	2501	6	360	140	54	26	2	7	7	2
Other species	4,820	160	6,785	3,868	412	1,774	220	572	216	215
TOTAL	**17,017**	**5,655**	**20,564**	**19,512**	**4,561**	**12,168**	**3,109**	**3,671**	**3,467**	**1,962**

Table 2

Continued.

Date	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Number of lifts	*12*	*12*	*13*	*17*	*12*	*15*	*11*	*2*	*9*	*11*
Time of first lift	*10:55*	*10:55*	*10:45*	*11:00*	*10:55*	*10:50*	*10:45*	*11:00*	*10:30*	*10:25*
Time of last lift	*16:00*	*16:20*	*15:50*	*18:50*	*18:45*	*18:00*	*17:05*	*17:10*	*18:25*	*15:35*
Fishing time (hours)	*5:05*	*5:25*	*5:05*	*7:50*	*7:50*	*7:10*	*6:20*	*6:10*	*7:55*	*5:10*
Average water temperature (°F)	*71.5*	*69.8*	*68.7*	*69.6*	*68.7*	*64.2*	*64.7*	*64.2*	*64.9*	*64.9*
American shad	234	217	285	373	91	198	789	0	143	66
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback herring	7	18	10	14	38	216	13	1100	2175	43
Gizzard shad	2260	4835	1385	1215	1270	6595	4820	30	3925	4220
Hickory shad	0	0	0	0	0	0	0	0	0	0
Striped bass	36	48	50	55	110	94	44	160	131	62
Carp	10	4	1	1	7	0	0	11	2	1
Other species	957	591	222	262	988	2,076	595	138	534	719
TOTAL	**3,504**	**5,713**	**1,953**	**1,920**	**2,504**	**9,179**	**6,261**	**1,439**	**6,910**	**5,111**

Date	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*		*TOTAL*
Number of lifts		*15*	*12*	*9*				*6*		*424*
Time of first lift		*10:45*	*10:45*	*10:30*				*10:46*		
Time of last lift		*18:20*	*18:40*	*16:20*				*13:50*		
Fishing time (hours)		*7:35*	*7:55*	*5:50*				*3:04*		***206:31***
Average water temperature (°F)		*64.4*	*63.2*	*65.3*				*68.6*		
American shad		92	110	260				205		**9,785**
Alewife		0	0	0				0		**9,189**
Blueback herring		0	2	2				2		**14,326**
Gizzard shad		4650	5525	1450				870		**366,099**
Hickory shad		0	0	0				0		**1**
Striped bass		39	36	11				45		**2,453**
Carp		4	14	9				5		**3,236**
Other species		902	552	167				359		**53,260**
TOTAL	-	**5,687**	**6,239**	**1,899**	-	-	-	**1,486**		**458,349**

Table 3

Summary of American shad transported from the Conowingo Dam West Fish Lift, 2000.

Date	Number of Shad Transported	Location	Observed Mortality	Percent Survival
5 May	103	PFBC Benner Springs	1	99.0%
6 May	117	Conestoga River	0	100.0%
8 May	59	Muddy Creek	0	100.0%
10 May	2	Conestoga River	0	100.0%
12 May	118	Conestoga River	0	100.0%
12 May	95	PFBC Benner Springs	0	100.0%
15 May	115	Conestoga River	1	99.1%
17 May	143	Conestoga River	0	100.0%
19 May	100	PFBC Benner Springs	0	100.0%
20 May	101	USFWS Lamar Hatchery	0	100.0%
24 May	615	Columbia PFBC Launch	0	100.0%
25 May	90	Columbia PFBC Launch	0	100.0%
26 May	91	PFBC Benner Springs	0	100.0%
27 May	92	Columbia PFBC Launch	0	100.0%
30 May	82	USFWS Lamar Hatchery	0	100.0%
1 June	58	PFBC Benner Springs	0	100.0%
5 June	107	USFWS Lamar Hatchery	0	100.0%
TOTAL	*2,088*		*2*	*99.9%*

Table 4

Summary of American shad transported by Maryland DNR from the Conowingo Dam West Fish Lift, 2000.

Date	Water Temperature (°F)	Number of Shad		Total Number of Shad Transported
		Female	Male	
04 May	62.2	98	152	250
08 May	69.9	88	150	238
15 May	74.3	85	154	239
31 May	72.4	102	151	253
22 May	68.7	100	175	275
24 May	64.7	100	165	265
31 May	65.3	61	40	101
01 Jun	64.4	45	60	105
TOTAL		*679*	*1,047*	*1,726*

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Table 5

Summary of alewife and blueback herring transported from the Conowingo Dam West Fish Lift, 2000.

Date	Number Collected	Water Temperature (°F)	Number Transported	Stocking Location	Observed Mortality	Percent Survival	D.O. (ppm) Start	D.O. (ppm) Finish	Water Temperature (°F) at Stocking Location
				Alewife					
1 May	3,025	57.6	1,020	Little Conestoga	0	100.0%	9.2	11.5	59.0
2 May	1,145	60.8	1,006	Little Conestoga	1	99.9%	11.9	11.0	60.8
TOTAL	*4,170*		*2,026*		*1*				
				Blueback herring					
8 May	2,750	68.9	502	Little Conestoga	0	100.0%	11.2	15.0	69.9
"	"	"	800	Muddy Creek	0	100.0%	13.0	10.2	71.6
9 May	5,240	71.6	1,059	Conestoga River	0	100.0%	10.0	11.0	66.2
"	"	"	1,000	Muddy Creek	0	100.0%	13.3	13.8	73.1
10 May	422	72.5	422	Conestoga River	2	99.5%	11.0	12.5	72.5
26 May	2,175	64.9	1,000	Conestoga River	0	100.0%	14.0	13.0	65.3
TOTAL	*10,587*		*4,783*		*2*				

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**

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 Lift, 1985-2000

Year	Number Days	Total Fish	Number Taxa	American Shad	Hickory Shad	Alewives	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	34	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**

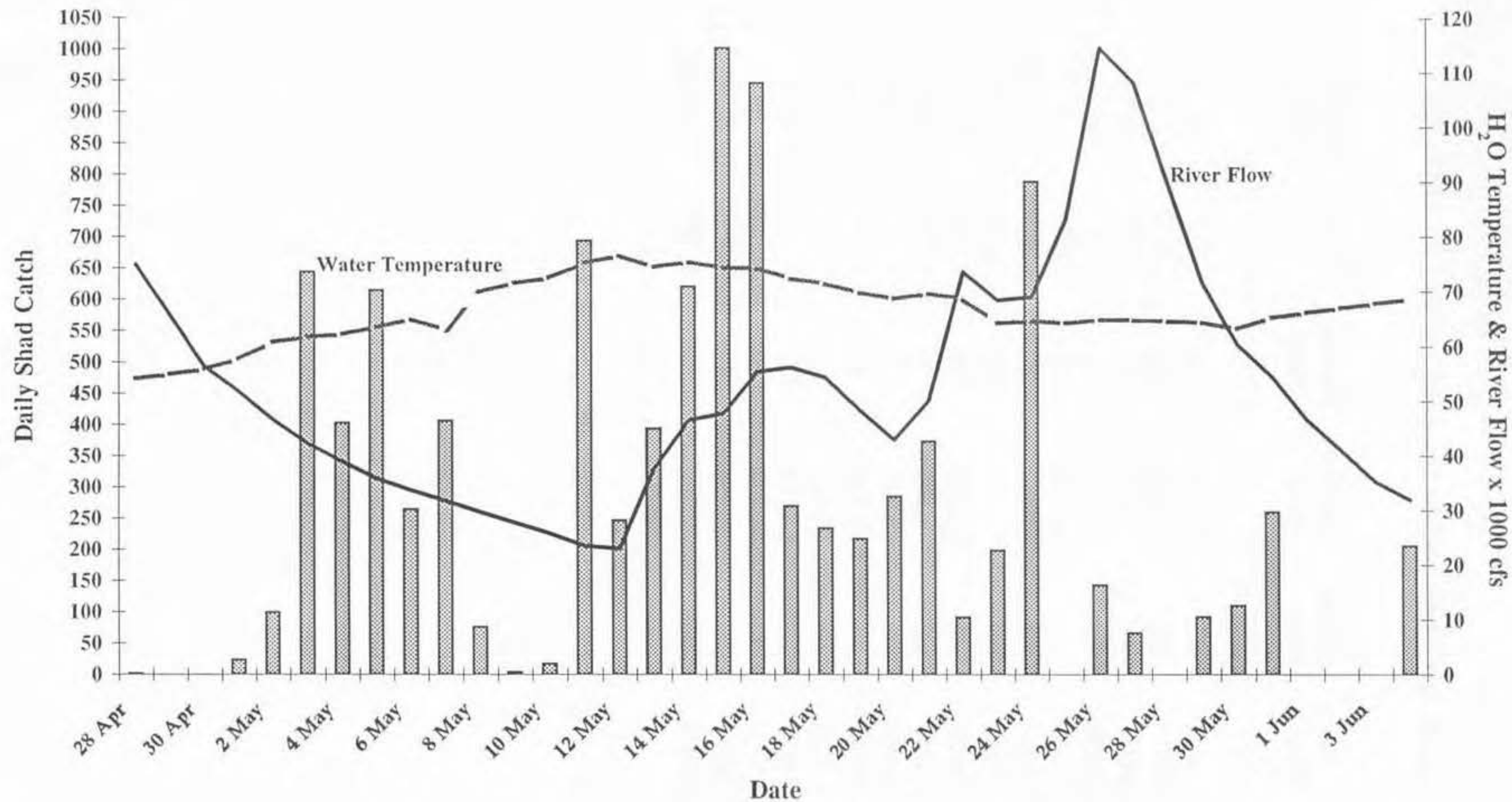

Figure 1

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 2000.

JOB I - Part 3
SUMMARY OF THE OPERATIONS OF THE HOLTWOOD FISH PASSAGE FACILITY IN SPRING 2000

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EXECUTIVE SUMMARY

Fishway operations at Holtwood Dam began on 6 May 2000. The tailrace lift was operated for 36 days while the spillway lift operated on 23 days. We terminated lift operations for the season on 14 June. Due to high river flows and low catch numbers, lift operations were suspended from 26 to 29 May. The tailrace and spillway lifts were functional 100% and 90% of the time during the 2000 season, respectively. We did not operate the spillway lift on 7, 8, and 9 May stemming from a mechanical problem with the tailrace hopper. Since most shad were being collected in the tailrace lift, parts from the spillway lift were used to repair the tailrace lift and minimize interruptions to fish passage operations.

The lifts passed 181,434 fish of 29 taxa plus one hybrid. Gizzard shad dominated the catch, and comprised nearly 78% of the total fish collected. *Alosa* species captured included 29,421 American shad and 27 blueback herring. The majority of American shad (21,110) were passed in the tailrace lift. Collection and passage of shad varied daily with 64% of total shad (18,838) passed between 6 and 15 May. Peak shad catch occurred on 15 May when 2,880 shad moved upstream in 10 hours of operation. On a daily basis, most shad passed through the fishway between 1000 hrs and 1659 hrs. American shad were collected and passed at water temperatures ranging from 61.0°F to 77.1°F, and river flows between 22,900 and 83,100 cfs.

We experienced excellent fish passage survival in 2000. Observations indicate that anadromous fish reaching the project area were captured and successfully passed into Lake Aldred. American shad passage this year was the second highest recorded since fishway start-up in 1997. Future operations will build on the past four years of operational experience.

INTRODUCTION

On 1 June 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (Holtwood) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream facility consisting of a tailrace and spillway lift successfully operated during spring 1997, 1998, and 1999. This year marked the fourth fish passage effort.

On 17 November 1999, a meeting of the Holtwood Fish Passage Technical Advisory Committee (HFPTAC) comprised of PPL, U. S. Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held at Holtwood. The meeting included discussions of, and a consensus on operation of the fishway during the 2000 spring migration season. Objectives of 2000 upstream fishway operation were (1) monitor passage of migratory and resident fishes through the fishway; and (2) continue to assess fishway operation.

HOLTWOOD OPERATIONS

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. Due to high river flows during spring 2000, flows exceeded station capacity nearly 70% of the time (25 of 36 operating days). The fishway was not operated from 26 to 29 May due to high river flows (71,700 cfs to 114,500 cfs), and the lack of shad in the catch from 22 to 25 May. Plant staff installed the summer flashboards on 12 May, and repaired the boards on 7 June after several days of high river flows damaged two sections. The two rubber dams were usually inflated during fishway operations to reduce the discharge of water into the east channel of the spillway. During spring 2000, fish lift operations had to contend with some level of spillage on all but four days of operation.

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 2000, 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 usually kept inflated. However, on six occasions one or both of the rubber dams were deflated. On four separate occasions during periods of high flow, the 300-ft. long section of rubber dam was deflated in an attempt to minimize or prevent damage to or loss of the flashboards. On one occasion (8 June), the 300' section of rubber dam was partially deflated in an attempt to limit spillage to the east channel section of the spillway. On 13 May, both rubber dams were deflated and then reinflated in conjunction with Safe Harbor reducing generation in order for three people stranded on Piney Island to safely return to the west shoreline.

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 all three entrances (A, B, and C), entrances A and B, or a combination of A and C were used in 2000.

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 100% and 90% of the time throughout the 2000 season, respectively. 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 6 May. We operated the tailrace lift for 36 days during the season while the spillway lift operated on 23 days. The spillway lift was not operated due to mechanical problems on 7, 8,and 9 May stemming from a problem with the tailrace hopper.

We utilized parts from the spillway hopper to repair the tailrace hopper, and keep passage operations underway with a minimum of disruption. This proved an effective strategy, since most of the American shad catch was occurring in the tailrace lift. The spillway lift was not operated during the installation/repair of the summer flash boards (12 May and 7 June), or during periods of heavy spillage that severely impacted the spillway lift attraction flow. The fishways operated from 1100 hrs to 1830 hrs from 6 to 12 May. We varied operational hours from 13 May until operations ceased on 14 June, based on daily shad catch and river flow.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. A three person staff consisting of a lift supervisor, supervising biologist, and biological technician manned the lifts daily. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

Fish Counts

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

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

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

Each day a permanent record (video tape) of daily fish passage is made. The video taping system is comprised of the following Panasonic equipment: (1) a black and white camera (Model # WV-BP310 Series 1/3" CCD); (2) a super wide angle lens (Model # WV-LD2.8); (3) a time-lapse Super VHS recorder/player (Model # 6-6730S-VHS/VSS); and (4) a color monitor (Model # CT-20611).

RESULTS

Relative Abundance

The diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2000 operational period is presented in Table 1. A total of 181,434 fish of 29 taxa and one hybrid passed upstream into Lake Aldred. Gizzard shad (141,176) dominated the catch comprising nearly 78% of the fishes passed. American shad numbered 29,421 (16% of the total) and represented the second largest portion of the catch. The American shad numbers were the second largest observed in the four years of fish lift operations. Other abundant fishes passed included shorthead redhorse (3,600), channel catfish (3,007), walleye (976), and smallmouth bass (825). Peak passage was on 14 May when 12,182 fish (78% gizzard shad) were passed. Other migratory species collected by the fishway included 27 blueback herring and 4 striped bass.

American Shad Passage

The lifts passed 18,838 American shad during the first ten days of operation, representing 64% of the season total. During this peak period, the fishway collected and passed more than 1,000 shad on 5 days, and passed more than 2,000 shad on 4 days. River flows averaged 32,670 cfs during the first 10 days of lift operations. Peak catch occurred on 15 May when 2,880 shad were captured and passed. The spillway lift captured nearly 2,000 of the shad passed on 15 May with the majority of those shad collected in the first two spillway lifts prior to the onset of a heavy spill event. Following the peak, (from 16 May to 14 June), we captured a total of 10,583 shad at river flows averaging 53,063 cfs.

We passed American shad at water temperatures between 61.0°F and 77.1°F, and river flows ranging from 22,900 cfs to 83,100 cfs (Table 2 and Figure 1). Water temperature and river flows during the peak catch period (from 6 May to 15 May) averaged 73.1°F (66.7°F to 75.9°F) and 32,670 cfs (22,900 cfs to 47,700 cfs), respectively. The Holtwood fish lifts were not operated from 26 to 29 May due to high river flows and lack of fish.

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 113-ft. to 120-ft. Typically, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2000, most tailrace fishway operation coincided with the operation of 10 turbines due to higher than normal spring river flows which enabled full project operation. The spillway lift operated at spillway elevations of 116-ft. to 129-ft. We noted that the spillway lift successfully attracted and passed shad during periods when spillway elevations were less than or equal to 127.5-ft.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164-ft. to 172-ft. (Table 2). Visual observations indicated that shad readily passed through the fishway into Lake Aldred at this range of forebay elevations. On 12 May and 7 June, during installation and repair 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 (22,013) passed through the fishway between 1000 hrs and 1659 hrs. Generally, shad passage increased from 1000 hrs to 1159 hrs, decreased slightly between 1200 hrs and 1359 hrs, increased again and peaked by 1659 hrs, then declined 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, 21,110 and 8,311 shad (71.8% and 28.2%), were captured in the tailrace and spillway lifts over the total operating period, respectively (Table 4). The contribution of each lift's catch to daily passage varied throughout the season. Both lifts appeared to catch shad effectively based on visual observations of fish movement up to and in the vicinity of the lift entrances.

Operation and effectiveness of the spillway lift was dependent on flow conditions in the spillway, particularly the east channel. Nearly 41% (3,371 shad) of the total spillway catch was collected during two days of operation (15 and 20 May; Table 4). Due to high spring river flows, spill events occurred on all but four days of operation. Spill episodes greater than 10,000 cfs were common in spring 2000 and may have been responsible for the inconsistent spillway lift performance. The spillway lift shad catch appeared highest either just after, or just prior to a spill event.

Passage Evaluation

In 2000, 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 both spring 2000 and 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 changed 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, particularly in the spillway. The use of gate No. 8 reduced the vortex in the fish trough. The consistently high river flows this spring did not allow 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. The occurrence of several spill events limited visual observations due to surface water turbulence and poor water clarity. 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. No surveys were conducted in the West spillway channel this spring due to personnel safety concerns.

Video Record

In accordance with the 2000 Holtwood Fish Lift Operational Plan, a review of the 2000 video record was not conducted. The hourly rate of passage never exceeded the 1,000 shad per hour trigger value used to initiate tape review. The highest hourly rate of shad passage (909) occurred on 15 May from 0900 to 0959 hrs. Fish passage was recorded on a daily basis and the video tapes archived and stored off site.

SUMMARY

In 2000, the Holtwood tailrace fish lift was operated for 36 days while the spillway lift operated on 23 days. The tailrace and spillway lifts were functional 100% and 90% of the time, respectively. Fishway systems and equipment functioned as designed and only minor difficulties were encountered. Minor problems resulted from safeguards designed into the electrical and/or mechanical aspects of equipment operation.

A total of 29,421 American shad were passed into Lake Aldred. Twenty-seven blueback herring were captured and passed the fishway. Observations indicated fish that reached the project area were effectively captured and passed upstream. The limited catch of shad and high river flows early in the season at Conowingo Dam delayed the start of Holtwood operations until 6 May. The majority of American shad (21,110) were captured in the tailrace lift. Collection and passage of shad varied daily with 64% of the shad total (18,838) captured and passed between 6 and 15 May. The peak shad passage day occurred on 15 May when 2,880 shad were captured and passed. Most shad passed through the fishway between 1000 and 1659 hrs. American shad were captured at water temperatures between 61.0°F to 77.1°F, and river flows ranging from 22,900 cfs to 83,100 cfs.

A low, stable, river flow appears to be critical for enhancing shad passage rates. The high flow events in spring 2000 were detrimental to fish passage, but 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 2000 was excellent. Observations indicated that migratory fishes that reached the project were captured and passed into Lake Aldred by the Holtwood lifts. The 2000 American shad passage total was the second highest recorded since the fishway's start-up in 1997. Future operations of the fishway will build on the past four 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.

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

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 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 2000.

Date:	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Hours of Operation - Tailrace:	*6.67*	*8.33*	*8.50*	*8.50*	*8.52*	*7.25*	*8.42*	*9.17*	*9.17*	*10.08*
Hours of Operation - Spillway:	*1.33*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*5.42*	*9.17*	*10.00*
Number of Lifts - Tailrace:	*9*	*11*	*10*	*10*	*11*	*12*	*14*	*13*	*13*	*15*
Number of Lifts - Spillway:	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*6*	*7*	*12*
Water Temperature (°F):	*66.7*	*69.4*	*72.0*	*74.0*	*75.9*	*75.6*	*75.6*	*75.3*	*73.9*	*72.5*
American shad	738	2,067	1,952	2,082	1,769	1,208	1,699	2,607	1,836	2,880
Blueback herring	0	0	0	0	1	5	10	0	0	2
Alewife	0	0	0	0	0	0	0	0	0	0
Gizzard shad	3,073	2,684	5,764	6,619	3,857	6,027	6,940	7,236	9,511	6,845
Sea lamprey	0	1	0	0	0	1	0	0	0	0
Rainbow trout	0	0	0	3	8	0	0	3	1	0
Brown trout	11	10	2	3	5	4	2	20	12	0
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	2
Muskellunge	0	0	0	0	0	0	0	0	0	0
Carp	26	1	71	51	41	24	16	62	91	25
Quillback	1	8	129	151	33	28	69	17	74	7
White sucker	1	1	2	3	3	2	5	8	0	0
Northern hogsucker	0	0	0	0	0	0	1	0	0	0
Shorthead redhorse	184	141	136	61	66	157	73	262	247	179
White catfish	0	0	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	1	0	0	0
Channel catfish	62	25	8	13	14	61	20	61	260	221
White perch	0	0	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0	0	0
Redbreast sunfish	0	27	13	6	11	5	3	74	32	5
Green sunfish	7	0	3	1	8	7	2	0	0	0
Pumpkinseed	0	0	4	2	2	4	1	0	0	0
Bluegill	1	0	6	3	4	10	11	4	2	2
Rock bass	12	12	1	8	17	11	2	10	19	8
Smallmouth bass	88	44	54	9	11	10	7	73	19	13
Largemouth bass	0	0	3	4	5	1	11	0	0	0
White crappie	0	3	6	0	10	10	1	11	3	2
Black crappie	0	0	0	7	1	0	6	0	0	0
Yellow perch	18	2	0	1	2	5	1	8	4	1
Walleye	23	14	30	13	23	13	3	53	71	33
Total	*4,245*	*5,040*	*8,184*	*9,040*	*5,891*	*7,593*	*8,884*	*10,509*	*12,182*	*10,225*

Table 1

Continued.

Date:	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*
Hours of Operation - Tailrace:	*10.33*	*7.45*	*8.00*	*7.33*	*9.75*	*8.83*	*8.00*	*7.75*	*7.33*	*7.38*
Hours of Operation - Spillway:	*10.00*	*0.00*	*0.00*	*6.58*	*9.67*	*7.92*	*0.00*	*0.00*	*0.00*	*0.00*
Number of Lifts - Tailrace:	*12*	*12*	*10*	*11*	*13*	*11*	*9*	*9*	*9*	*9*
Number of Lifts - Spillway:	*1:35*	*0*	*0*	*6*	*13*	*10*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*69.6*	*67.9*	*67.3*	*67.6*	*67.2*	*65.4*	*62.3*	*61.3*	*61.0*	*62.1*
American shad	532	371	119	288	1,638	188	53	31	30	29
Blueback herring	0	3	0	0	0	0	2	1	0	0
Alewife	0	0	0	0	0	0	0	0	0	0
Gizzard shad	7,026	4,330	4,087	5,150	6,451	2,586	374	710	3,852	4,811
Sea lamprey	0	0	0	0	0	1	0	0	0	0
Rainbow trout	3	1	3	1	0	1	0	0	2	1
Brown trout	0	0	0	0	3	2	0	0	0	0
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	1	0
Muskellunge	0	0	0	0	1	0	0	0	0	0
Carp	7	3	2	3	1	1	0	0	0	0
Quillback	4	4	2	2	6	1	0	1	0	0
White sucker	3	1	0	0	0	1	0	0	4	14
Northern hogsucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	108	47	20	35	91	67	30	10	0	0
White catfish	0	0	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0	0	0
Channel catfish	437	120	170	110	97	32	46	34	18	20
White perch	0	0	4	0	0	0	0	0	1	0
Striped bass	0	1	0	0	0	0	0	0	0	0
Redbreast sunfish	10	15	12	5	7	4	1	2	0	1
Green sunfish	14	4	4	0	0	0	0	0	0	0
Pumpkinseed	0	1	0	0	0	0	0	0	0	0
Bluegill	21	7	1	4	0	0	0	1	0	0
Rock bass	10	4	4	6	7	1	0	2	2	2
Smallmouth bass	32	10	7	0	3	4	4	13	12	2
Largemouth bass	2	1	0	1	0	1	2	0	0	0
White crappie	2	0	0	0	0	1	0	0	0	1
Black crappie	0	2	0	0	0	0	0	0	0	0
Yellow perch	0	1	1	0	0	0	0	0	0	0
Walleye	109	28	29	20	34	19	14	11	9	19
Total	*8,320*	*4,954*	*4,465*	*5,625*	*8,339*	*2,910*	*526*	*816*	*3,931*	*4,900*

* Lift operation suspended due to high river flows

Table 1

Continued.

Date:	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*
Hours of Operation - Tailrace:	*	*	*	*	*7.00*	*8.62*	*8.83*	*8.88*	*10.25*	*8.58*
Hours of Operation - Spillway:					*0.00*	*8.68*	*9.58*	*8.82*	*10.50*	*8.67*
Number of Lifts - Tailrace:					*9*	*9*	*9*	*11*	*9*	*8*
Number of Lifts - Spillway:					*0*	*11*	*14*	*11*	*13*	*12*
Water Temperature (°F):					*61.8*	*62.6*	*64.4*	*67.2*	*69.8*	*72.0*
American shad					30	232	367	764	855	424
Blueback herring					0	0	0	0	0	0
Alewife					0	0	0	0	0	0
Gizzard shad					4,202	3,984	5,350	5,653	2,368	2,731
Sea lamprey					0	0	0	0	0	0
Rainbow trout					0	1	0	5	1	1
Brown trout					1	0	4	2	2	0
Splake (brook x lake trout)					0	0	0	0	0	0
Muskellunge					0	0	0	0	0	0
Carp					0	0	0	2	2	2
Quillback					0	7	10	24	12	32
White sucker					1	2	0	0	3	3
Northern hogsucker					0	0	1	0	0	0
Shorthead redhorse					2	33	105	307	90	201
White catfish					0	0	0	0	0	0
Brown bullhead					0	0	0	0	0	0
Channel catfish					61	210	10	145	5	6
White perch					0	0	0	0	0	0
Striped bass					0	0	0	1	0	0
Redbreast sunfish					0	0	1	3	5	5
Green sunfish					0	1	0	0	0	0
Pumpkinseed					0	0	0	0	0	0
Bluegill					0	0	4	6	3	5
Rock bass					2	1	1	1	1	0
Smallmouth bass					2	4	14	48	10	19
Largemouth bass					0	4	0	6	1	0
White crappie					0	0	1	0	3	1
Black crappie					0	0	0	0	0	0
Yellow perch					0	0	0	0	1	1
Walleye					32	11	10	63	5	17
Total	*0*	*0*	*0*	*0*	*4,333*	*4,490*	*5,878*	*7,030*	*3,367*	*3,448*

* Lift operation suspended due to high river flows

Table 1

Continued.

Date:	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*	*TOTAL*
Hours of Operation - Tailrace:	*9.58*	*9.15*	*2.67*	*8.48*	*7.40*	*9.05*	*8.13*	*7.00*	*7.13*	*7.08*	***294.6***
Hours of Operation - Spillway:	*9.42*	*9.08*	*6.58*	*8.53*	*6.30*	*8.90*	*8.17*	*6.93*	*7.05*	*4.75*	***182.1***
Number of Lifts - Tailrace:	*11*	*9*	*3*	*10*	*9*	*13*	*9*	*7*	*7*	*7*	***363***
Number of Lifts - Spillway:	*9*	*8*	*11*	*8*	*6*	*14*	*12*	*9*	*8*	*6*	***208***
Water Temperature (°F):	*72.3*	*71.0*	*68.5*	*67.4*	*68.0*	*70.4*	*73.3*	*75.4*	*77.1*	*76.7*	
American shad	686	401	577	321	610	1,291	357	133	95	161	***29,421***
Blueback herring	0	0	0	3	0	0	0	0	0	0	***27***
Alewife	0	0	0	0	0	0	0	0	0	0	***0***
Gizzard shad	2,670	1,497	870	3,200	2,570	3,372	2,309	1,293	366	808	***141,176***
Sea lamprey	0	0	0	0	0	0	0	0	0	0	***3***
Rainbow trout	0	0	2	0	0	4	5	0	1	0	***47***
Brown trout	0	0	0	0	0	0	0	0	0	0	***83***
Splake (brook x lake trout)	0	0	0	0	0	0	0	0	0	0	***3***
Muskellunge	0	0	0	0	0	0	0	0	0	0	***1***
Carp	2	5	1	0	3	1	3	8	29	66	***549***
Quillback	35	4	16	2	0	1	4	23	42	36	***785***
White sucker	0	0	0	0	0	0	1	0	0	0	***58***
Northern hogsucker	0	0	0	0	0	0	0	0	0	0	***2***
Shorthead redhorse	87	42	63	33	8	121	159	99	115	221	***3,600***
White catfish	0	0	0	1	0	0	0	0	0	0	***1***
Brown bullhead	0	0	0	0	1	0	0	0	0	0	***2***
Channel catfish	23	11	267	43	76	49	173	26	15	58	***3,007***
White perch	0	0	0	0	0	0	0	0	0	2	***7***
Striped bass	0	0	0	0	0	0	1	0	0	1	***4***
Redbreast sunfish	18	2	0	12	5	8	12	4	3	2	***313***
Green sunfish	1	0	0	1	0	0	3	0	0	1	***57***
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	***14***
Bluegill	3	6	0	6	3	3	10	10	4	2	***142***
Rock bass	0	0	0	1	2	0	3	2	0	1	***153***
Smallmouth bass	20	6	39	22	11	92	43	30	34	16	***825***
Largemouth bass	1	1	0	1	0	0	0	7	0	0	***52***
White crappie	0	1	0	0	0	1	1	0	0	0	***58***
Black crappie	0	0	0	2	0	0	0	0	1	0	***19***
Yellow perch	0	0	2	0	0	1	0	0	0	0	***49***
Walleye	14	18	5	19	30	51	43	27	24	39	***976***
Total	*3,560*	*1,994*	*1,842*	*3,667*	*3,319*	*4,995*	*3,127*	*1,662*	*729*	*1,414*	*181,434*

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 2000.

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)
6 May	33,600	66.7	18	10	150		0/220	118-119	116-118	165-167
7 May	31,700	69.4	18	10	150			118-119	116-118	164.5-168
8 May	29,700	72.0	32	10	150			115-119	116-120	164.5-169
9 May	27,700	74.0	28	10	150			117-119	116-120	165-167
10 May	25,800	75.9	28	5-10	150			113-119	116	165-167
11 May	23,400	75.6	28	10	150			119	117	165
12 May	22,900	75.6	32	9-10	150			117	116	164
13 May	37,700	75.3	28	10	150		0/220	118-119	116	164-170
14 May	46,500	73.9	20	10	150	150/0	220	119	126	171-172
15 May	47,700	72.5	18	10	150		220	119	117-123	169-171
16 May	55,400	69.6	18	10	150	0/150	220/0	119	126	171-172
17 May	56,200	67.9	10	10	150			119	126	172
18 May	54,300	67.3	8	10	150	150/0		120	131	172
19 May	48,300	67.6	12	10	150		220	119	124-128	172
20 May	42,900	67.2	9	10	150		220	116-119	116-125	168-171
21 May	50,100	65.4	10	10	150		220	119	116-129	169-171
22 May	73,600	62.3	4	10	150	150/0		120	131	172
23 May	68,400	61.3	4	10	150			120	131	172
24 May	69,000	61.0	4	10	150			119	131	172
25 May	83,100	62.1	8	10	150			120	131	172
30 May	60,400	61.8	4	10	150			120	128	171
31 May	54,400	62.6	18	10	150		220	119	122-128	170
1 Jun	46,600	64.4	12	9-10	150		220	116-118	125-129	170-171
2 Jun	41,000	67.2	18	10	150		220	116-119	120-128	168-171
3 Jun	35,200	69.8	18	10	150		220	116-119	120-124	168-170

Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
4 Jun	31,900	72.0	18	10	150		220	116-117	120-122	168-170
5 Jun	28,000	72.3	18	10	150		220	117-119	120-122	168-169
6 Jun	29,000	71.0	18	3-10	150		220	112-119	120-122	168-169
7 Jun	35,100	68.5	15	10	150/0		0/220	117	116	164-165
8 Jun	42,100	67.4	15	10	150		220/0	119	124-125	171
9 Jun	38,300	68.0	18	10	150		220	116-117	124-127	171-172
10 Jun	33,800	70.4	18	10	150		220	117-119	116-121	168-171
11 Jun	31,500	73.3	18	10	150		220	119	116	169
12 Jun	32,400	75.4	18	10	150		220	119	116-117	168-170
13 Jun	30,100	77.1	18	10	150		220	119	116	168
14 Jun	36,800	76.7	18	10	150		220/0	117-119	116-125	169-171

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 2000.

Date:	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Observation Time (Start):	*12:00*	*11:33*	*11:00*	*10:50*	*10:35*	*10:45*	*11:00*	*10:14*	*9:47*	*8:40*	*8:30*
Observation Time (End):	*18:40*	*19:30*	*19:25*	*19:20*	*19:12*	*19:00*	*19:15*	*19:15*	*19:15*	*19:00*	*19:15*
MILITARY TIME (HRS)											
0800 to 0859										35	50
0900 to 0959										909	71
1000 to 1059					285			263	80	767	22
1100 to 1159		24	211	360	425	66	191	202	66	187	18
1200 to 1259	69	109	101	327	138	190	140	298	83	167	26
1300 to 1359	127	142	82	209	78	97	237	289	198	130	31
1400 to 1459	54	285	172	233	154	269	267	502	218	168	36
1500 to 1559	141	253	229	288	323	195	117	380	341	138	56
1600 to 1659	212	420	546	318	161	132	153	200	333	139	81
1700 to 1759	131	341	214	207	73	142	221	273	262	116	69
1800 to 1859	4	301	283	102	70	117	291	184	175	124	60
1900 to 1959		192	114	38	62		82	16	80		12
TOTAL CATCH	**738**	**2,067**	**1,952**	**2,082**	**1,769**	**1,208**	**1,699**	**2,607**	**1,836**	**2,880**	**532**

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*30 May*	*31 May*
Observation Time (Start):	*11:48*	*8:55*	*11:45*	*9:04*	*8:26*	*9:00*	*8:15*	*8:15*	*8:25*	*9:30*	*9:10*
Observation Time (End):	*19:15*	*16:59*	*18:55*	*19:00*	*17:20*	*16:45*	*16:00*	*15:50*	*15:59*	*16:15*	*18:00*
MILITARY TIME (HRS)											
0800 to 0859					17		2	5	1		
0900 to 0959		7		305	49	10	0	4	1		4
1000 to 1059		9		591	46	5	7	4	6	6	20
1100 to 1159	47	6	1	510	21	7	1	3	2	5	39
1200 to 1259	102	17	8	118	13	6	1	3	2	6	19
1300 to 1359	37	4	24	25	12	4	5	4	9	1	32
1400 to 1459	40	12	34	19	6	14	8	3	3	6	58
1500 to 1559	30	28	59	18	12	1	7	4	5	3	27
1600 to 1659	41	36	48	15	7	6				3	22
1700 to 1759	28		67	11	5						11
1800 to 1859	32		47	26							
1900 to 1959	14										
TOTAL CATCH	**371**	**119**	**288**	**1,638**	**188**	**53**	**31**	**30**	**29**	**30**	**232**

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Table 3

Continued.

Date:	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*
Observation Time (Start):	*8:25*	*8:35*	*8:17*	*8:15*	*8:30*	*8:20*	*9:10*	*9:15*	*10:20*	*9:15*	*8:45*
Observation Time (End):	*18:00*	*18:00*	*18:00*	*16:30*	*17:45*	*17:50*	*19:00*	*18:11*	*17:55*	*18:00*	*17:00*
MILITARY TIME (HRS)											
0800 to 0859	11	1	69	64	35	32					3
0900 to 0959	15	121	27	34	146	60	4	10		131	64
1000 to 1059	25	189	41	83	122	17	2	63	16	388	109
1100 to 1159	21	117	94	79	102	61	3	57	192	170	72
1200 to 1259	38	87	212	40	58	90	30	45	99	162	21
1300 to 1359	38	92	109	27	33	49	170	23	64	174	28
1400 to 1459	36	39	123	40	22	35	117	17	54	100	33
1500 to 1559	55	43	69	38	60	16	76	28	85	66	13
1600 to 1659	73	35	51	19	65	33	87	56	65	68	14
1700 to 1759	55	40	60		43	8	40	18	35	32	
1800 to 1859							48	4			
1900 to 1959											
TOTAL CATCH	**367**	**764**	**855**	**424**	**686**	**401**	**577**	**321**	**610**	**1,291**	**357**

Date:	*12 Jun*	*13 Jun*	*14 Jun*	
Observation Time (Start):	*8:42*	*8:30*	*8:41*	
Observation Time (End):	*16:00*	*16:00*	*16:00*	*TOTAL*
MILITARY TIME (HRS)				
0800 to 0859	3	8	3	**339**
0900 to 0959	45	34	38	**2,089**
1000 to 1059	36	8	9	**3,219**
1100 to 1159	15	8	50	**3,433**
1200 to 1259	9	6	26	**2,866**
1300 to 1359	4	14	12	**2,614**
1400 to 1459	14	10	10	**3,211**
1500 to 1559	7	7	13	**3,231**
1600 to 1659				**3,439**
1700 to 1759				**2,502**
1800 to 1859				**1,868**
1900 to 1959				**610**
TOTAL CATCH	**133**	**95**	**161**	**29,421**

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2000.

Date	Shad Catch	Number Collected Tailrace	Number Collected Spillway	Percent Collected Tailrace	Percent Collected Spillway
6 May	738	738	0	100%	0%
7 May	2067	2,067	0	100%	0%
8 May	1952	1,952	0	100%	0%
9 May	2082	2,082	0	100%	0%
10 May	1769	1,769	0	100%	0%
11 May	1208	1,208	0	100%	0%
12 May	1699	1,699	0	100%	0%
13 May	2607	2,164	443	83%	17%
14 May	1836	1,781	55	97%	3%
15 May	2880	950	1,930	33%	67%
16 May	532	532	0	100%	0%
17 May	371	371	0	100%	0%
18 May	119	119	0	100%	0%
19 May	288	259	29	90%	10%
20 May	1638	197	1,441	12%	88%
21 May	188	94	94	50%	50%
22 May	53	53	0	100%	0%
23 May	31	31	0	100%	0%
24 May	30	30	0	100%	0%
25 May	29	29	0	100%	0%
30 May	30	30	0	100%	0%
31 May	232	70	162	30%	70%
1 Jun	367	92	275	25%	75%
2 Jun	764	229	535	30%	70%
3 Jun	855	128	727	15%	85%
4 Jun	424	127	297	30%	70%
5 Jun	686	480	206	70%	30%
6 Jun	401	120	281	30%	70%
7 Jun	577	6	571	1%	99%
8 Jun	321	299	22	93%	7%
9 Jun	610	573	37	94%	6%
10 Jun	1291	633	658	49%	51%
11 Jun	357	36	321	10%	90%
12 Jun	133	27	106	20%	80%
13 Jun	95	15	80	16%	84%
14 Jun	161	121	40	75%	25%
Total	*29,421*	*21,110*	*8,311*	*71.8%*	*28.2%*

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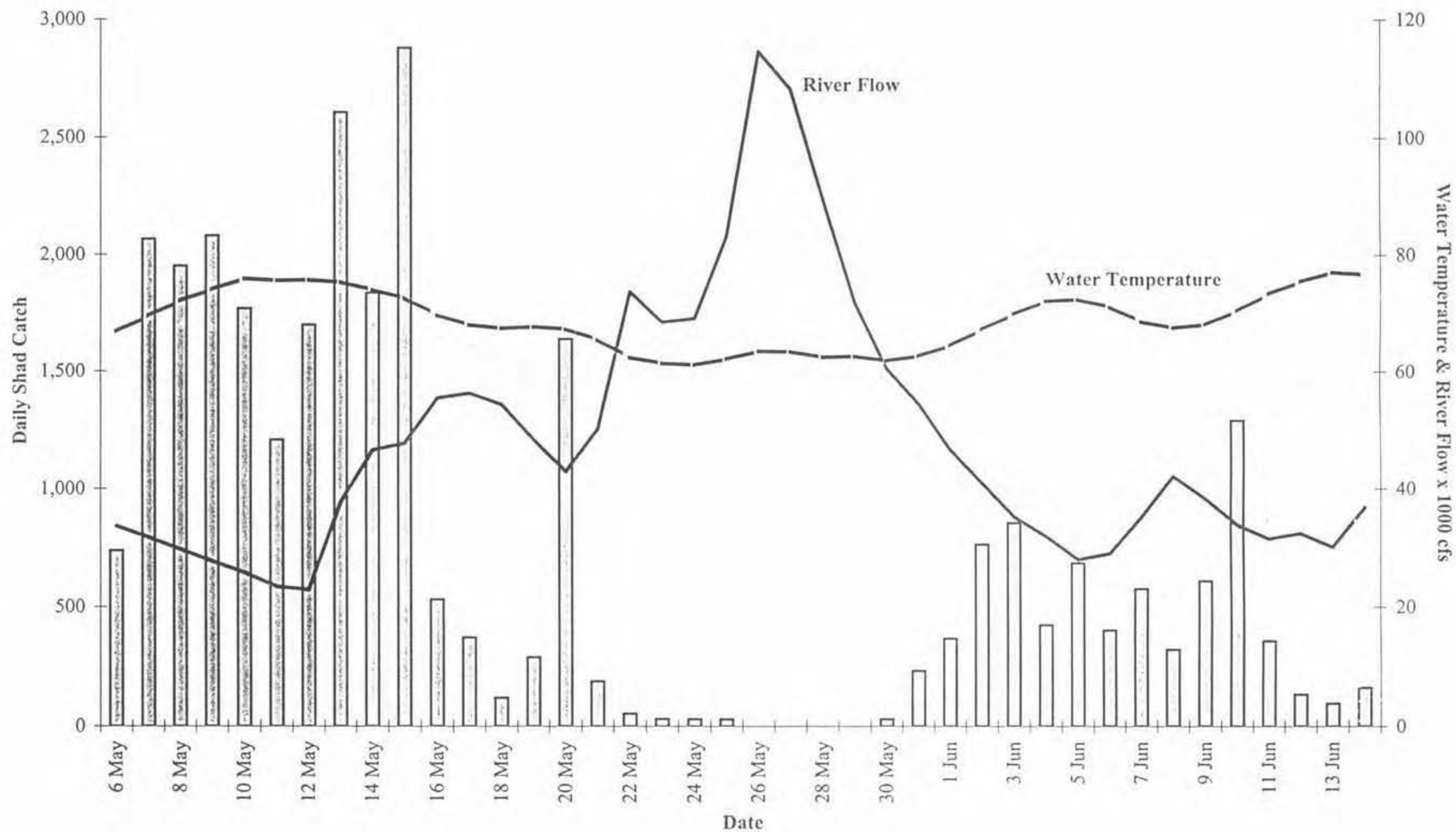

Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Holtwood fish lift, spring 2000.

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Normandeau Associates, Inc.

JOB I - Part 4
SUMMARY OF OPERATION AT THE SAFE HARBOR FISH PASSAGE FACILITY IN 2000

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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.

On 24 March 2000, prior to the start of fishway operation, a meeting of the Safe Harbor Fish Passage Technical Advisory Committee (SHFPTAC) comprised of SHWPC, U. S. Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held at Safe Harbor. During the meeting the PFBC indicated that it would not be necessary for Safe Harbor to collect American shad for otolith analysis during the 2000 season. Also, with the success of Safe Harbor's 1999 season (passing 98% of the fish passed by the Holtwood Fishway), the committee made no recommendations for changes in operation during the 2000 season. Objectives for 2000 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATIONS

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. All operation during the first portion of the 2000 season (May 8 to May 19) utilized a combination of entrances A and C. Operation during the second portion of the season (May 20 to June 15) utilized a combination of entrances A and C or B and C (Table 2).

On 16 May, the trough was fitted with an aeration system to deter debris from floating into and collecting around the trough's exit. The aeration system was operated for the remainder of the season and was found to be effective at deflecting debris away from the trough exit.

Fishway Operation

Fishway operation was scheduled to commence when 500 American shad were passed via the Holtwood Fishway, which occurred by 7 May. The Safe Harbor fishway began operation on 8 May and continued until 26 May, when it was temporarily discontinued due to high river flows and a low number of American shad in the river system. Operation resumed on 30 May. Operation ceased on 15 June, at which time the fish catch was dwindling and the water temperature was rising; indications that the migration run was ending.

Throughout the 2000 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 2000 season, three mechanical incidences occurred; each without loss of fishing time:

(1) On 11 May the crowder drive cable broke. While the crowder was inoperable, the crowder doors were kept in fishing position, and lift operation continued. The crowder was repaired 12 May.

(2) On 11 May the door to the hopper would not open. Until it was repaired on 13 May, the door was operated manually.

(3) On 4 June, the gearing was stripped on Motor Operated Valve 1 (MOV1). MOV1 was stuck at a setting that did not allow enough water into the fishway system; to compensate MOV2 was opened a greater amount, thus maintaining an adequate attraction flow through the fishing gates. Operation continued for the remainder of the season with this modified MOV1 and MOV2 setting.

On a trial basis, the fishway was operated from Safe Harbor's control room for 18 days (15 May to 5 June) without incident. This exercise established that it is possible to operate the fishway remotely.

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 to adequately capture fish passage on videotape. 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.

Each day a permanent record (video tape) of daily fish passage was made. The video system was comprised of the following Panasonic equipment: (1) a black and white camera (Model # WV-BP310 Series 1/3" CCD); (2) a super wide angle lens (Model # WV-LD2.8); (3) a time-lapse Super VHS recorder/player (Model # 6-6730S-VHS/VSS); and (4) a color monitor (Model # CT-20611). The recorded tapes can be reviewed using a video cassette recorder/player equipped with a jog/shuttle control. This feature allows a day's tape to be reviewed at different speeds during playback, including slow motion and frame by frame. If shad passage exceeded 1,000 in one hour, a technician was to review that segment of tape, to confirm the number of shad passing the window during that time period.

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed in 2000 by the Safe Harbor fishway is presented in Table 1. A total of 169,942 fish of 27 species passed upstream into Lake Clarke. Gizzard shad (120,696) was the dominant species passed and comprised 71% of the catch. Some 21,079 American shad were passed upstream through the fishway. Other predominant fishes passed included quillback (8,020), walleye (6,816), shorthead redhorse (4,482), channel catfish (2,884), and smallmouth bass (2,718). Peak passage occurred on May 8, when 19,161 fish were passed.

Passage of American Shad and Other Alosids

The Safe Harbor fishway passed 21,079 American shad in 2000 during 35 days of operation (Table 1). Though collection and passage of shad varied daily, numbers remained relatively steady through most of May with over 70% (14,797) of the catch passing in the 15 day period prior to 23 May. Peak shad passage occurred on 8 May when 1,651 shad were captured and passed in approximately seven hours of operation.

American shad were passed at water temperatures of 61.0°F to 77.1°F and river flows of 83,100 to 22,900 cfs (Table 2 and Figure 1). Water temperature and river flow from 8 May to 22 May, the 15 day period when most shad passage occurred, averaged 70.8°F (62.3°F to 75.9°F) and 42,813 cfs (22,900 cfs to 73,600 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 1995 hr. Nearly 90% of shad (18,793) passed during the seven hour period between 1000 and 1659 hr. The highest hourly passage (3,497) occurred between 1400 and 1459 hr.

The Safe Harbor fishway passed six tagged American shad during the 2000 season. Five fish with orange floy tags passed on 9 May and one fish with an orange floy tag passed on 16 May. The orange floy tagged fish were captured and released in Conowingo's tailrace by the MDDNR via hook and line in 2000.

Passage of other alosids at the Safe Harbor fishway included 657 alewife and 159 blueback herring (Table 1), although no alewife and only 27 blueback herring passed into Lake Aldred by way of the Holtwood fishway. The Little Conestoga River and the Conestoga River were both stocked with alosids from the Conowingo West fish lift facility. The Little Conestoga River was stocked with a total of 2,026 alewife and 502 blueback herring, and the Conestoga River was stocked with a total of 2,481 blueback herring. Apparently some of the stocked alosids swam downstream into Lake Aldred and found their way into the Safe Harbor fishway. No hickory shad were observed.

Video Record

All shad passage was captured on video in 2000. As recommended in 1998, a count review of these records was to be done only when hourly shad passage exceeded 1,000 fish. During the 2000 season there was no hour when 1,000 or more shad passed the window.

SUMMARY

The 2000 Safe Harbor fishway operating season was successful. Although high river flow and low numbers of shad available in Lake Aldred halted fishway operations in the middle of the season, this did not impact the overall effectiveness of the lift. In 35 days 21,079 American shad were passed into Lake Clarke, or over 71% 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 (657 alewife, 159 blueback herring) were also passed at Safe Harbor.

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.

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

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 2000.

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Hours Of Operation:	*6.9*	*7.1*	*6.7*	*6.5*	*7.0*	*6.8*	*7.5*	*8.3*
Start Time:	*10:05*	*10:35*	*9:50*	*11:00*	*9:55*	*9:57*	*9:25*	*8:40*
End Time:	*17:00*	*17:40*	*16:30*	*17:30*	*16:55*	*16:45*	*17:15*	*17:00*
Numbers Of Lifts:	*18*	*18*	*18*	*15*	*20*	*18*	*21*	*22*
Water Temperature (F):	*72.0*	*74.0*	*75.9*	*75.6*	*75.6*	*75.3*	*73.9*	*72.5*
American shad	1,651	1,065	813	913	1,059	1,512	1,454	503
Blueback herring	28	0	0	0	0	0	0	0
Alewife	0	117	55	289	2	0	0	188
Gizzard shad	10,760	5,050	2,960	6,350	7,838	5,450	3,390	7,275
Rainbow trout	0	0	2	0	0	0	0	0
Brown trout	0	6	2	0	1	0	1	1
Tiger muskie	1	0	0	0	0	0	0	0
Carp	157	108	7	90	351	8	2	1
Spottail shiner	0	0	0	0	0	0	0	0
Quillback	2,985	2,790	67	461	1,130	43	86	22
White sucker	7	2	1	2	3	5	0	2
Shorthead redhorse	1,020	550	7	78	261	31	2	10
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	167	268	45	119	366	102	64	118
White perch	0	0	0	0	0	0	3	0
Striped bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	11	18	6	25
Green sunfish	0	0	0	0	3	5	1	0
Pumpkinseed	5	0	0	6	0	2	5	0
Bluegill	25	75	57	35	19	16	0	27
Rock bass	86	121	53	33	14	45	9	28
Smallmouth bass	1,288	705	61	114	117	46	6	33
Largemouth bass	16	80	29	12	4	17	2	14
White crappie	0	0	0	1	1	0	0	0
Black crappie	1	1	1	0	0	1	0	0
Yellow perch	8	23	1	5	1	2	2	1
Walleye	956	960	168	313	749	230	59	152
Total	***19,161***	***11,921***	***4,329***	***8,821***	***11,930***	***7,533***	***5,092***	***8,400***

Table 1

Continued.

Date:	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*
Hours Of Operation:	*7.5*	*9.3*	*7.3*	*8.1*	*9.7*	*8.9*	*9.2*	*8.7*
Start Time:	*10:00*	*8:45*	*10:15*	*8:24*	*7:46*	*8:37*	*8:21*	*8:50*
End Time:	*17:30*	*18:00*	*17:30*	*16:31*	*17:30*	*17:30*	*17:30*	*17:30*
Numbers Of Lifts:	*20*	*26*	*21*	*19*	*17*	*15*	*21*	*21*
Water Temperature (F):	*69.6*	*67.9*	*67.3*	*67.6*	*67.2*	*65.4*	*62.3*	*61.3*
American shad	1,424	1,137	948	542	794	577	405	281
Blueback herring	0	0	10	1	1	0	0	1
Alewife	5	1	0	0	0	0	0	0
Gizzard shad	10,125	9,350	4,870	6,839	4,047	3,920	687	787
Rainbow trout	0	1	0	0	0	0	0	1
Brown trout	0	0	1	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0
Carp	1	0	0	3	1	0	0	0
Spottail shiner	0	0	0	0	0	0	0	0
Quillback	23	6	16	18	3	3	0	4
White sucker	0	1	0	0	1	0	1	0
Shorthead redhorse	66	73	102	78	42	16	5	25
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	245	66	62	94	34	6	63	183
White perch	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	1	0	0
Redbreast sunfish	0	1	0	0	3	0	2	0
Green sunfish	0	4	8	2	0	0	0	0
Pumpkinseed	0	2	0	1	0	0	0	0
Bluegill	12	14	25	5	0	0	0	1
Rock bass	34	32	14	5	2	1	3	3
Smallmouth bass	3	8	20	3	4	2	2	7
Largemouth bass	2	1	6	0	3	0	1	0
White crappie	0	0	7	3	0	1	0	0
Black crappie	0	2	0	0	0	0	0	0
Yellow perch	0	0	2	0	0	0	0	0
Walleye	159	173	170	173	187	64	68	113
Total	***12,099***	***10,872***	***6,261***	***7,767***	***5,122***	***4,591***	***1,237***	***1,406***

Table 1

Continued.

Date:	24 May	25 May	26 May	27 May	28 May	29 May	30 May	31 May
Hours Of Operation:	*6.5*	*1.8*	*	*	*	*	*7.5*	*9.3*
Start Time:	*8:40*	*8:35*					*10:00*	*8:07*
End Time:	*15:10*	*10:20*					*17:30*	*17:25*
Numbers Of Lifts:	*12*	*4*					*16*	*25*
Water Temperature (F):	*61.0*	*62.1*					*61.8*	*62.6*
American shad	47	11					395	346
Blueback herring	0	0					0	4
Alewife	0	0					0	0
Gizzard shad	71	19					2,318	2,590
Rainbow trout	0	0					0	0
Brown trout	0	0					4	1
Tiger muskie	0	0					0	0
Carp	0	0					0	0
Spottail shiner	0	0					0	0
Quillback	0	0					1	1
White sucker	0	0					0	1
Shorthead redhorse	11	1					9	29
Brown bullhead	0	0					0	0
Channel catfish	2	10					12	6
White perch	0	0					0	0
Striped bass	0	0					1	0
Redbreast sunfish	1	0					5	0
Green sunfish	0	0					0	0
Pumpkinseed	0	0					0	0
Bluegill	0	0					0	1
Rock bass	1	0					4	1
Smallmouth bass	1	0					17	10
Largemouth bass	0	0					1	1
White crappie	0	0					0	3
Black crappie	0	0					0	0
Yellow perch	0	0					0	0
Walleye	25	12					97	129
Total	***159***	***53***	***0***	***0***	***0***	***0***	***2,864***	***3,123***

* Lift operation suspended due to high river flow and a lack of target fish species in the river system.

Table 1

Continued.

Date:	1 Jun	2 Jun	3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	8 Jun
Hours Of Operation:	*9.6*	*8.7*	*9.1*	*8.8*	*6.2*	*8.0*	*9.8*	*9.2*
Start Time:	*8:17*	*8:50*	*8:25*	*8:15*	*11:00*	*8:50*	*9:00*	*8:20*
End Time:	*17:50*	*17:30*	*17:28*	*17:00*	*17:12*	*16:50*	*18:50*	*17:30*
Numbers Of Lifts:	*23*	*14*	*13*	*13*	*11*	*15*	*18*	*19*
Water Temperature (F):	*64.4*	*67.2*	*69.8*	*72.0*	*72.3*	*71.0*	*68.5*	*67.4*
American shad	280	123	483	392	329	257	593	773
Blueback herring	2	0	0	0	0	0	0	1
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	3,455	2,347	4,013	1,421	2,160	499	2,061	2,130
Rainbow trout	0	0	1	1	0	0	0	1
Brown trout	0	1	0	0	0	0	0	0
Tiger muskie	0	0	0	0	0	0	0	0
Carp	1	2	2	3	27	0	1	2
Spottail shiner	0	0	75	0	0	0	0	0
Quillback	7	5	73	124	53	25	2	3
White sucker	0	2	2	1	0	0	0	0
Shorthead redhorse	184	609	423	414	220	19	5	1
Brown bullhead	0	0	0	0	0	1	0	0
Channel catfish	3	43	25	21	14	4	3	5
White perch	0	0	0	0	0	0	0	0
Striped bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	4	0	2	1	1	0	4
Green sunfish	0	0	0	1	0	0	0	1
Pumpkinseed	1	2	0	0	0	0	0	0
Bluegill	6	10	24	3	3	4	12	2
Rock bass	1	12	8	0	0	0	0	3
Smallmouth bass	25	27	20	4	17	10	12	14
Largemouth bass	6	1	5	6	3	0	3	0
White crappie	1	1	3	0	5	0	2	1
Black crappie	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	82	347	369	278	109	87	44	51
Total	*4,054*	*3,536*	*5,526*	*2,671*	*2,941*	*907*	*2,738*	*2,992*

Table 1

Continued.

Date:	9 Jun	10 Jun	11 Jun	12 Jun	13 Jun	14 Jun	15 Jun	TOTAL
Hours Of Operation:	*5.1*	*8.9*	*9.5*	*8.8*	*7.3*	*6.6*	*2.8*	*269.0*
Start Time:	*9:15*	*8:10*	*7:30*	*8:12*	*8:40*	*9:08*	*8:14*	
End Time:	*14:20*	*17:01*	*17:00*	*17:00*	*16:00*	*15:45*	*11:00*	
Numbers Of Lifts:	*10*	*18*	*15*	*18*	*15*	*15*	*1*	*585*
Water Temperature (F):	*68.0*	*70.4*	*73.3*	*75.4*	*77.1*	*76.7*	*73.9*	
American shad	58	462	722	349	185	123	73	*21,079*
Blueback herring	110	0	1	0	0	0	0	*159*
Alewife	0	0	0	0	0	0	0	*657*
Gizzard shad	365	2,229	1,930	1,335	598	1,405	52	*120,696*
Rainbow trout	0	0	0	1	2	0	0	*10*
Brown trout	0	0	0	0	0	0	0	*18*
Tiger muskie	0	0	0	0	0	0	0	*1*
Carp	1	15	3	3	5	1	0	*795*
Spottail shiner	0	0	0	0	0	0	0	*75*
Quillback	1	1	8	15	9	35	0	*8,020*
White sucker	0	1	1	0	0	0	0	*33*
Shorthead redhorse	1	8	29	40	35	67	11	*4,482*
Brown bullhead	0	0	0	0	0	0	0	*1*
Channel catfish	5	30	42	107	135	398	17	*2,884*
White perch	0	0	0	0	0	0	0	*3*
Striped bass	0	0	1	0	0	0	0	*3*
Redbreast sunfish	3	0	11	11	2	0	0	*111*
Green sunfish	1	0	5	1	0	0	0	*32*
Pumpkinseed	2	4	1	2	1	0	0	*34*
Bluegill	6	20	13	16	17	11	0	*459*
Rock bass	0	2	4	5	2	0	1	*527*
Smallmouth bass	4	33	32	34	13	24	2	*2,718*
Largemouth bass	1	5	16	7	0	0	0	*242*
White crappie	0	0	1	3	1	0	0	*34*
Black crappie	0	1	0	0	0	0	0	*7*
Yellow perch	0	1	0	0	0	0	0	*46*
Walleye	15	63	56	111	106	130	11	*6,816*
Total	*573*	*2,875*	*2,876*	*2,040*	*1,111*	*2,194*	*167*	*169,942*

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 2000.

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)
8 May	29,700	72.0	24	7	1, 3 to 7, 9	A & C	500	169.6-171.8	227.0-224.1
9 May	27,700	74.0	24	7	2 to 7, 9	A & C	500	170.0-172.0	227.0-224.8
10 May	25,800	75.9	24	2	2, 6	A & C	500	167.6-170.2	226.4-224.4
11 May	23,400	75.6	24	8	2 to 7, 9, 10	A & C	500	169.7-170.6	226.5-225.4
12 May	22,900	75.6	18	5	2, 4 to 7	A & C	500	169.7-169.7	226.1-225.7
13 May	37,700	75.3	24	11	1 to 7, 9 to 12	A & C	500	171.1-174.7	226.9-224.9
14 May	46,500	73.9	20	11	1 to 7, 9 to 12	A & C	500	173.8	226.6
15 May	47,700	72.5	20	9	2 to 7, 9, 11,12	A & C	500	172.0-173.8	226.1-225.3
16 May	55,400	69.6	1-8	9	1 to 7, 9, 11	A & C	500	173.0-172.4	224.6-224.5
17 May	56,200	67.9	12-18	10	1 to 7, 9, 11,12	A & C	500	174.0-172.9	225.2-224.7
18 May	54,300	67.3	12-22	10	2 to 9, 11, 12	A & C	500	175.2-173.1	225.2-224.4
19 May	48,300	67.6	14-16	9	2 to 9, 11	A & C	500	172.8-172.7	225.7-224.5
20 May	42,900	67.2	10	7	3 to 9	A & C, B & C	500	169.0-171.5	226.8-225.5
21 May	50,100	65.4	12	8	3 to 10	A & C, B & C	500	170.7-173.6	227.0-225.9
22 May	73,600	62.3	12	10	2 to 11	A & C, B & C	500	175.3-174.7	225.9-225.7
23 May	68,400	61.3	18	11	1 to 11	B & C	500	173.9-174.3	226.8-226.4
24 May	69,000	61.0	16	11	2 to 12	A & C	500	174.4-175.3	226.9-225.9
25 May	83,100	62.1	16	12	1 to 12	A & C	500	175.9-175.4	226.2-226.1
30 May	60,400	61.8	24	10	2 to 11	A & C, B & C	500	174.5-175.7	226.3-224.6
31 May	54,400	62.6	22	9	2 to 10	B & C	500	171.7-173.7	226.7-225.7
1 Jun	46,600	64.4	22	11	1 to 11	B & C	500	173.1-174.7	226.7-224.6
2 Jun	41,000	67.2	24	8	2 to 7, 9, 10	A & C	500	171.1-174.2	226.8-224.6
3 Jun	35,200	69.8	--	5	3 to 7	A & C	500	170.8-172.8	226.7-225.5
4 Jun	31,900	72.0	16	8	3 to 10	A & C	500	171.4-172.9	227.0-225.5

Table 2

Continued.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
5 Jun	28,000	72.3	20-22	8	1 to 7, 9	A & C	500	171.7-170.8	226.4-224.7
6 Jun	29,000	71.0	18-20	5	1, 2, 4 to 6	A & C	500	169.7-172.3	226.8-225.6
7 Jun	35,100	68.5	20-24	3	1, 2, 4 to 6	B & C	500	169.5-173.3	226.6-226.6
8 Jun	42,100	67.4	20-24	9	1 to 7, 9, 10	B & C	500	172.9-173.0	226.8-225.5
9 Jun	38,300	68.0	20-24	8	1 to 4, 6, 7, 9, 10	A & C	500	172.7-172.1	226.2-226.1
10 Jun	33,800	70.4	28	6	2 to 7	B & C	500	171.1-173.6	226.6-226.0
11 Jun	31,500	73.3	18-20	3	2, 5, 6	B & C	500	169.1-173.3	226.7-225.7
12 Jun	32,400	75.4	18-22	6	1 to 4, 6, 7	B & C	500	169.9-172.5	227.0-225.3
13 Jun	30,100	77.1	20-24	6	1 to 4, 6, 7	B & C	500	170.6-171.8	226.7-226.1
14 Jun	36,800	76.7	20-24	7	1 to 4, 6, 7, 9	A & C	500	170.8-173.68	227.0-225.8
15 Jun	41,100	73.9	18-36	7	1 to 4, 6, 7, 9	A & C	500	171.1-170.2	227.0-226.6

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2000.

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Observation Time (Start):	*10:15*	*11:00*	*10:00*	*11:00*	*10:00*	*10:05*	*9:35*	*10:10*	*10:30*	*9:00*
Observation Time (End):	*17:15*	*18:00*	*16:45*	*18:00*	*17:15*	*16:55*	*17:35*	*17:20*	*17:45*	*18:15*
Military time (hrs)										
0700 to 0759										
0800 to 0859										
0900 to 0959							105			50
1000 to 1059	73		107		48	131	347	162	30	92
1100 to 1159	198	290	211	102	78	239	190	90	78	125
1200 to 1259	330	250	95	168	251	315	148	18	100	180
1300 to 1359	462	106	154	153	216	301	78	83	275	251
1400 to 1459	192	80	139	253	162	230	253	68	670	48
1500 to 1559	186	74	31	83	163	200	122	14	150	73
1600 to 1659	207	74	76	100	137	96	109	34	67	42
1700 to 1759	3	191		54	4		102	34	54	224
1800 to 1859										52
1900 to 1959										
Total	***1,651***	***1,065***	***813***	***913***	***1,059***	***1,512***	***1,454***	***503***	***1,424***	***1,137***

Table 3

Continued.

Date:	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Observation Time (Start):	*10:00*	*8:30*	*8:15*	*9:00*	*8:00*	*9:20*	*8:45*	*8:47*	*	*
Observation Time (End):	*17:45*	*16:45*	*17:40*	*17:45*	*17:45*	*17:50*	*15:20*	*10:25*		
Military time (hrs)										
0700 to 0759										
0800 to 0859		18	16		16		8	3		
0900 to 0959		39	43		7	14	12	5		
1000 to 1059	37	92	38	9	7	29	6	3		
1100 to 1159	247	72	48	13	6	48	3			
1200 to 1259	180	99	101	8	63	60	2			
1300 to 1359	65	47	164	53	58	35	1			
1400 to 1459	126	65	95	188	81	52	6			
1500 to 1559	149	42	130	167	72	16	9			
1600 to 1659	50	68	95	97	63	17				
1700 to 1759	94		64	42	32	10				
1800 to 1859										
1900 to 1959										
Total	*948*	*542*	*794*	*577*	*405*	*281*	*47*	*11*	*0*	*0*

* Lift operation suspended due to high river flow and a lack of target fish species in the river system.

Table 3

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*
Observation Time (Start):	*	*	*10:35*	*9:00*	*9:24*	*9:10*	*9:00*	*9:15*	*11:00*	*9:00*
Observation Time (End):			*17:45*	*17:45*	*18:10*	*17:50*	*17:35*	*17:22*	*17:38*	*17:15*
Military time (hrs)										
0700 to 0759										
0800 to 0859										
0900 to 0959				28	31	9	33	55		19
1000 to 1059			2	17	26	8	38	47		7
1100 to 1159			16	28	21	2	64	58	65	26
1200 to 1259			19	28	23	1	75	49	65	35
1300 to 1359			51	50	31	21	89	69	78	45
1400 to 1459			118	36		30	55	39	42	46
1500 to 1559			110	60	73	18	54	41	17	46
1600 to 1659			67	60	46	11	50	32	38	28
1700 to 1759			12	39	21	23	25	2	24	5
1800 to 1859					8					
1900 to 1959										
Total	***0***	***0***	***395***	***346***	***280***	***123***	***483***	***392***	***329***	***257***

* Lift operation suspended due to high river flow and a lack of target fish species in the river system.

Table 3

Continued.

Date:	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*	*15 Jun*	*TOTAL*
Observation Time (Start):	*9:35*	*9:30*	*9:20*	*9:00*	*8:53*	*9:20*	*9:15*	*9:20*	*9:00*	
Observation Time (End):	*19:05*	*17:58*	*14:40*	*17:30*	*17:15*	*17:20*	*16:25*	*16:00*	*11:15*	
Military time (hrs)										
0700 to 0759										***0***
0800 to 0859					51					***112***
0900 to 0959	12	71	27	70	131	48	39	1	1	***850***
1000 to 1059	51	66	12	132	110	79	29	9	72	***1,916***
1100 to 1159	67	90	3	86	81	29	14	7		***2,695***
1200 to 1259	33	104	7	45	39	31	11	0		***2,933***
1300 to 1359	31	118	7	25	29	35	25	69		***3,275***
1400 to 1459	85	150	2	59	36	32	41	18		***3,497***
1500 to 1559	76	77		16	127	38	15	19		***2,468***
1600 to 1659	123	46		21	95	49	11			***2,009***
1700 to 1759	70	51		8	23	8				***1,219***
1800 to 1859	42									***102***
1900 to 1959	3									***3***
Total	***593***	***773***	***58***	***462***	***722***	***349***	***185***	***123***	***73***	***21,079***

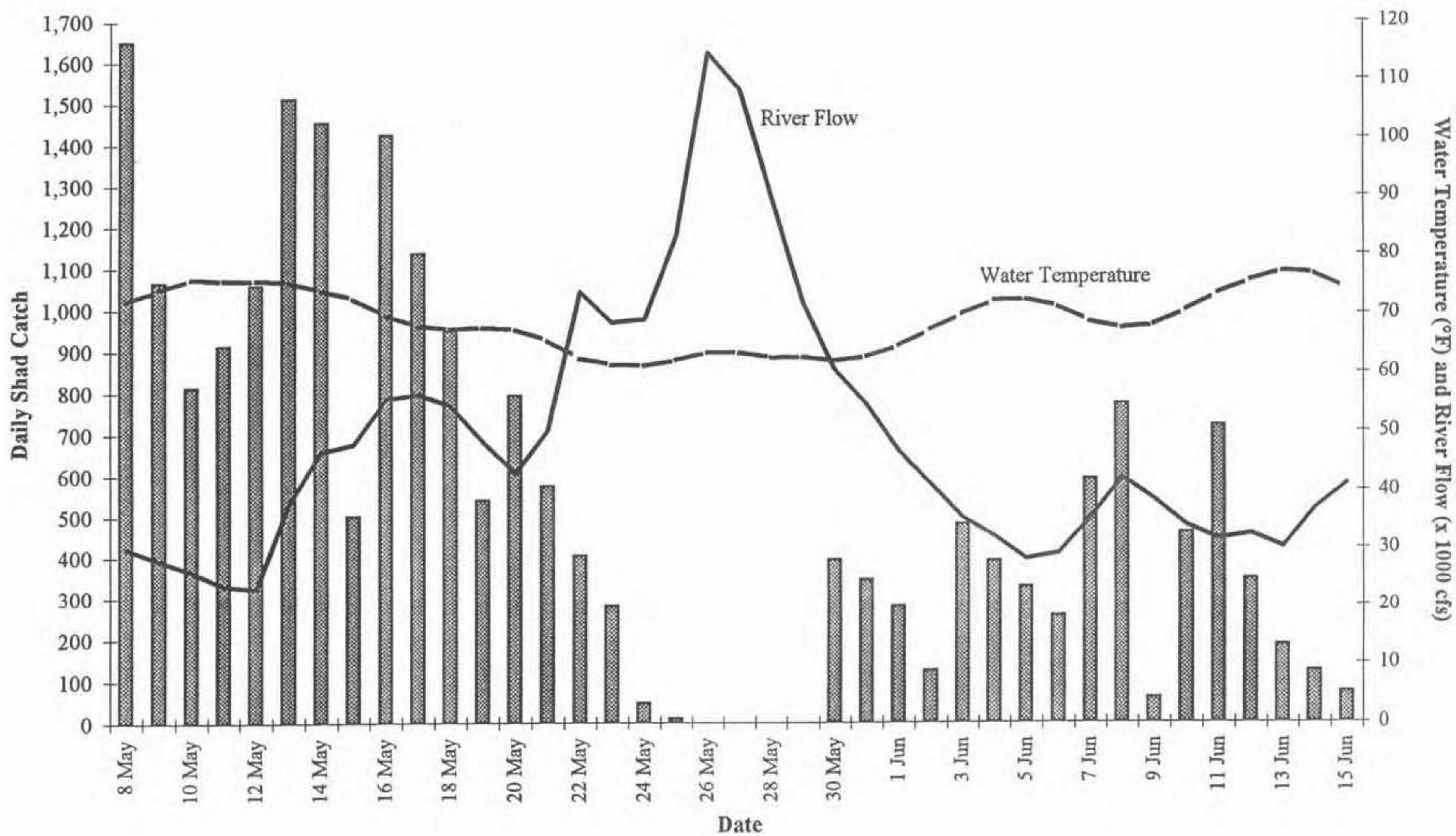

Figure 1

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 2000.

JOB I - Part 5

SUMMARY OF OPERATION AT THE YORK HAVEN FISHWAY IN 2000

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INTRODUCTION

On June 1, 1993 representatives of York Haven Power Company (YHPC), a GPU Energy Company and two upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed York Haven, Holtwood, and Safe Harbor Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. The agreement required that fishways 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 (*Alosa sapidissima*) population and completion of a permanent fish passage facility at Conowingo Dam in 1991.

Construction of the York Haven fishway began in June 1998 and preliminary testing of the fishway was completed in the fall of 1999. The fishway is located in Dauphin County, PA at the Three Mile Island end of the East Channel dam at the York Haven Hydroelectric Project (FERC No. 1888). It was designed according to United States Fish and Wildlife Service (USFWS) guidelines and specifications, which resulted from extensive study, design review, hydraulic modeling, and discussions with resource agencies. Construction was completed in January of 2000, several months ahead of schedule.

On 19 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 by YHPC at York Haven. The meeting included discussions and consensus on operation of the fishway during the 2000 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 2000 operation were: (1) monitor passage of migratory and resident fishes through the newly installed fishway; and (2) assess fishway effectiveness and efficiency and make modifications as feasible.

York Haven Project Operation

The hydroelectric station located in York Haven, PA built in 1904, is situated at river mile 55 in Dauphin and York counties, Pennsylvania (Figure 1). It is the fourth upstream hydroelectric facility on the river and is located 12 miles south of Harrisburg, the state's capital. The project, a 20 unit run-of-river facility is capable of producing approximately 19 MW and has an estimated hydraulic capacity of 16,000 cfs. It includes two dams which 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.

River flow exceeds station hydraulic capacity over 55% of the year which results in water being spilled over the two dams. As part of the 1993 agreement, York Haven Power Company agreed to a minimum flow release during spring fishway operation, totaling 6,000 cfs, over the two dams before generating with any of the stations turbines. This included maintaining a release of 4,000 cfs over the main dam and a minimum release of 2,000 cfs in the East Channel through the fishway. River flow in excess of spring minimum flow requirements and station capacity is spilled over the Main and East Channel dams and through the fishway.

FISHWAY DESIGN AND OPERATION

Fishway Design

Fishway design incorporated numerous criteria established by the USFWS and the resource agencies. This included an anticipated operating period for the fishway beginning in late April or early May through June with 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 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. The fishway was operated this season with both layers of sill blocks installed. Each sill block is one foot thick which resulted in an elevation of 273-ft. at the top of the 67-ft. weir.

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 by 1 April. The fishway was opened on 12 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 1600 hrs on 19 June, a 39 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 and the "exit gate" located at each end of the ladder were opened. Then the "diffuser gate" was opened. These five gates remained opened the entire season. Since volume of flow through the diffuser, the ladder, and fixed wheel gates are outlet controlled the velocity and flow patterns that were observed in the ladder and "weir cut" were a result of flow in the East Channel. The entrance gate was the only gate that was adjusted throughout the season. This gate was adjusted either manually or automatically 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, was normally closed. However, the gate was opened for short periods of time on occasions to see how this gate would affect the flow patterns downstream of the fishway. Keeping the gate closed appeared to enhance conditions at the entrance to the ladder under the range of flows experienced this season.

Initially, two people manned and operated the fishway from 0800 hrs to 1900 hrs. During this period water velocity in and at the entrance to the ladder was measured and found to be similar to that described in the Alden model study. Configuration of the "weir cut" precluded measuring the water velocity in the triangle portion of the "weir cut" and downstream of the 67-ft. weir. However, on several different occasions surface water velocity was measured several feet downstream of each wheel gate. As measured, velocities were generally found to be one to two ft/sec higher than those reported in the model study. Since it was not feasible to measure the velocities at the same locations and/or at the same depths, measuring velocity at or in the vicinity of the fixed wheel gate was only done to gain a better understanding of what water velocities were like downstream of the two gates.

After the initial week of operation, the fishway was usually 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 hourly through the ladder, 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 in the East Channel from the South Bridge and below the Main dam. This individual also recorded water elevations several times each day on staff gauges located throughout the fishway.

Fish Counting Methods

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 8.5-ft. 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, which form 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 on an as needed basis. Fish passage by the viewing window was manually controlled by opening or closing an aluminum grating gate with a hand winch that was located outside the viewing room. Excluding the last three days of the season, this gate was normally closed each night at 1900 hrs. Normally, each morning this gate was opened by 0800 hrs and only closed for brief periods of time on an as needed basis each day to enable the person manning the fishway to conduct other activities.

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 YHP's on-site coordinator/manager and other appropriate YHP and GPU personnel on a daily basis. In addition, weekly passage information was supplied electronically to YHP 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 comprised of the following equipment: (1) a Phillips black and white camera (Model #LTC 0531/21 A); (2) a Phillips 1/3 in Vari-Focal lens with manual Iris (Model # LTC 0371/20 A); (3) a Toshiba time-lapse VHS recorder/player (Model # KV-7024A); and (4) a 19-in. Sanyo color TV that was used as a monitor.

The camera was mounted on a tripod set approximately 5-ft. off the floor and positioned in the back corner of the counting room. The camera was aimed at the fish viewing window. 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 134,279 fish of 27 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (72,972) was the dominant fish species passed and comprised nearly 55% of the catch. Some 4,687 American shad were counted as they passed through the ladder. Other predominant fishes passed included quillback (20,264), channel catfish (17,613), shorthead redhorse (6,734) and carp (4,929). Peak passage occurred on 19 May when some 15,358 fish were passed.

American Shad Passage

The York Haven fish ladder allowed a minimum of 4,687 American shad to pass upstream during this first year of operation (Table 1). Passage of shad varied daily with approximately 94% (4,420) of the shad passing between 13 May and 13 June. In May, the fishway passed over 200 American shad per day on 5 occasions. Peak shad passage occurred on 19 May when 425 shad were passed. Some 55.4% and 45.6% of the shad passed in May and June, respectively.

American shad were collected and passed at water temperatures of 59.0°F to 76.0°F, river flows of 27,000 cfs to 114,800 cfs and/or East Channel flows of 2,650 cfs and 18,200 cfs (Table 2 , Figures 3 and 4). Thirty shad passed the ladder on 12 May, the day the ladder was opened, at a water temperature of 73.0°F. American shad passage through the ladder occurred in three waves or pulses. Peak passage occurred between 13 and 20 May. During this period 1,685 American shad passed the ladder as water temperatures declined from 72.0°F to 61.8°F and at river flows that varied from 32,500 cfs to 46,950 cfs. The number of shad that passed the ladder declined from 21 to 28 May. This decline in passage coincided with a high flow event that peaked at 114,800 cfs on 26 May.

Following a drop in river flow, two smaller peaks in shad passage were observed between 29 May and 13 June. Of the 2,428 American shad that passed during this period 1,455 and 973 shad passed from 29 May to 6 June and 7 to 13 June, respectively. During this period river flow declined from 71,300 cfs on 29 May to 21,850 cfs on 5 June. River flow increased daily to 33,500 cfs on 8 June, fell to 22,800 cfs on 12 June before it increased for the last time during the season to 50,150 cfs on 17 June. Water temperature varied over 14 degrees during this period, increasing from 61.5 °F on 29 May to 71.3°F on 3 June, falling to 63.5°F on 7 June and rising to a season high of 76.0°F on 12 June.

The hourly passage of American shad in the fish ladder is given in Table 3. Peak hourly passage of shad (490) occurred between 0800 hrs and 0859 hrs. Excluding the first hour, total hourly passage of shad through the ladder was relatively constant and ranged from 205 to 298 fish each hour. Although total hourly passage was considered to be constant, further examination of the data revealed that a trend in shad passage was evident. Early in the season, from 12 May to 20 May, most shad passed between 1200 hrs and 1900 hrs. After the high flow event, from 30 May through the end of the season most shad passed between 0800 hrs and 1400 hrs, with the majority passing each day during the first three hours. 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 and this is when shad collection, egg stripping and fertilization activities usually begin each day on the Delaware River for the Susquehanna River Anadromous Fish Restoration Committee.

Just two alosids other than American shad were passed. Both were alewife and they passed on 17 May. Based on passage records at downstream fishways these alewife were apparently transported from the West lift at Conowingo Dam and stocked in the Little Conestoga Creek, a tributary of the Conestoga River, which is located downstream of Safe Harbor Dam. No blueback herring or hickory shad were observed passing through the ladder.

Video Record

A limited review of the video record showed that fish passage was not adequately captured on the tape record. Data in Table 4 lists by date and time the shad count, the tape count, and the difference between the two counts. The tape count derived from the review of the five periods was always less than that derived from the visual estimate. The differences between visual counts and tape counts varied from 12 to 21 shad. Poor tape quality caused by high turbidity made it difficult to distinguish fish species. During the season visibility varied from 6 to 22 inches and on 23 days (59% of season) visibility was 10 inches or less (Table 2). Generally, poor visibility conditions resulted in tape derived counts that consistently underestimated the numbers of shad passing through the ladder.

Although the tape record was considered to be of limited quality, three hours of relatively good quality tape between 0800 hrs and 0859 hrs was reviewed. Table 5 lists by date and time the shad count, the tape derived count, and the difference between the two counts. All three tape derived counts were higher than the visually estimated counts conducted each day. This is not surprising since it took several minutes to open the gate, enter the counting building and walk down the stairs which allowed an unknown number of fish to pass by the viewing window without being enumerated. Fish also passed by undetected while the gate was being closed.

Poor viewing conditions coupled with the knowledge that shad and other fish passed through the ladder without being enumerated while the gate downstream of the viewing window was being opened/closed means that the number of fish, including American shad, that were reported as passing should be considered a minimum number.

Observations

Once each day visual observations of fish activity were made on a random basis below the Main dam and from the South bridge. On just one occasion several carp and quillback were observed trying to swim over the Main dam. Although turbid water conditions may have limited the value of visual observations it provided the person conducting fish counts to take a short break from counting fish.

Since it was anticipated that some American shad might be able to pass though the "weir cut" observations were made several times each day in an attempt to see if American shad or other fishes passed upstream through the weir gates. No fish were observed passing through this portion of the fishway.

Data in Table 6 obtained from the Alden model study shows that in five of the six flows tested water velocity downstream of the wheel gates and the 67- ft. weir exceeded the burst swimming capabilities of American shad and resident fish species at selected locations downstream from each of these fixtures. The burst speed, the speed that a fish can maintain for a few seconds, for an American shad is considered to be 12 to 13 ft/sec.

Although weir height is adjustable, in one foot increments totaling 2-ft., once the upstream passage season has ended it does not appear that any adjustment is warranted at this time. Based on a combination of factors including visual observation of flow, turbulence and lack of fish passage through the "weir cut" this season, velocity measurements taken below each wheel gate this year, and velocity measurements in the model study it does not appear that any fish would be able to pass upstream through the "weir cut" under any of the three potential 67-ft. weir configurations. Although lowering the height of the weir may improve conditions for passage downstream of the weir this will result in higher water velocities downstream from each of the wheel gates. Since velocities downstream of the wheel gates were one to two ft/sec higher than those reported in the model study adjusting the height of the weir does not appear that it will help create suitable conditions for upstream passage of American shad through the "weir cut" at any East Channel flow regardless of the weir configuration which was what was envisioned would occur during design of the fishway.

SUMMARY

The spring 2000 York Haven fishway operating season was very successful considering water temperature was 73.0 °F on the first day of operation and several of the shad that passed though the ladder that day visually appeared as if they had started to spawn. Survival of fish that utilized the fishway was considered excellent since no mortalities were observed. A minimum of 4,687

American shad used the ladder to pass into Lake Frederic or at least 22.2% of the shad that were passed into Lake Clarke this year.

Operation of the fishway opened the river to the Fabridam at Sunbury as well as most of the Juniata River, a major tributary of the Susquehanna. Solutions to resolve difficulties encountered with fish counts this season shall be in place before the start of next year. Combining proposed recommendations and solutions with operating experience gained this season 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 in the future.

RECOMMENDATIONS

1. Operate the fishway at York Haven per an annual guideline developed and approved by the FPTAC. Fishway operation including hours the fishway is manned should adhere to the guideline, however, flexibility must remain with operating personnel to maximize fishway performance.

2. Install an electric hoist on the aluminum grating gate so that this gate can be opened and closed from inside the viewing room allowing all fish that pass by the viewing window to be enumerated.

3. Improve fish viewing conditions at the counting window by installing an adjustable screen capable of reducing the exit channel width from 24 inches to a minimum of 12 inches at the counting window. Screen design should also allow the screen to be set at 18 inches. Channel width would be set daily based on visibility and/or water clarity conditions.

4. Since passage of American shad through the ladder was excellent and changing the configuration of the adjustable weir will not likely facilitate or even allow American shad to pass through the "weir cut", maintain the same 67-ft. weir configuration that was used in 2000 in the future.

LITERATURE CITED

Whited. 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 2000.

Date	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-May
Observation Time	9:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00
Water Temperature (°F)	73.0	72.0	69.5	66.0	64.0	64.5	66.5	66.0	61.8	60.0
AMERICAN SHAD	30	285	263	41	138	286	167	425	80	20
ALEWIFE	-	-	-	-	-	2	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-	-	-
GIZZARD SHAD	765	2,469	5,415	4,128	12,350	8,545	4,979	4,632	3,226	1,626
HICKORY SHAD	-	-	-	-	-	-	-	-	-	-
STRIPED BASS	-	-	-	-	-	-	1	1	1	-
WHITE PERCH	-	-	-	-	-	-	-	-	-	-
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	2	-	-	-	1	1	1	-	-	-
BROWN TROUT	2	-	1	1	-	4	1	5	1	1
MUSKELLUNGE	0	-	-	-	-	-	-	-	-	-
CARP	237	579	288	91	214	126	124	251	38	16
QUILLBACK	30	5,470	3,641	170	1,201	1,545	770	1,093	111	23
WHITE SUCKER	43	43	11	1	14	9	4	8	21	3
SHORTHEAD REDHORSE	90	979	873	326	581	543	251	192	79	46
YELLOW BULLHEAD	-	-	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-	-	-
CHANNEL CATFISH	115	3,071	2,752	1,125	723	447	453	670	59	88
ROCK BASS	-	-	-	-	-	-	-	-	-	-
REDBREAST SUNFISH	1	1	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-	-	-
PUMKINSEED	-	2	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	91	87	64	-	1	2	2	2	8	-
LARGEMOUTH BASS	1	-	-	-	-	-	-	-	-	1
WHITE CRAPPIE	-	-	-	-	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-	-	-
WALLEYE	31	184	137	14	135	263	140	144	131	62
RIVER CHUB	7	-	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	1	-	-	-	-	-	-	-	-	-
FALLFISH	5	-	-	-	-	-	-	-	-	-
Total	1,451	13,170	13,445	5,897	15,358	11,773	6,893	7,423	3,755	1,886

Table 1. Continued

Date	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
Observation Time	11:00	11:00	11:00	11:00	11:00	11:00	11:00	10:00	11:00	11:00
Water Temperature (°F)	60.0	59.0	61.0	62.0	61.5	62.0	61.0	61.5	62.0	63.0
AMERICAN SHAD	32	28	93	35	77	16	53	117	165	245
ALEWIFE	-	-	-	-	-	-	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-	-	-
GIZZARD SHAD	1,034	437	977	1,163	1,068	699	653	614	1,261	1,804
HICKORY SHAD	-	-	-	-	-	-	-	-	-	-
STRIPED BASS	-	-	-	1	-	-	-	-	-	1
WHITE PERCH	-	-	-	-	-	-	-	-	-	-
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	-	-	-	-	-	-	-	-	-	-
BROWN TROUT	-	-	-	-	-	1	-	-	-	-
MUSKELLUNGE	-	-	-	-	-	-	-	-	1	-
CARP	97	41	22	239	284	57	27	25	50	76
QUILLBACK	251	70	476	685	253	191	13	13	118	552
WHITE SUCKER	1	2	7	3	2	3	-	1	-	9
SHORTHEAD REDHORSE	116	44	69	115	119	52	26	27	117	254
YELLOW BULLHEAD	-	-	-	-	-	-	-	-	-	-
BROWN BULLHEAD	-	-	-	-	-	-	-	-	-	-
CHANNEL CATFISH	315	87	171	657	2,031	767	122	28	119	129
ROCK BASS	-	-	-	-	-	-	-	-	-	2
REDBREAST SUNFISH	-	-	-	-	-	-	-	-	-	-
GREEN SUNFISH	-	-	-	-	-	-	-	-	-	-
PUMKINSEED	-	-	-	-	-	-	-	-	-	-
BLUEGILL	-	-	-	-	-	-	-	-	-	-
SMALLMOUTH BASS	-	-	2	4	-	1	1	21	101	124
LARGEMOUTH BASS	-	-	-	-	-	-	1	-	7	-
WHITE CRAPPIE	-	-	-	-	-	-	-	4	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-	-	-
WALLEYE	30	32	51	70	45	16	16	75	492	551
RIVER CHUB	-	-	-	-	-	-	-	-	-	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-	-	-
FALLFISH	-	-	-	-	-	-	-	-	-	-
Total	1,876	741	1,868	2,972	3,879	1,803	912	925	2,431	3,747

Table 1. Continued

Date	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun
Observation Time	11:00	11:00	11:00	11:00	10:00	11:00	11:00	11:00	11:00	11:00
Water Temperature (°F)	68.8	71.0	71.3	69.0	68.5	65.0	63.5	66.5	68.8	70.8
AMERICAN SHAD	172	186	77	173	144	99	40	156	184	139
ALEWIFE	-	-	-	-	-	-	-	-	-	-
BLUEBACK HERRING	-	-	-	-	-	-	-	-	-	-
GIZZARD SHAD	1,980	1,554	1,172	900	989	556	605	560	949	825
HICKORY SHAD	-	-	-	-	-	-	-	-	-	-
STRIPED BASS	2	-	1	-	2	-	-	-	1	-
WHITE PERCH	-	-	-	-	-	-	-	-	-	-
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	1	-	1	-	-	-	-	-	-	-
BROWN TROUT	3	4	-	4	-	1	-	-	1	-
MUSKELLUNGE	-	-	-	-	-	-	-	-	-	-
CARP	466	288	233	118	116	59	62	85	140	119
QUILLBACK	706	935	474	212	170	128	77	48	70	164
WHITE SUCKER	46	19	12	30	5	7	5	2	14	17
SHORTHEAD REDHORSE	215	289	165	96	74	54	52	29	118	148
YELLOW BULLHEAD	-	-	-	2	-	-	-	-	-	-
BROWN BULLHEAD	-	1	1	-	-	-	-	-	-	2
CHANNEL CATFISH	153	227	168	91	62	113	119	125	222	370
ROCK BASS	-	-	-	-	1	-	-	-	1	1
REDBREAST SUNFISH	-	-	-	-	-	-	-	-	-	1
GREEN SUNFISH	2	-	-	2	-	-	1	-	-	-
PUMKINSEED	-	1	1	5	-	-	-	-	-	-
BLUEGILL	-	-	-	1	4	-	-	1	2	7
SMALLMOUTH BASS	138	141	117	104	97	49	18	12	54	194
LARGEMOUTH BASS	-	-	-	2	3	2	-	1	6	13
WHITE CRAPPIE	-	-	-	2	-	-	-	-	-	-
BLACK CRAPPIE	-	-	-	-	-	-	-	-	-	1
WALLEYE	473	270	172	190	146	123	51	42	62	117
RIVER CHUB	1	-	-	-	2	-	-	-	1	-
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-	-	-
FALLFISH	-	-	-	-	-	-	-	-	-	-
Total	4,358	3,915	2,594	1,932	1,815	1,191	1,030	1,061	1,825	2,118

Table 1. Continued

Date	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun	Total
Observation Time	11:00	11:00	11:00	11:00	11:00	11:00	9:00	8:00	8:00	417:00
Water Temperature (°F)	75.0	76.0	73.0	68.5	66.5	68.3	74.0	73.5	71.5	
AMERICAN SHAD	101	193	160	69	51	60	64	15	8	**4,687**
ALEWIFE	-	-	-	-	-	-	-	-	-	**2**
BLUEBACK HERRING	-	-	-	-	-	-	-	-	-	-
GIZZARD SHAD	430	348	453	549	304	502	1,268	672	511	**72,972**
HICKORY SHAD	-	-	-	-	-	-	-	-	-	-
STRIPED BASS	-	-	-	-	-	-	1	-	-	**12**
WHITE PERCH	-	-	-	-	-	-	-	-	-	-
AMERICAN EEL	-	-	-	-	-	-	-	-	-	-
RAINBOW TROUT	-	4	1	-	-	-	-	-	-	**12**
BROWN TROUT	1	1	-	1	-	-	-	-	-	**33**
MUSKELLUNGE	-	-	-	-	-	-	-	-	-	**1**
CARP	74	106	78	30	19	14	17	17	6	**4,929**
QUILLBACK	150	119	115	45	10	39	88	30	8	**20,264**
WHITE SUCKER	8	4	9	2	1	1	15	12	0	**394**
SHORTHEAD REDHORSE	67	64	61	41	58	58	120	72	54	**6,734**
YELLOW BULLHEAD	-	-	-	-	-	-	-	-	-	**2**
BROWN BULLHEAD	-	-	-	-	-	-	-	-	-	**4**
CHANNEL CATFISH	174	206	237	204	91	160	518	316	128	**17,613**
ROCK BASS	2	-	1	-	-	-	-	-	-	**8**
REDBREAST SUNFISH	-	-	-	-	-	-	-	-	-	**3**
GREEN SUNFISH	6	-	-	-	-	-	-	-	-	**11**
PUMKINSEED	-	-	-	-	-	-	-	-	-	**9**
BLUEGILL	-	7	4	-	-	-	-	-	-	**26**
SMALLMOUTH BASS	140	173	102	30	9	13	10	1	3	**1,916**
LARGEMOUTH BASS	-	1	3	1	-	-	-	-	-	**42**
WHITE CRAPPIE	-	-	-	-	-	-	-	-	-	**6**
BLACK CRAPPIE	-	-	-	-	-	-	-	-	-	**1**
WALLEYE	48	72	45	34	29	25	37	17	9	**4,581**
RIVER CHUB	-	-	-	-	-	-	-	-	-	**11**
NORTHERN HOG SUCKER	-	-	-	-	-	-	-	-	-	**1**
FALLFISH	-	-	-	-	-	-	-	-	-	**5**
Total	1,201	1,298	1,269	1,006	572	872	2,138	1,152	727	134,279

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East Channel, sum of average flow from the powerhouse and Main Dam, water temperature, secchi, stop gate position, and East Channel and fishway water elevations during operation of the York Haven fishway in 2000.

	River Flow	East Channel	Station Main Dam	Water Temp.	Secchi (in)			Stop log	Elevation (ft)					
									Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	Flow (cfs)	(^oF)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
12-May	22,400	2,650	19,750	73.0	18.0	18.0	18.0	Closed	278.9	278.9	279.0	274.1	274.0	274.2
13-May	40,200	5,400	34,800	72.0	18.0	18.0	18.0	Closed	280.0	279.9	280.0	275.4	275.4	275.4
14-May	41,900	5,000	36,900	69.5	22.0	22.0	22.0	Closed	279.9	279.8	279.9	275.4	275.3	275.5
15-May	46,500	5,700	40,800	66.0	6.0	6.0	6.0	Closed	280.1	280.0	280.2	275.7	275.6	275.8
16-May	52,400	6,750	45,650	64.0	8.0	8.0	8.0	Closed	280.3	280.3	280.3	276.0	275.9	276.1
17-May	53,700	6,750	46,950	64.5	10.0	10.0	10.0	Closed	280.3	280.3	280.4	276.0	276.0	276.1
18-May	49,800	6,400	43,400	66.5	10.0	10.0	10.0	Closed	280.2	280.1	280.2	275.9	275.8	276.0
19-May	39,900	5,000	34,900	66.0	9.6	8.0	10.0	Closed	279.9	279.8	280.0	275.4	275.3	275.5
20-May	37,100	4,600	32,500	61.8	10.0	10.0	10.0	Closed	279.7	279.7	279.7	275.0	275.0	275.1
21-May	53,500	6,750	46,750	60.0	10.0	10.0	1.0	Closed	280.3	280.0	280.6	276.0	275.4	276.5
22-May	68,300	10,550	57,750	60.0	6.2	5.0	8.0	Closed	280.8	280.8	280.8	277.1	277.0	277.1
23-May	61,800	9,250	52,550	59.0	8.4	8.0	10.0	Closed	280.6	280.5	280.6	276.6	276.5	276.7
24-May	62,100	9,250	52,850	61.0	10.0	10.0	10.0	Closed	280.6	280.6	280.7	276.7	276.6	276.7
25-May	87,200	13,500	73,700	62.0	7.1	6.0	8.0	Closed	281.2	281.0	281.5	278.0	277.3	278.5
26-May	114,800	18,200	96,600	61.5	6.0	6.0	6.0	Closed	281.9	281.9	281.9	279.2	279.2	279.3
27-May	106,000	16,100	89,900	62.0	6.0	6.0	6.0	Closed	281.6	281.5	281.7	278.7	278.5	278.9
28-May	84,200	12,900	71,300	61.0	6.0	6.0	6.0	Closed	281.1	281.0	281.3	277.7	277.5	278.0
29-May	66,200	10,000	56,200	61.5	7.0	7.0	7.0	Closed	280.7	280.6	280.8	276.7	276.5	277.0
30-May	55,100	6,750	48,350	62.0	12.0	12.0	12.0	Closed	280.3	280.3	280.4	276.2	276.1	276.3
31-May	48,900	6,400	42,500	63.0	14.0	14.0	14.0	Closed	280.2	280.1	280.3	275.8	275.7	276.0
1-Jun	41,300	5,000	36,300	68.8	10.0	10.0	10.0	Closed	279.9	279.8	279.9	275.3	275.2	275.4
2-Jun	36,200	4,600	31,600	71.0	8.9	8.0	10.0	Closed	279.7	279.6	279.7	275.0	274.9	275.1
3-Jun	31,300	4,900	26,400	71.3	8.5	8.0	10.0	Closed	279.5	279.4	279.6	274.7	274.7	274.8
4-Jun	27,400	3,400	24,000	69.0	12.0	12.0	12.0	Closed	279.3	279.3	279.4	274.3	274.2	274.5
5-Jun	25,000	3,150	21,850	68.5	15.0	15.0	15.0	Closed	279.2	279.1	279.2	274.4	274.3	274.4
6-Jun	25,500	3,400	22,100	65.0	12.7	12.0	14.0	Closed	279.3	279.3	279.3	274.4	274.3	274.5
7-Jun	34,500	4,600	29,900	63.5	12.0	12.0	12.0	Closed	279.7	279.5	279.8	274.9	274.7	275.0
8-Jun	38,300	4,800	33,500	66.5	10.0	10.0	10.0	Closed	279.8	279.7	279.8	275.2	275.2	275.2
9-Jun	34,100	4,150	29,950	68.8	11.3	10.0	12.0	Closed	279.6	279.6	279.7	274.9	274.9	275.0
10-Jun	30,500	3,550	26,950	70.8	14.0	14.0	14.0	Closed	279.4	279.3	279.6	274.6	274.5	274.8

Table 2. Continued

Date	River Flow (cfs)	East Channel Flow (cfs)	Station Main Dam Flow (cfs)	Water Temp. (°F)	Secchi (in)			Stop log Gate	Elevation (ft)					
									Head Pond			Tailwater		
					Avg.	Min.	Max.		Avg.	Min.	Max.	Avg	Min.	Max.
11-Jun	28,700	3,550	25,150	75.0	14.0	14.0	14.0	Closed	279.4	279.4	279.4	274.5	274.5	274.5
12-Jun	26,200	3,400	22,800	76.0	13.5	12.0	14.0	Closed	279.3	279.2	279.3	274.4	274.3	274.5
13-Jun	27,100	3,400	23,700	73.0	15.8	14.0	18.0	Closed	279.3	279.3	279.3	274.4	274.4	274.4
14-Jun	35,300	4,600	30,700	68.5	12.0	12.0	12.0	Closed	279.7	279.7	279.7	275.0	275.0	275.0
15-Jun	39,800	5,000	34,800	66.5	8.0	8.0	8.0	Closed	279.9	279.9	280.0	275.2	275.1	275.3
16-Jun	51,300	6,750	44,550	68.3	8.0	8.0	8.0	Closed	280.3	280.1	280.5	275.9	275.5	276.3
17-Jun	58,700	8,550	50,150	74.0	12.0	12.0	12.0	Closed	280.5	280.4	280.6	276.5	276.3	276.8
18-Jun	53,500	7,700	45,800	73.5	9.4	9.0	10.0	Closed	280.4	280.3	280.4	276.1	276.0	276.2
19-Jun	48,900	6,400	42,500	71.5	6.0	6.0	6.0	Closed	280.2	280.1	280.2	275.9	275.8	275.9

NOTE: East Channel flows derived from rating curve developed in the Alden model study and the average head pond elevation recorded from a staff gage at the exit of the fish ladder. Main Dam and powerhouse flow derived by subtracting East Channel flow from average daily river flow.

Table 3. Hourly summary of American shad passage through the vertical notch fish ladder at the York Haven Hydroelectric Project in 2000.

Date	12-May	13-May	14-May	15-May	16-May	17-May	18-May	19-May	20-May	21-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		33	1	-	4	20	10	9	8	6
0900 - 0959		20	3	1	2	5	10	3	3	2
1000 - 1059	-	12	6	-	5	13	20	3	-	-
1100 - 1159	-	35	24	1	-	65	23	10	3	-
1200 - 1259	8	46	15	-	9	15	31	13	5	2
1300 - 1359	2	32	30	6	16	27	21	22	3	3
1400 - 1459	10	16	30	2	15	14	11	66	9	3
1500 - 1559	-	15	56	3	22	15	15	74	17	1
1600 - 1659	6	15	38	15	15	40	9	79	17	2
1700 - 1759	4	23	23	9	21	32	7	89	9	-
1800 - 1900		38	37	4	29	40	10	57	6	1
Total Catch	**30**	**285**	**263**	**41**	**138**	**286**	**167**	**425**	**80**	**20**

Date	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-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	3	5	19	5	15	1	14		31	42
0900 - 0959	3	-	5	2	7	-	4	25	16	27
1000 - 1059	3	1	2	2	5	4	3	6	7	25
1100 - 1159	1	4	9	12	8	4	4	10	13	32
1200 - 1259	3	1	17	4	6	-	9	5	17	31
1300 - 1359	-	3	2	-	6	1	4	15	15	22
1400 - 1459	5	-	16	1	10	3	2	17	23	21
1500 - 1559	6	10	11	4	6	-	8	6	18	6
1600 - 1659	5	2	-	1	5	2	3	3	4	5
1700 - 1759	3	1	5	3	5	1	1	10	13	20
1800 - 1900	-	1	7	1	4	-	1	20	8	14
Total Catch	**32**	**28**	**93**	**35**	**77**	**16**	**53**	**117**	**165**	**245**

Table 3. Continued

Date	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-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	43	101	42	63		22	9	13	43	63
0900 - 0959	20	17	8	31	64	11	4	20	30	33
1000 - 1059	28	19	2	12	22	12	1	18	19	13
1100 - 1159	15	10	3	19	17	5	4	29	14	10
1200 - 1259	8	3	4	14	4	11	4	11	19	3
1300 - 1359	17	15	3	5	10	12	6	16	14	3
1400 - 1459	7	4	1	10	15	7	3	3	9	1
1500 - 1559	8	-	3	2	6	5	1	19	13	1
1600 - 1659	2	5	6	4	5	8	5	14	11	2
1700 - 1759	9	4	2	9	1	3	1	3	3	10
1800 - 1900	15	8	3	4	-	3	2	10	9	-
Total Catch	**172**	**186**	**77**	**173**	**144**	**99**	**40**	**156**	**184**	**139**

Date	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun	Total
Observation Time (Start)	0800	0800	0800	0800	0800	0800	0800	0800	0800	
Observation Time (End)	1900	1900	1900	1900	1900	1900	1700	1600	1600	
Military Time (HRS)										
0800 - 0859	61	101	87	17	11	8	25	13	-	**948**
0900 - 0959	9	22	8	4	3	7	10	-	1	**440**
1000 - 1059	8	6	22	10	3	11	3	-	1	**327**
1100 - 1159	3	22	8	2	10	5	14	-	-	**448**
1200 - 1259	8	3	13	3	2	4	2	-	1	**354**
1300 - 1359	1	11	1	6	2	4	1	-	-	**357**
1400 - 1459	3	7	9	5	4	6	7	-	-	**375**
1500 - 1559	4	7	5	3	5	6	1	2	5	**389**
1600 - 1659	1	8	4	6	8	4	1			**360**
1700 - 1759	1	3	1	10	-	3				**342**
1800 - 1900	2	3	2	3	3	2				**347**
Total Catch	**101**	**193**	**160**	**69**	**51**	**60**	**64**	**15**	**8**	**4687**

Table 4

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 2000 York Haven fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
16-May	8 in	1700 to 1759	21	19	2 (10%)
26-May	6 in	1400 to 1459	10	8	2 (20%)
2-Jun	8 in	0900 to 0959	17	15	2 (12%)
5-Jun	15 in	1000 to 1059	22	18	4 (18%)
17-Jun	12 in	1100 to 1159	14	13	1 (7%)

Table 5

Comparison of American shad passage, visual counts versus video based counts, during the first hour of passage on three days during the 2000 York Haven fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
31-May	14 in	0800 to 0859	42	49	7 (17%)
6-Jun	12 in	0800 to 0859	22	27	5 (23%)
10-Jun	14 in	0800 to 0859	63	71	8 (13%)

Table 6. Minimum and maximum water velocities reported in the Alden model study downstream of each wheel gate and 67 ft weir at the six flow conditions tested.

East Channel Flow (cfs)	Range in Point Velocities Just D/S of Area Indicated (ft/sec) (see notes)					
	Wheel Gate 1		Wheel Gate 2		67 ft Weir	
	Min	Max	Min	Max	Min	Max
2000	9.3	9.8	8.9	9.9	13.5	15.3
4000	10.8	11.4	10.8	12	15	16.5
6000	11	12	11.1	12	13.6	14.9
12000	12.5	13.4	12.7	13.8	9.6	14.5
17000	12	13.2	12	13	6.6	10.4
22000	9.7	10.6	9.7	10.1	3.5	7.4

Notes: 1. Data obtained from ARL model study report (White & Larsen, 8/98) (Figures 32, 34, 36, 38, 40, 42).
2. Velocities are at 2' depth if > 4' or mid-depth if < 4'.

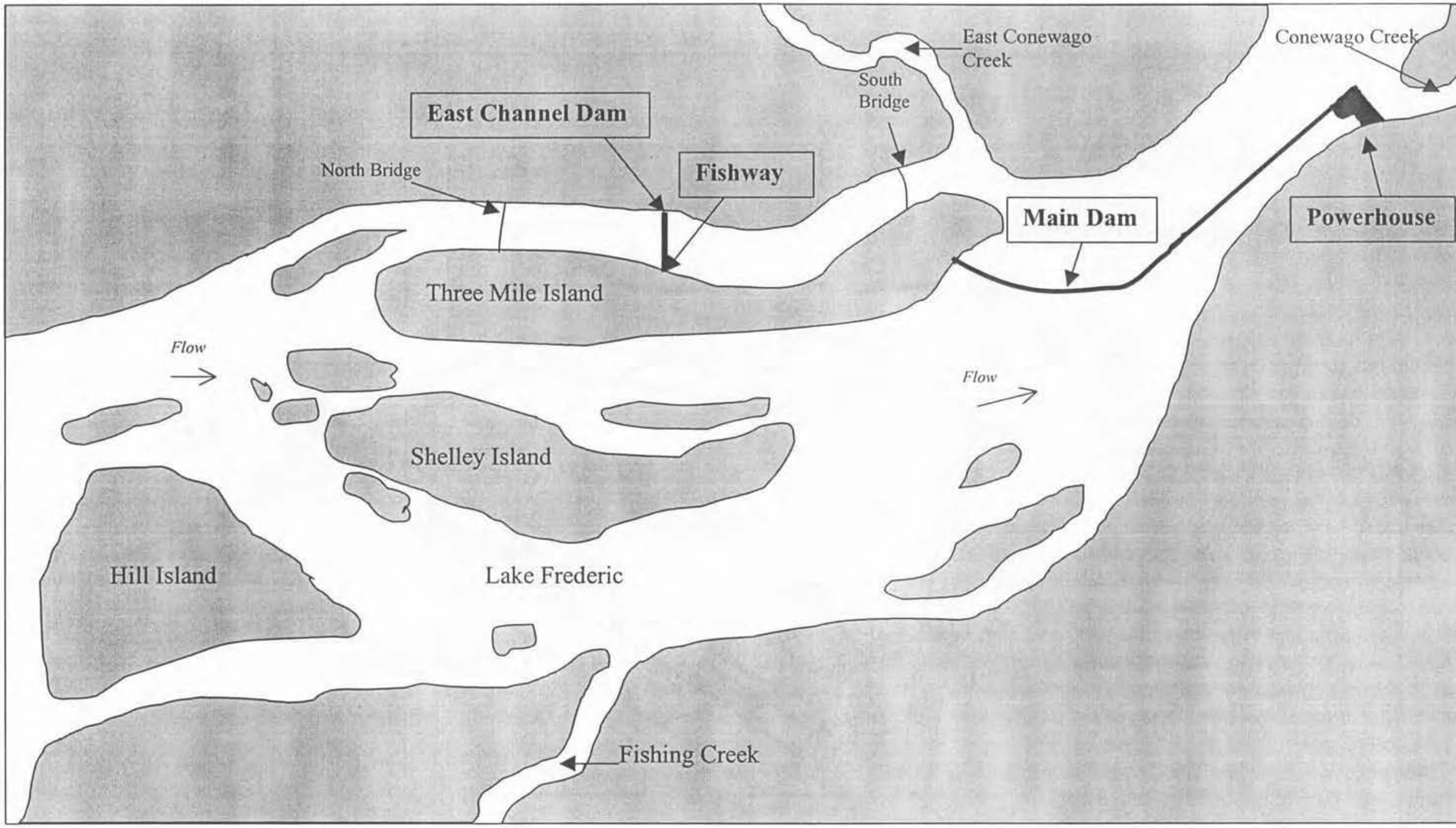
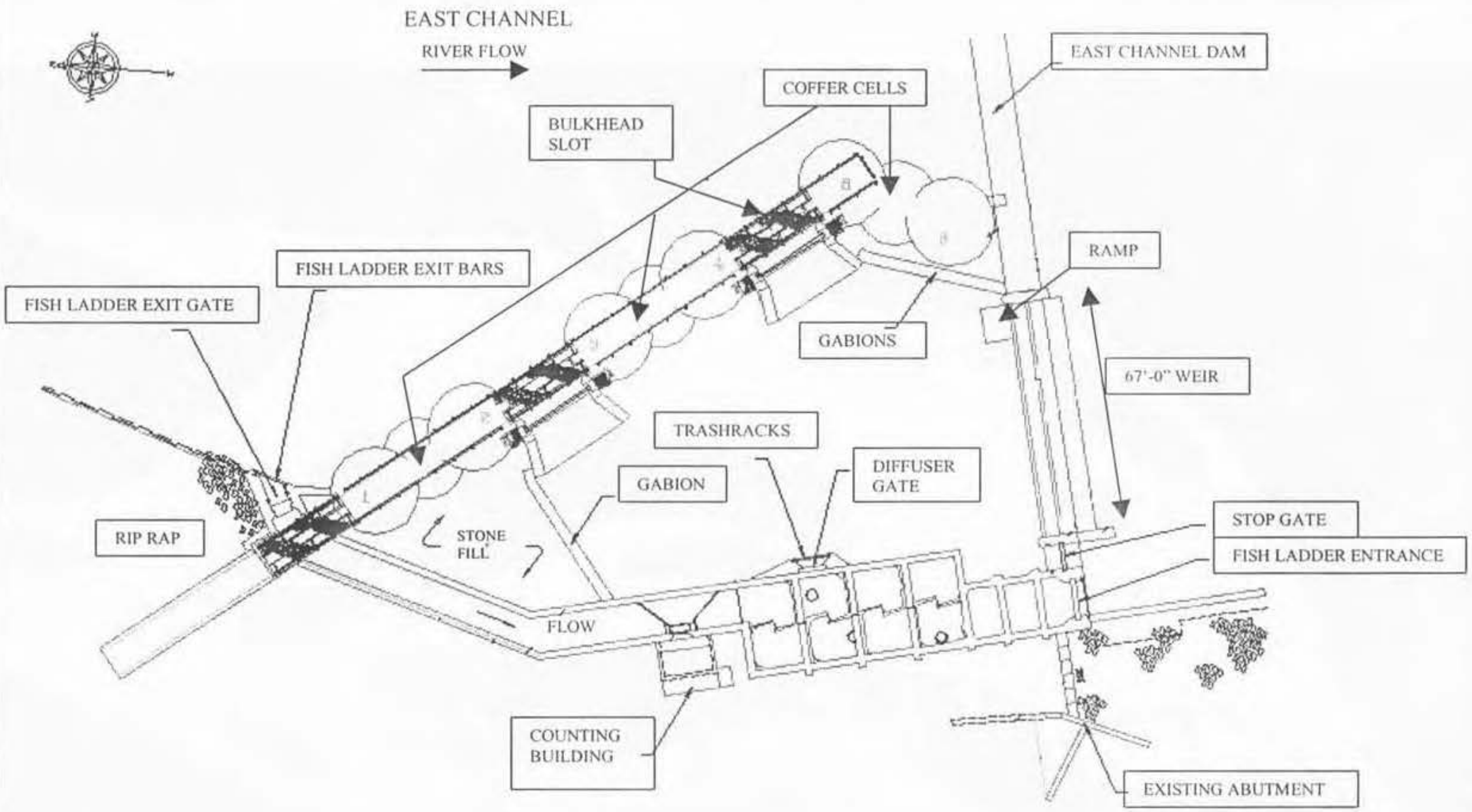


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



GENERAL ARRANGEMENT
YORK HAVEN FISHWAY
FIGURE 2

Figure 3. A Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Catch at the York Haven Fishway in Spring 2000

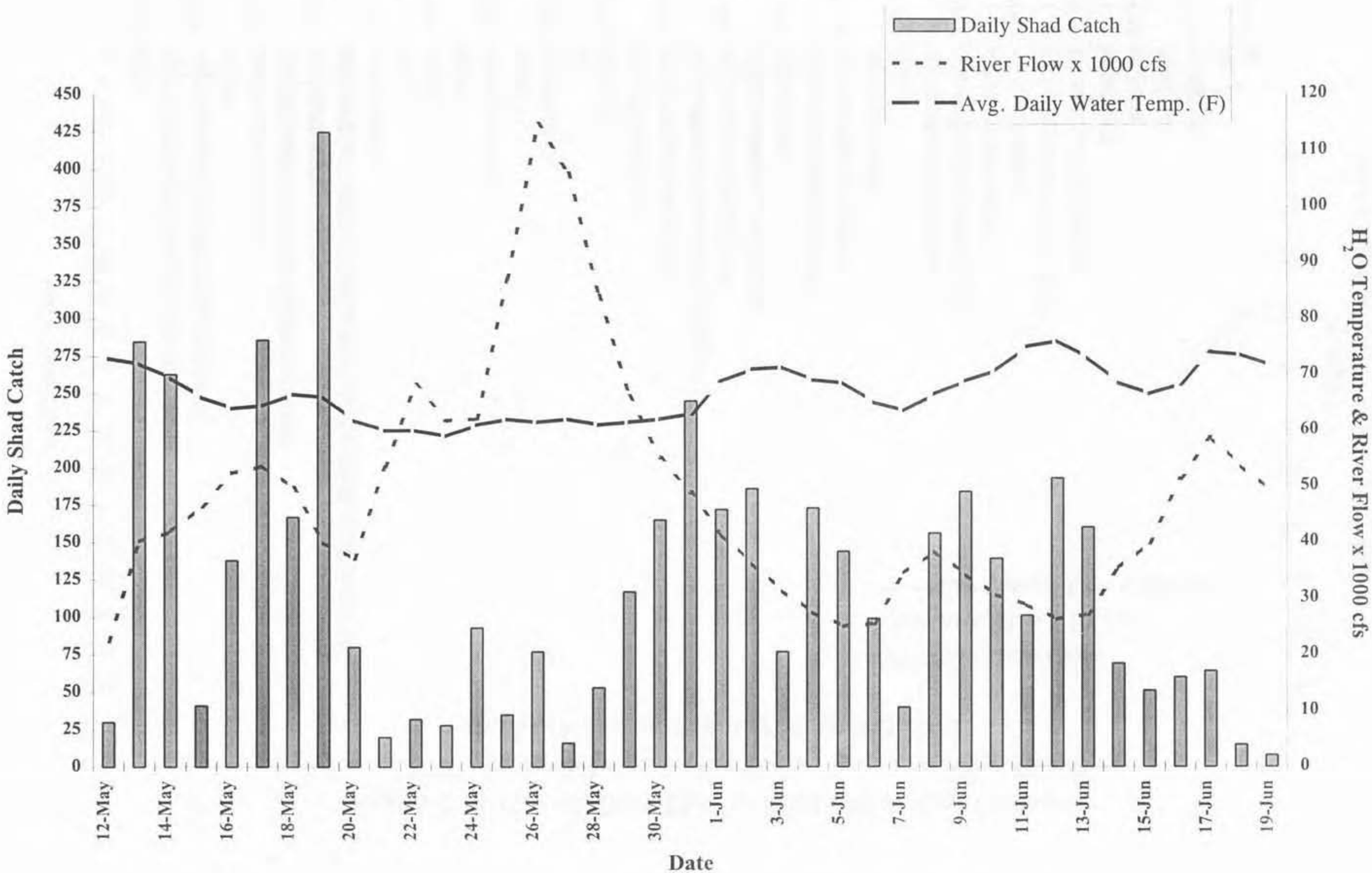
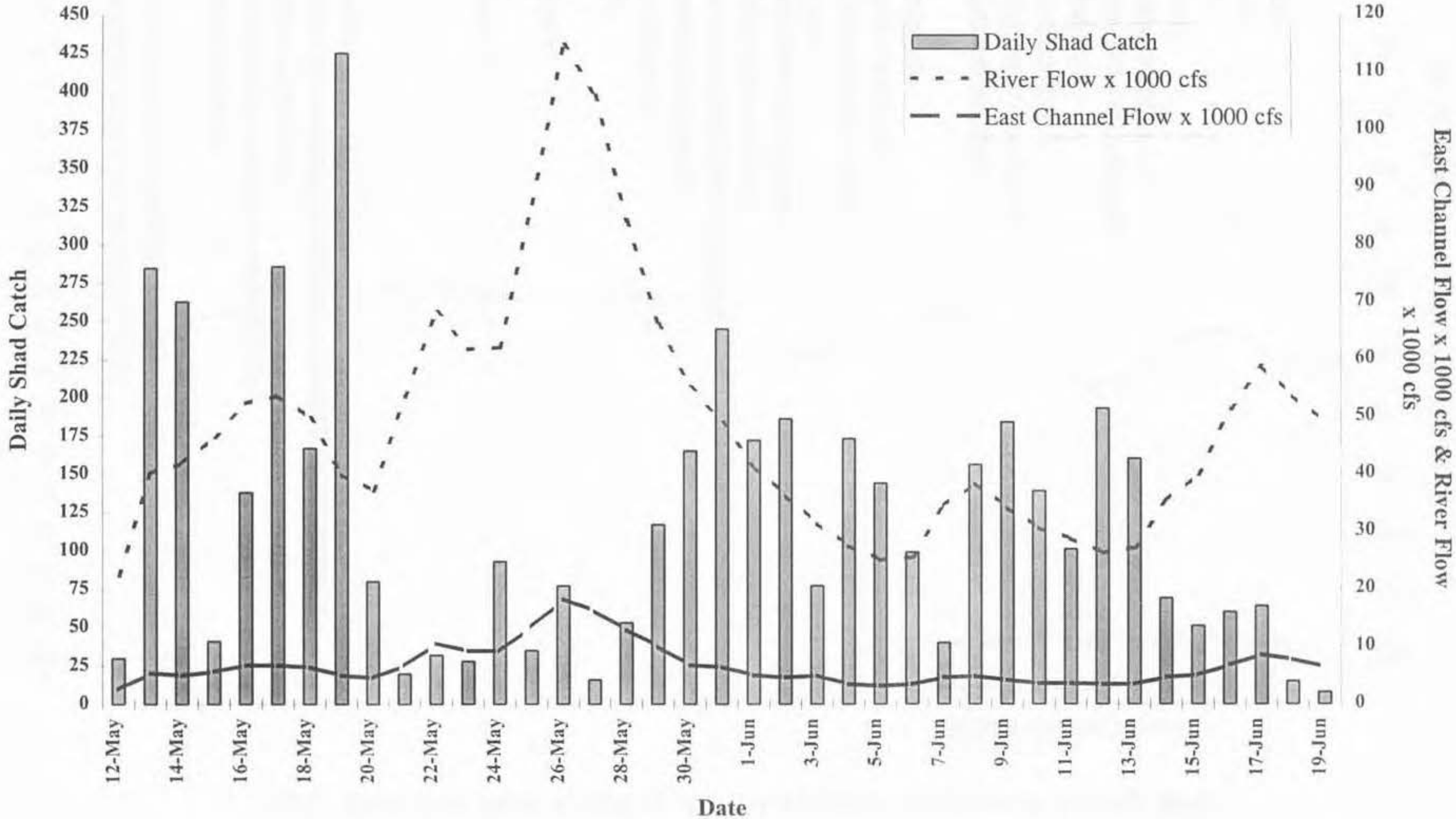


Figure 4. A Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Catch at the York Haven Fishway in Spring 2000



AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2000

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INTRODUCTION

The Pennsylvania Fish and Boat Commission (PFBC) is cooperating with other state and federal agencies and hydro-power companies to restore the American shad (*Alosa sapidissima*) to the Susquehanna River. The restoration effort is coordinated through the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). One component of that effort is production of hatchery-reared 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 2000 was to deliver 10 to 20 million fertilized American shad eggs with a viability of 60-70%.

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).

PROJECT MANAGEMENT

The Wyatt Group provided project management and two field crews to capture ripe American shad and to strip, fertilize and pack eggs for shipment and deliver to the Van Dyke Hatchery. Both crews operated from boats that were fully equipped to capture shad by gill net. One crew was also equipped to work, when river conditions warranted, with a commercial fisherman to process ripe shad taken by haul seine. Until such conditions existed, the crew was assigned to gill net for ripe shad. A driver was provided to deliver shad eggs to the Van Dyke Hatchery, Thompsontown, Pennsylvania.

Water temperatures and local conditions were monitored, and PFBC Project Officer, Mr. Mike Hendricks, was consulted to decide the start date for egg collection operations. The Wyatt Group used procedures that it has employed since 1989. This included regular contact with commercial fishermen and resource agency personnel beginning on April 1. After this date, contact was made once a week until April 15 and then every two days until conditions showed that it was time to start the project. Persons contacted included: (a) Everett Nack, commercial fisherman, Clavarack, NY, (b) Tom Lake, commercial fisherman, Wappinger Falls, NY, and (c) Andy Kahnle and Kathy Hattala, New York Department of Environmental Conservation (NYDEC), New Paltz, NY.

Mssrs. Nack and Lake began gill netting for shad in the second week of April. They were initially contacted to obtain water temperature data. As shad fishing season progressed, they were asked about the size of catches and spawning conditions of shad. Mr. Lake set gill nets in the Wappinger Falls area (river mile 70) and data obtained from him was a good indication that the shad spawning migration had begun. Mr. Nack fishes in the Cheviot/Rogers Island reach (river miles 106 to 114) and his data represents conditions at locations where The Wyatt Group would net shad. The NYDEC biologists were contacted to obtain water temperature and fisheries data not available to Mssrs. Lake or Nack. Information obtained by The Wyatt Group was conveyed to the PFBC Project Officer to establish a start date for the project.

The project commenced when water temperature and local conditions on the Hudson River showed that ripe shad were available for capture. This occurred in the first week of May when the water temperature reached 55°F. The selection of days that were suitable for fishing from project start-up to end was the decision of the PFBC Project Officer, following consultation with The Wyatt Group field supervisor.

Gill net and haul seine operations were conducted in areas of the river where it has been shown that ripe shad can be captured with consistency. 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. Haul seining began when pre-spawned shad were available. The Wyatt Group checked the catch for ripe shad when water temperature was suitable for spawning. The project was terminated when eggs were no longer being taken regularly in a quantity (5 liters or more) which justified shipment to the Van Dyke Hatchery. This occurred when the water temperature reached 63°F, in the last week of May.

The Wyatt Group obtained a "License to Collect or Possess" Hudson River American shad from the NYDEC. The project complied with all regulations and requirements imposed by the State of New York. Disposal of carcasses was according to conditions of the permit. Daily oral reports were filed on a telephone answering machine immediately after each egg collection. This was to update the PFBC Project Officer on success of egg collection efforts, estimated time of arrival of eggs, and prospects for egg collection efforts for the next nights fishing.

After consultation with The Wyatt Group, the Project Officer decided when the fieldwork would begin and end and the daily level of effort expanded (one or two field crews). These determinations were based on availability of funds, water temperatures, success of the collection efforts, trends in numbers of eggs collected, viability, and other factors. As needed, The Wyatt Group reported problem areas and their impact on the project and on each task with recommendations.

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. The Wyatt Group project manager observed the haul seine operation to determine if conditions were appropriate for collection of ripe shad. Mr. Everett Nack, a commercial fisherman, provided two boats and six people for haul seining. A Wyatt Group collecting crew was available to help in the operation but was mainly responsible for the processing of ripe shad.

Gill net and haul seine captured shad. 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.

The Nack haul seine fishery was conducted in May, when tidal conditions were appropriate. The haul seine was 500 feet long, 12 feet deep and had 2-inch meshes. Seine operations were conducted on an ebb tide between late afternoon and dusk. With this tidal condition, a landing site was available where the catch could be beached and processed. Gill netting and haul seining were planned to alternate with the changing tidal conditions with the haul seine to be used during periods of low water and gill nets at all other times. The haul seine is appropriate at the Rogers Island site because a shallow beach provides a net landing area at the low slack tide. The effectiveness of gill netting is influenced by water depth with nets typically fished in waters 4-8 feet deep.

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 137). The only collection site used in 2000 was Coxsackie (RM 123). The haul seine fishery is located at Rogers Island (RM 114).

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.

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. Haul seining was conducted when tidal conditions provided a suitable net landing site at Rogers Island. Usually this occurred for a 7-10 day period at a time when the water temperature was suitable for spawning. The hours for haul seining were from 4:00 – 9:00 PM.

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. The bags were placed into coolers and labeled with river location, date of collection, quantity of eggs and water temperature.

When the volume of eggs was five liters or more, eggs were delivered by automobile to the Van Dyke Hatchery. Eggs from each night of collection from both crews were brought to Catskill, NY and loaded for delivery. The goal was to have the eggs arrive at the hatchery between 10:00 and 11:30 AM with all shipments arriving before 3:00 PM the next day. The field supervisor (or a designate) notified the hatchery regarding the number of liters of eggs shipped and the estimated arrival time.

RESULTS AND DISCUSSION

The first crew began sampling on May 4. The second crew started gill netting on May 6. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on May 31 when water temperature reached 63°F. Sampling occurred on 21 dates during this period including 41 boat-days of gill netting. Haul seining was not used during the 2000 shad-fishing season.

A total of 14.88 million eggs were shipped to the Van Dyke Hatchery (Table 2). Hudson River egg collection in 2000 was less than that of 1999 when 21.1 million eggs were taken. All of the eggs in both years came from the Coxsackie site. The Cheviot and Castleton sites were not fished. The goal of 60-70% viability was exceeded with an average of 71.3% and a range from 48.9% to 84.1% in individual shipments.

Eggs were collected over a period of 27 days from May 4 to May 31. Eggs were available on a consistent basis at Coxsackie. Because of this success no effort was made at other sites. Boat 1 began collection efforts on May 4 and ended on May 31. Boat 2 joined the collection efforts on May 6 and ended on May 31. Weather conditions did not hamper egg collection in 2000. Water temperature increased gradually contributing, in part, to consistent collection of eggs.

SUMMARY

A total of 14.88 million American shad eggs were collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 2000. This success is attributed in part to favorable weather and water temperature conditions. The use of two independent boat crews increased the probability of capturing sufficient bucks to fertilize the eggs obtained by the combined effort. Egg viability averaged 71.3%, exceeding the goal of 60-70% established by the PFBC.

Table 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson rivers and delivered to the Van Dyke Hatchery, 1983-2000.

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
	134.48	137.12	271.60

Table 2. Collection data for Hudson River American shad eggs, 2000.
All eggs were taken at Coxsackie.

Date	Volume (liters)	Number of eggs	PFBC shipment #	Water temp. (F)	Percent viability
04 May	7.9	235,787	1	56	62.9
06 May	38.7	1,388,180	2	58	77.0
07 May	24.4	769,623	3	59	73.4
08 May	34.0	1,026,140	5	60	74.4
09 May	21.8	815,243	7	62	55.7
11 May	39.0	1,630,800	11	63	73.6
14 May	5.0	173,766	12	60	48.9
16 May	3.7	115,432	13	60	63.4
17 May	11.0	303,342	15	61	77.8
18 May	19.8	732,817	16	60	73.3
20 May	15.5	499,684	18	59	80.0
21 May	13.5	459,292	19	58	67.5
22 May	25.5	831,029	20	56	64.3
23 May	23.4	787,638	21	57	73.0
24 May	40.9	1,436,531	22	58	65.3
25 May	25.4	969,659	23	59	72.0
27 May	34.5	1,263,668	24	60	70.3
28 May	13.5	489,346	25	62	75.0
29 May	14.6	557,363	26	62	80.4
30 May	8.5	265,182	27	63	84.1
31 May	4.4	131,325	29	63	74.1
Totals	425.0	14.881,847	21	57	71.3

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2000

M L. Hendricks

Pennsylvania Fish and Boat Commission

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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 1999, 127 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, 12.7 million in the Lehigh River and 2.3 million in the Schuylkill River. The goal of this activity in 2000, 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, 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 5.75 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 supersaturation 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 2000. American shad spawning operations commenced on May 7, when river flow was 3,840cfs, and river temperature was 19.9 C (67.8 F). Egg take ended on June 4, when river flow was 4,430cfs and temperature was 20.0 C (68.0 F). The 2000 egg-take operation was conducted during episodic high flow conditions (Figure 1), thus the nets were operating at their upper threshold for flows. Vegetative debris clinging on the nets also hampered activities and reduced the catch of shad.

Nets were set on twelve nights with 16 nets set each night, except on May 10 and 14 (15 nets each) and May 11 (14 nets). The number of nets set per mesh size (stretch, inch) each night was: two each for the 5.25, 5.5, and 6.0 inch mesh; five 5.0 inch mesh, and one 4.50 inch mesh. The number of nets set per mesh size on May 10, 11 and 14 were reduced by one net in the 5.0 inch mesh size. In addition the number of nets set on May 11 was also reduced by one 5.5 inch mesh net.

A total of 541 adult American shad were caught (Table 1). Nightly catches ranged from a low of 2 to a high of 109 shad. Sex ratio (female to male) was 1.4:1. The egg-take was terminated on June 4, 2000, due to low numbers of shad and eggs being collected and low viability of the collected eggs. The river temperature on June 4 was 20.0 C (68.0 F).

Summary

Shad eggs were collected and shipped on 12 of the 13 nights that were fished from 7 May through 4 June 2000. During this time, 541 adult shad were captured and 78 liters of eggs were shipped for a hatchery count of 3.8 million eggs. This compares to 714 shad and 5.5 million eggs in 1999 and 1,237 shad and 10.4 million eggs in 1998 (Figure 2). The poor catch of shad in 2000 can be attributed to high water conditions throughout the egg collection season. Overall, the percent viability of eggs was 40%.

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).

Figure 1. Delaware River American shad egg collection and flow, 2000.

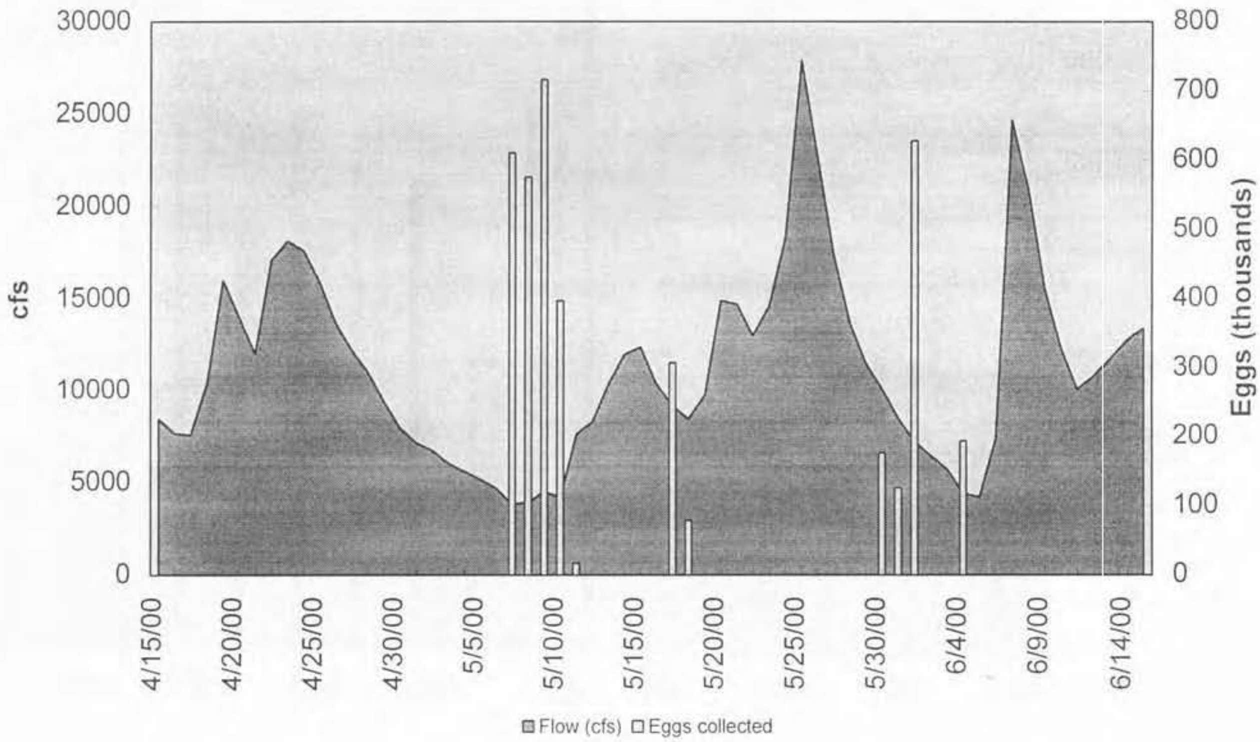

Figure 2. American shad eggs collected from the Delaware River.

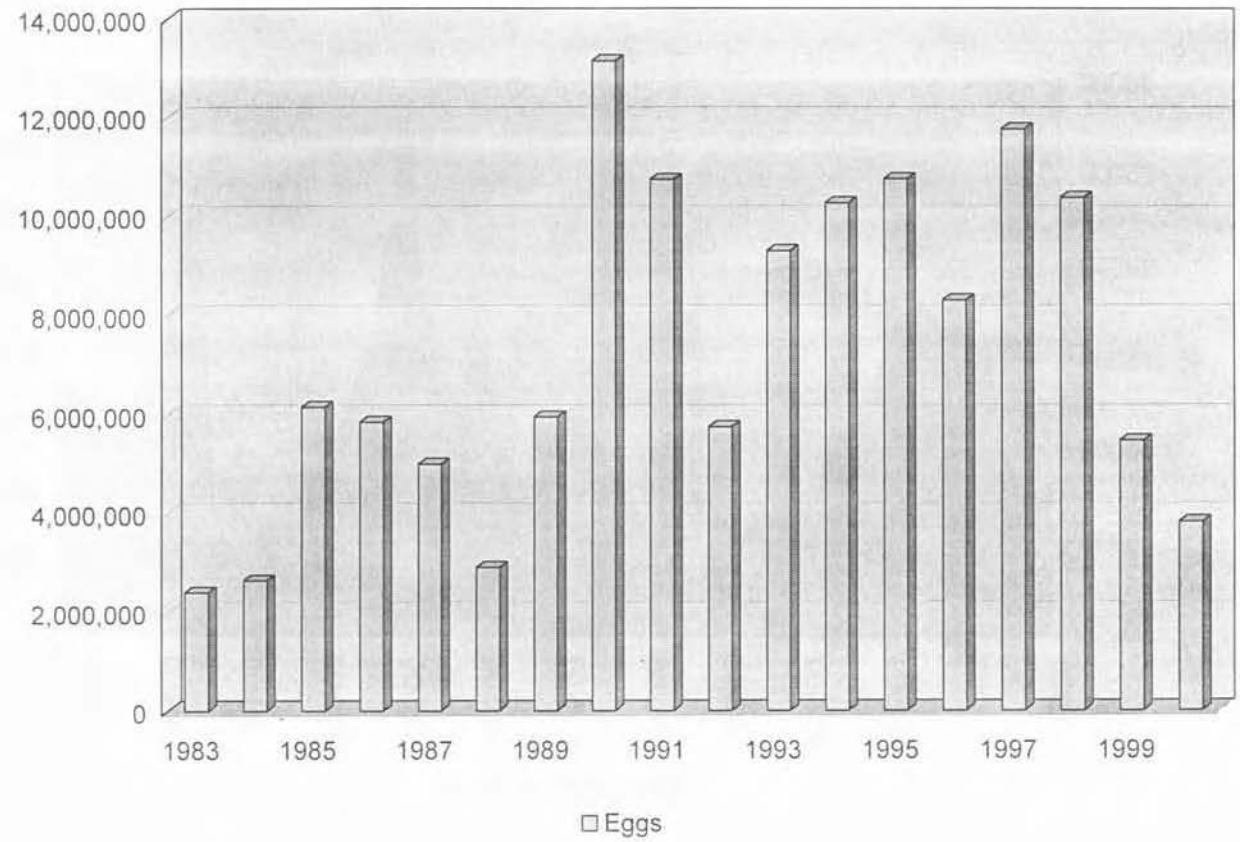

Table 1. Delaware River American shad egg collection data, 2000.

Date	No. of nets	Water Temp ©	No. of shad captured	No. of eggs shipped (Liters)	No. of eggs shipped (millions)	Percent Viability
5/7/00	16	19.9	108	12.1	0.611	33.1
5/8/00	16	21	109	11.9	0.576	38
5/9/00	16	23.6	53	9.6	0.716	52.4
5/10/00	15	19	56	8.2	0.397	25.9
5/11/00	14	18	12	0.7	0.017	68.3
5/14/00	15	17	2	No shipment		
5/17/00	16	17	32	10.2	0.308	65.1
5/18/00	16	16	25	2.6	0.079	36.5
5/30/00	16	16	25	5	0.176	51.1
5/31/00	16	17	18	2.5	0.126	17.3
6/1/00	16	19	59	11	0.628	36.7
6/4/00	16	20	42	4.2	0.194	17.1
Totals	188		541	78	3.828	39.6

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2000

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INTRODUCTION

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

Production goals for 2000 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 18.7 million eggs (503 L) were received in 32 shipments in 2000 (Table 1). This was second fewest eggs since 1992 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 64.8%.

Egg collection efforts on the Delaware River were hampered by availability of spawners due to high water. Delaware River shipments were received from May 7 to June 4. A total of 11 shipments of eggs were received from the Delaware River (3.8 million eggs) with a viability of 39.6%. As in 1999, Delaware River shipments exhibited lower egg viability, compared to pre-1999, due to use of a new method to enumerate dead eggs. Due to the high number of small eggs which do not layer out and cannot be siphoned, we estimated viability by taking samples and counting live and dead eggs. Three samples of at least 100 eggs each were taken 4 to 5 days after fertilization. The percentage of live eggs in the samples was recorded as the viability. This assumes there is no egg mortality after 4 to 5 days of incubation. Years of experience suggests that this is a reasonable assumption. Very few developed embryos have been noted in samples of dead eggs taken over the years. This method was used for all but two of the 14 Delaware shipments. This method is more time consuming but, we believe it to be more accurate than our standard method.

Hudson River eggs were collected only from the site at Coxsackie, where water depths permit gill netting at all stages of the tide. Twenty-one shipments (14.9 million eggs) were delivered with an overall viability of 71.3%. The U. S. Fish and Wildlife Service, Northeast Fishery Center, in Lamar, PA continued tank-spawning operations in 2000. 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 2 million eggs were produced, but none were shipped to the Van Dyke hatchery.

Research was conducted in 2000 to attempt to improve viability of American shad eggs collected on the Delaware River. Those experiments are discussed in Appendix 2.

SURVIVAL

Overall survival of larvae was 87% compared to a range of 41% to 94% for the period 1984 through 1999. 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). Forty-four tanks exhibited 13d survival averaging 94%. Three tanks exhibited 23-day survival averaging 34%. These tanks exhibited steady mortalities from day 8 until stocking. The cause for these mortalities is not known. Three tanks exhibited high mortality within the first three days after hatch due to larvae laying on top of each other. Nine-day survival for these tanks was 83%. This has 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 three years, and, when possible, attempted to maintain water temperatures at 65 or 66F. The newly installed furnace allowed us to maintain these temperatures for most of the 2000 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, shows promise in eliminating the problem of smothering of shad larvae.

LARVAL PRODUCTION

Production and stocking of American shad larvae, summarized in Tables 2, 3 and 4, totaled 10.5 million. A total of 6.2 million was released in the Juniata River, 1.1 million in the Susquehanna River at Montgomery Ferry, Liverpool and Mahantango, 974 thousand in the North Branch Susquehanna River and 632 thousand in the West Branch Susquehanna River. American shad larvae were also stocked in tributaries: 111 thousand in Conodoguinet Creek, 231 thousand in the Conestoga River, 33 thousand in Swatara Creek, and 109 thousand in West Conewago Creek. In addition, 447 thousand larvae were stocked in the Lehigh River and 536 thousand stocked in the Schuylkill River to support restoration efforts there. Some 91 thousand larvae were provided to Delaware Division of Wildlife and stocked in Delaware waters of the Nanticoke River.

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. Larvae from out-of-basin egg sources and stocked in the Juniata River were marked at 3 days of age. Larvae stocked in the Conodoguinet Creek were given a quadruple mark at 3, 9, and 12 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 West Branch Susquehanna River were given a quadruple mark at 3, 6, 9, and 15 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.

The raceways at Benner Spring were used for another study and were not available for grow-out of mark verification fish. Verification of mark retention was accomplished by examining otoliths from larvae. Larvae were reared for at least five days after administration of the last mark. They were collected from the tank and transported to Benner Spring where they were crushed between a microscope slide and cover slip and viewed at 200X. Retention of tetracycline marks for American shad was 100% for all groups analyzed. Analysis of relative survival of each uniquely marked group is discussed in Appendix 1.

SUMMARY

A total of 32 shipments (18.7million eggs) was received at Van Dyke in 2000. Total egg viability was 65% and survival of viable eggs to stocking was 87%, resulting in production of 10.5 million larvae. The majority of the larvae were stocked in the Juniata River (6.2 million) and the middle Susquehanna River near Montgomery Ferry (1.1 million). Larvae were also released in Conodoguinet Cr. (111 thousand), Conestoga River (231 thousand), Swatara Creek (33 thousand), West Conewago Creek (109 thousand), the North Branch Susquehanna River (974 thousand), the West Branch Susquehanna River (632 thousand), the Lehigh River (447 thousand), the Schuylkill River (536 thousand) and the Nanticoke River (91 thousand).

Overall survival of larvae was 87%. 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. Retention of tetracycline marks was 100% for all production marks.

RECOMMENDATIONS FOR 2000

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.

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Figure 1. Survival of American shad larvae, Van Dyke, 2000.

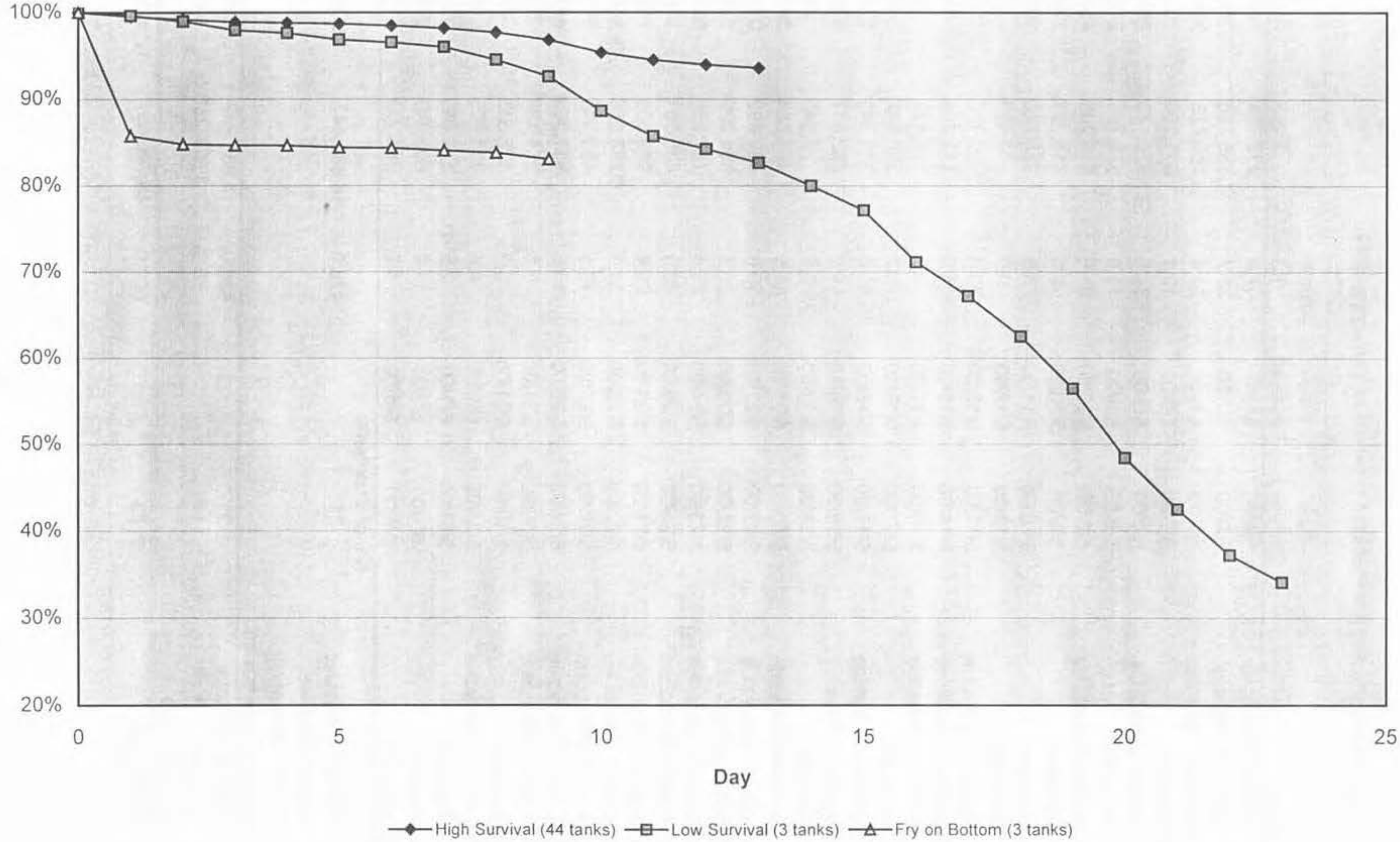

Table 1. American shad egg shipments received at Van Dyke, 2000.

No.	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	Hudson-Coxsackie	5/4/00	5/5/00	7.9	235,787	148,417	62.9%
2	Hudson-Coxsackie	5/6/00	5/7/00	38.7	1,388,180	1,068,508	77.0%
3	Hudson-Coxsackie	5/7/00	5/8/00	24.4	769,623	564,563	73.4%
4	Delaware	5/7/00	5/8/00	12.1	611,250	202,028	33.1%
5	Hudson Coxsackie	5/8/00	5/9/00	34.0	1,026,140	763,197	74.4%
6	Delaware	5/8/00	5/9/00	11.9	575,764	218,733	38.0%
7	Hudson-Coxsackie	5/9/00	5/10/00	21.8	815,243	454,206	55.7%
8	Delaware	5/9/00	5/10/00	9.6	715,791	374,905	52.4%
9	Delaware	5/10/00	5/11/00	8.2	396,745	102,836	25.9%
10	Delaware	5/11/00	5/12/00	0.7	17,123	11,699	68.3%
11	Hudson-Coxsackie	5/11/00	5/12/00	39.0	1,630,800	1,200,750	73.6%
12	Hudson-Coxsackie	5/14/00	5/15/00	5.0	173,766	84,903	48.9%
13	Hudson-Coxsackie	5/16/00	5/17/00	3.7	115,432	73,223	63.4%
14	Delaware	5/17/00	5/18/00	10.2	307,842	200,517	65.1%
15	Hudson-Coxsackie	5/17/00	5/18/00	11.0	303,342	235,973	77.8%
16	Hudson-Coxsackie	5/18/00	5/19/00	19.8	732,817	536,935	73.3%
17	Delaware	5/18/00	5/19/00	2.6	79,345	28,961	36.5%
18	Hudson-Coxsackie	5/20/00	5/21/00	15.5	499,684	399,972	80.0%
19	Hudson-Coxsackie	5/21/00	5/22/00	13.5	459,292	309,822	67.5%
20	Hudson-Coxsackie	5/22/00	5/23/00	25.5	831,029	534,430	64.3%
21	Hudson-Coxsackie	5/23/00	5/24/00	23.4	787,638	574,800	73.0%
22	Hudson-Coxsackie	5/24/00	5/25/00	40.9	1,436,531	938,298	65.3%
23	Hudson-Coxsackie	5/25/00	5/26/00	25.4	969,659	697,755	72.0%
24	Hudson-Coxsackie	5/27/00	5/28/00	34.5	1,263,668	888,228	70.3%
25	Hudson-Coxsackie	5/28/00	5/29/00	13.5	489,346	367,192	75.0%
26	Hudson-Coxsackie	5/29/00	5/30/00	14.6	557,363	448,171	80.4%
27	Hudson-Coxsackie	5/30/00	5/31/00	8.5	265,182	223,031	84.1%
28	Delaware	5/30/00	5/31/00	5.0	175,615	89,762	51.1%
29	Hudson-Coxsackie	5/31/00	6/1/00	4.4	131,325	97,365	74.1%
30	Delaware	5/31/00	6/1/00	2.5	125,611	21,713	17.3%
31	Delaware	6/1/00	6/2/00	11.0	628,447	230,902	36.7%
32	Delaware	6/4/00	6/5/00	4.2	193,717	33,170	17.1%
Totals		No. of shipments					
	Hudson-Coxsackie	21		425.0	14,881,847	10,609,741	71.3%
	Hudson-Cheviot						
	Hudson-Vlomankill						
	Hudson-Rogers Island						
	Hudson- Subtotal	21		425.0	14,881,847	10,609,741	71.3%
	Delaware	11		78.0	3,827,250	1,515,226	39.6%
	Susquehanna						
	Grand total	32		503.0	18,709,097	12,124,966	64.8%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976-2000.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of shad stocked (all rivers) Fry (exp.3)	Fing-erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.19	0.37
1977	145	6.4	46.7	2.9	969	35	1,003	0.16	0.34
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.10	0.33
1979	164	6.4	41.4	2.6	629	34	664	0.10	0.25
1980	347	12.6	65.6	8.2	3,526	5	3,531	0.28	0.43
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.18	0.39
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.20	0.55
1983	938	34.5	55.6	19.2	4,048	98	4,146	0.12	0.22
1984	1157	41.1	45.2	18.6	11,996	30	12,026	-	0.73
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.28	0.68
1986	1535	52.7	40.7	21.4	15,876	61	15,928	0.30	0.74
1987	974	33.0	40.7	15.8	10,274	81	10,355	0.31	0.66
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.33	0.86
1989	1220	42.7	60.1	25.7	22,267	60	22,327	0.52	0.87
1990	896	28.6	56.7	16.2	12,034	253	12,287	0.43	0.76
1991	902	29.8	60.7	18.1	12,963	233	13,196	0.44	0.73
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.25	0.37
1993	558	21.5	58.3	12.8	7,870	79	7,949	0.37	0.62
1994	551	21.2	45.9	9.7	7,720 *	140	7,860	0.31	0.68
1995	768	22.6	53.9	12.2	10,930 *	-	10,930	0.43	0.79
1996	460	14.4	62.7	9.0	8,466 *	-	8,466	0.59	0.94
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.35	0.76
1998	628	27.7	57.4	15.9	11,757	2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412	-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535	-	10,535	0.56	0.87
						Total	207,713		
				Total since 1985 (OTC marked)			176,316		

*Includes fry reared at Manning.

Table 3. American shad stocking and fish transfer activities, 2000.

Date	Tank	Number	OTC mark (days)	Location	Origin	Age	Size
5/19/00	A1 1	146,561	3	Millerstown (Greenwood)	Hudson	7	Fry
6/2/00	A2 1	303,222	3,6,12,15,18	North Branch Susquehanna River	Hudson	19	Fry
6/2/00	A3 1	334,984	3,6,12,15,18	North Branch Susquehanna River	Hudson	19	Fry
6/2/00	A4 1	336,408	3,6,12,15,18	North Branch Susquehanna River	Hudson	19	Fry
5/22/00	B1 1	285,785	3	Millerstown (Rt. 17 Bridge)	Hudson	6	Fry
5/22/00	B2 1	208,393	3	Millerstown (Rt. 17 Bridge)	Hudson	7	Fry
5/30/00	B3 1	196,798	3,6,9,12	Schuylkill River	Delaware	15	Fry
5/23/00	B4 1	253,032	3	Miller's Canoe Rental	Hudson	6	Fry
5/23/00	C1 1	257,290	3	Miller's Canoe Rental	Hudson	6	Fry
6/1/00	C2 1	211,781	3	Montgomery Ferry	Hudson	15	Fry
5/30/00	C3 1	213,297	3,6,9,12	Schuylkill River	Delaware	13	Fry
6/5/00	C4 1	111,017	3,9,12	Conodoguinet Creek	Hudson	15	Fry
6/5/00	D1 1	109,352	9,12,15	West Conewago Creek	Hudson	18	Fry
6/12/00	D2 1	33,321	3,6,9,15,18	Swatara Creek	Hudson	25	Fry
5/30/00	D3 1	125,895	3,6,9,12	Schuylkill River	Delaware	13	Fry
6/7/00	D4 1	91,092	3,6,9,12,15,18	Nanticoke River	Delaware	19	Fry
6/12/00	E1 1	231,178	3,9,12,15	Conestoga River	Hudson	23	Fry
5/29/00	E2 1	283,775	3	Thompsontown	Hudson	9	Fry
6/1/00	E3 1	270,012	3	Montgomery Ferry	Hudson	12	Fry
6/2/00	E4 1	253,498	3	Muskrat Springs	Hudson	13	Fry
6/2/00	F1 1	77,544	3	Muskrat Springs	Hudson	10	Fry
6/3/00	F2 1	69,504	3	Arch Rock	Hudson	9	Fry
6/16/00	F3 1	200,000	3,6,9,12,18	Lehigh River	Delaware	21	Fry
6/3/00	F4 1	232,201	3	Arch Rock	Hudson	8	Fry
6/4/00	G1 1	259,791	3	Mexico	Hudson	8	Fry
6/4/00	G2 1	256,052	3	Mexico	Hudson	8	Fry
6/5/00	G3 1	396,465	3	Millerstown (Greenwood)	Hudson	7	Fry
6/8/00	G4 1	303,087	3	Liverpool	Hudson	9	Fry
6/9/00	H1 1	164,133	3	Mahantango	Hudson	9	Fry
6/9/00	H2 1	170,128	3	Mahantango	Hudson	9	Fry
6/10/00	H3 1	170,693	3	Millerstown (Rt. 17 Bridge)	Hudson	10	Fry
6/10/00	H4 1	248,773	4	Millerstown (Rt. 17 Bridge)	Hudson	9	Fry
6/11/00	I1 1	256,345	4	Thompsontown	Hudson	10	Fry
6/11/00	I2 1	231,240	3	Thompsontown	Hudson	9	Fry
6/13/00	I3 1	206,134	3	Millerstown (Rt. 17 Bridge)	Hudson	11	Fry
6/13/00	I4 1	204,388	3	Millerstown (Rt. 17 Bridge)	Hudson	11	Fry
6/13/00	A1 2	212,798	3	Miller's Canoe Rental	Hudson	11	Fry
6/13/00	B1 2	215,860	3	Miller's Canoe Rental	Hudson	10	Fry
6/13/00	B2 2	213,023	3	Mifflin	Hudson	10	Fry
6/13/00	B3 2	216,869	3	Mifflin	Hudson	10	Fry
6/26/00	B4 2	204,343	3,6,9,15	West Banch Susquehanna River	Hudson	21	Fry
6/26/00	C1 2	217,614	3,6,9,15	West Banch Susquehanna River	Hudson	21	Fry
6/26/00	C2 2	210,429	3,6,9,15	West Banch Susquehanna River	Hudson	21	Fry
6/14/00	C3 2	357,870	3	Mifflin	Hudson	8	Fry
6/14/00	E2 2	422,170	3	Mifflin	Hudson	7	Fry
6/14/00	E3 2	218,081	3	Mifflin	Hudson	6	Fry
7/5/00	E4 2	39,132	3,6,9,12,18	Lehigh River	Delaware	27	Fry
6/14/00	F1 2	95,583	3	Mifflin	Hudson	5	Fry
7/5/00	F2 2	196,892	3,6,9,12,18	Lehigh River	Delaware	25	Fry
7/5/00	F4 2	11,366	3,6,9,12,18	Lehigh River	Delaware	22	Fry

Table 4. Production and utilization of juvenile American shad, Van Dyke, 2

	Site	Fry
Releases	Millerstown (Greenwood)	543,027
	Millerstown (Rt. 17 Bridge)	1,324,166
	Miller's Canoe Rental	938,981
	Thompsontown	771,361
	Muskrat Springs	331,042
	Mexico	515,843
	Mifflin	1,523,594
	Arch Rock	301,705
	Treaster's Exxon	
	Juniata River Subtotal	6,249,719
	Montgomery Ferry	481,793
	Liverpool	303,087
	Mahantango	334,261
	Conodoguinet Creek	111,017
	Conestoga River	231,178
	Swatara Creek	33,321
	West Conewago Creek	109,352
	North Branch Susquehanna River	974,614
	West Banch Susquehanna River	632,386
	Susquehanna River Basin	9,460,728
	Schuylkill River	535,990
	Lehigh River	447,390
	Nanticoke River*	91,092
	Total	10,535,200

* Stocked by Delaware Division of Wildlife

Table 5. Tetracycline marking regime for American shad stocked in the Mid-Atlantic region, 2000.

			Mark		Hatchery						Mark	
			Immersion		Fry	Fingerling	Stocking	Egg	Taggant		Retention (%)	
Year	Number	Size	(days)	Feed	Culture	Culture	Location	Source	Immersion	Feed	Immers.	Feed
2000- American shad												
	7,368,860	Fry	3	-	Van Dyke	-	Juniata & Susq. R.	Hudson	256ppm OTC	-	100	-
	111,017	Fry	3,9,12	-	Van Dyke	-	Conodoguinet Cr.	Hudson	256ppm OTC	-	100	-
	109,352	Fry	9,12,15	-	Van Dyke	-	W. Conewago Cr.	Hudson	256ppm OTC	-	100	-
	535,990	Fry	3,6,9,12	-	Van Dyke	-	Schuylkill R.	Delaware	256ppm OTC	-	100	-
	632,386	Fry	3,6,9,15	-	Van Dyke	-	W. Br. Susq. R.	Hudson	256ppm OTC	-	100	-
	328,596	Fry	3,6,9,15	-	Lamar	-	W. Br. Susq. R.	Susq.	256ppm OTC	-	100	-
	231,178	Fry	3,9,12,15	-	Van Dyke	-	Conestoga R.	Hudson	256ppm OTC	-	100	-
	447,390	Fry	3,6,9,12,18	-	Van Dyke	-	Lehigh R.	Delaware	256ppm OTC	-	100	-
	33,321	Fry	3,6,9,15,18	-	Van Dyke	-	Swatara Cr.	Hudson	256ppm OTC	-	100	-
	974,614	Fry	3,6,12,15,18	-	Van Dyke	-	N. Br. Susq. R.	Hudson	256ppm OTC	-	100	-
	10,772,704	Fry	Subtotal									
	91,092	Fry	3,6,9,12,15,18	-	Van Dyke	-	Nanticoke R.	Delaware	256ppm OTC	-	100	-
	209,000	Fry	9,12	-	Manning	-	Patuxent R.	Susq.	200ppm OTC	-		-
	140,000	Fry	3,12	-	Manning	-	Patuxent R.	Susq.	200ppm OTC	-		-
	132,000	Fry	6,12	-	Manning	-	Choptank R.	Susq.	200ppm OTC	-		-
	225,000	Fry	Egg,6	-	Manning	-	Choptank R.	Susq.	1000/200ppm OTC	-		-
	706,000	Fry	Subtotal									
	36,250	Early juv.	3,6	-	Manning	PEPCO Ponds	Patuxent R.	Susq.	200ppm OTC	-		-
	26,765	Fing.	-	single*	Manning	PEPCO Ponds	Patuxent R.	Susq.	-	500mg/kg live wt.		
	3,000	Fing.	-	single	Manning	PEPCO Ponds	Patuxent R.	Susq.	-	500mg/kg live wt.		-
	64,399	Fing.	-	single*	Manning	PEPCO Ponds	Choptank R.	Susq.	-	500mg/kg live wt.		-
	94,164	Fing.	Subtotal									
	3,204,166	Fry	3,9	-	Harrison L.	-	Potomac R.	Potomac R.	200ppm OTC	-		-
	1,151,860	Fry	3,6,15	-	Harrison L.	-	Chickahominy L.	York R.	200ppm OTC	-	100	-
	1,841,391	Fry	3,6,15	-	Harrison L.	-	James R.	York R.	200ppm OTC	-	100	-
	516,614	Fry	3,6,12,15	-	Harrison L.	-	York R.	York R.	200ppm OTC	-	100	-
	5,910,538	Fry	9	-	King & Queen	-	James R.	York R.	271ppm OTC	-	100	-
	3,176,722	Fry	3,6,12,15	-	King & Queen	-	York R.	York R.	271ppm OTC	-	100	-
	5,000,000	Fry	15	-	PTG	-	Pamunkey R.	Pamunkey R.	200ppm OTC	-		-
	4,500,000	** Fry	6, 15	-	MTG	-	Mattaponni R.	Mattaponni R.	200ppm OTC	-		-
	90,000	Fry	3,6,12	-	Edenton	-	Roanoke R.	Meherrin R.	200ppm OTC	-	-	-
	445,000	Fry	3,6,12	-	Edenton	-	Roanoke R.	Tar R.	200ppm OTC	-	-	-
	308,000	Fry	3,6,12	-	Watha	-	Roanoke R.	Tar R.	300ppm OTC	-	-	-
Hickory Shad												
	5,634,000	Fry	Egg,3	-	Manning	-	Choptank R.	Susq.	1000/200ppm OTC	-		-
	1,250,000	Fry	Egg,3	-	Manning	-	Nanticoke R.	Susq.	1000/200ppm OTC	-		-
	500,000	Fry	Egg,3	-	Manning	-	Patapsco R.	Susq.	1000/200ppm OTC	-		-
	8,235,000	Fry	Egg,3	-	Manning	-	Patuxent R.	Susq.	1000/200ppm OTC	-		-
	15,619,000	Fry	Subtotal									
	38,778	Fing.	-	single*	Manning	PEPCO Ponds	Choptank R.	Susq.	-	500mg/kg live wt.	-	-
	28,436	Fing.	-	single*	Manning	PEPCO Ponds	Patuxent R.	Susq.	-	500mg/kg live wt.	-	-

*Also recieved coded wire tags

**500,000 marked

Appendix 1

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2000.

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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 2000 and summarizes results from 1995 to 2000.

Materials and Methods

The majority (63%) of production larvae stocked in 2000 was marked at three days of age and 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. No fingerlings were stocked in 2000.

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 outmigrating population as a whole. 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). Recovery rates were calculated for each group by dividing the 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 2000 are tabulated in tables 1-1 through 1-6, respectively. In 2000, 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). Larvae stocked in Conewago Cr. also survived well (relative survival 0.86). Larvae stocked in the North Branch and in Conodoguinet Cr. did relatively less well with a relative survival of 0.48 and 0.51, respectively. Larvae stocked in the West Branch Susquehanna River and in Conestoga R. did poorly with relative survival of 0.20 and 0.24. No larvae were recovered from the Swatara Cr. release.

A summary of the results of four years of uniquely marking larvae according to stocking site is provided in Table A1-7. Recovery rates for 2000 varied from 0.0 to 0.53.

The overall recovery rate for 2000 (0.45) was second only to 1997 (0.57).

Larvae stocked in the North Branch did extremely well in previous years, but only average in 2000. Larvae stocked in the West Branch have not done well, exhibiting relative survival of 0.00 to 0.38 during the period 1996 to 2000.

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 (0.35) and 2000 (0.24) and were not detected in 1996 and 1998. The high survival, 1995 and 1999 releases 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 exhibited good relative survival in 1999 (0.77) fair relative survival in 1996 and 2000(0.50 and 0.51), but poor relative survival in other years (0.18 to 0.25; 1995, 1997 and 1998). 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 0.93 and 0.81, respectively), but were not detected in 2000, probably due to the low number stocked (33,000). In Conewago Cr., larvae did well in 1998, poorly in 1999, and well in 2000 (relative survival 1.00 , 0.15, and 0.86 respectively), 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.

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%	308	87	0.34	0.27
Conodoguinet Cr.	19	6/6	220,000	2%	5	1	0.23	0.18
mouth of Conodoguinet Cr.	19	6/6	230,000	2%	9	3	0.39	0.31
Conestoga R.	22	6/15	198,000	2%	25	7	1.26	1.00
mouth of Conestoga R.	22	6/15	190,000	2%	8	2	0.42	0.33
Muddy Cr.	22	6/19	93,000	1%	0	0	0.00	0.00
		Total	10,001,000		355		0.35	

*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.

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%	45	66	0.08	0.33
Conodoguinet Cr.	16	6/14	171,700	2%	2	3	0.12	0.50
Conestoga R.	17	6/17	277,100	4%	0	0	0.00	0.00
Standing Stone Cr.	21	7/2	42,900	1%	0	0	0.00	0.00
W. Br. Susq. R.	17	6/15	561,100	8%	5	7	0.09	0.38
N. Br. Susq. R.	13	6/19	682,500	9%	16	24	0.23	1.00
		Total	7,465,500		68		0.09	

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.

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%	211	46	0.69	1.00
Juniata R./ various sites	18-20	6/9-7/1	2,270,000	30%	140	31	0.62	0.89
Conodoguinet Cr.	18	6/24	174,000	2%	3	1	0.17	0.25
Conestoga R.	25	7/1	231,000	3%	6	1	0.26	0.37
Huntingdon	10	5/31	486,000	7%	26	6	0.53	0.77
W. Br. Susq. R.	23	6/30	622,000	8%	15	3	0.24	0.35
N. Br. Susq. R.	17-19	6/23	1,199,000	16%	57	12	0.48	0.68
		Total	8,019,000		458		0.57	

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.

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%	119	26	0.13	0.71
Juniata R./ Susq. egg source	11-12	6/11-6/15	565,000	5%	5	1	0.09	0.47
Conodoguinet Cr.	16	5/29	305,000	3%	1	0	0.03	0.18
Conestoga R.	20	6/1	229,000	2%	0	0	0.00	0.00
Conewago Cr.	16	5/29	321000	3%	6	1	0.19	1.00
Swatara Cr.	20	6/1	230000	2%	4	1	0.17	0.93
W. Br. Susq. R.	15	6/19-6/25	56,000	0%	0	0	0.00	0.00
N. Br. Susq. R.	17-20	5/27	1,126,000	10%	21	5	0.19	1.00
Standing Stone Cr.	fing.	9/9	2,200	0%	0	0	0.00	0.00
		Total	11,759,200		156		0.13	

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.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	%	Juveniles Recovered N	%	Recovery Rate	Relative Survival
Juniata R./	5-10	5/17-6/1	10,229,000	87%	456	100	0.45	0.75
Juniata R./ Susq. egg source	-	-	0	0%		0	0.00	0.00
Conodoguinet Cr.	14	6/11	373,000	3%	17	4	0.46	0.77
Conestoga R.	20	6/10	236,000	2%	14	3	0.59	1.00
Conewago Cr.	19	6/8	219000	2%	2	0	0.09	0.15
Swatara Cr.	20	6/10	249000	2%	12	3	0.48	0.81
W. Br. Susq. R.	17-22	6/21	984,000	8%	0	0	0.00	0.00
N. Br. Susq. R.	19	6/4	1,211,000	10%	16	3	0.13	0.22
		Total	13,501,000		517		0.38	

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.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	%	Juveniles Recovered N	%	Recovery Rate	Relative Survival
Juniata R./ middle Susq. R. near Mont. Ferry	7-15	5/19-6/1	7,368,860	63%	393	86	0.53	1.00
Conodoguinet Cr.	15	6/5	111,017	1%	3	1	0.27	0.51
Conestoga R.	23	6/12	231,178	2%	3	1	0.13	0.24
Conewago Cr.	18	6/5	109,352	1%	5	1	0.46	0.86
Swatara Cr.	25	6/12	33,321	0%	0	0	0.00	0.00
W. Br. Susq. R.	21	6/26	960,982	8%	10	2	0.10	0.20
N. Br. Susq. R.	16-19	6/2-6/29	974,614	8%	25	5	0.26	0.48
		Total	9,789,324		439		0.45	

Table A1-7. 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, 1995-2000.

Stocking	Recovery Rate						Relative Survival					
Site	1995	1996	1997	1998	1999	2000	1995	1996	1997	1998	1999	2000
Juniata R./Susq. R. @ Mont. Ferry	0.34	0.08	0.69			0.53	0.27	0.33	1.00			1.00
Juniata R.(various sites)			0.62	0.13	0.45				0.89	0.71	0.75	
Juniata R.(Susq. eggs)				0.09						0.47		
Huntingdon			0.53						0.77			
Standing Stone Cr.		0.00		0.00				0.00		0.00		
Conodoguinet Cr.	0.23	0.12	0.17	0.03	0.46	0.27	0.18	0.50	0.25	0.18	0.77	0.51
mouth of Conodiguinet C	0.39						0.31					
Conestoga R.	1.26	0.00	0.26	0.00	0.59	0.13	1.00	0.00	0.37	0.00	1.00	0.24
mouth of Conestoga Cr.	0.42						0.33					
Muddy Cr.	0.00						0.00					
Conewago Cr.				0.19	0.09	0.46				1.00	0.15	0.86
Swatara Cr.				0.17	0.48	0.00				0.93	0.81	0.00
W. Br. Susq. R.		0.09	0.24	0.00	0.00	0.10		0.38	0.35	0.00	0.00	0.20
N. Br. Susq. R.		0.23	0.48	0.19	0.13	0.26		1.00	0.68	1.00	0.22	0.48
Overall	0.35	0.09	0.57	0.13	0.38	0.45						

Appendix 2

Evaluation of methods to improve the viability of Delaware River American shad eggs, 2000.

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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.

There is considerable literature on fish sperm motility, sperm activation, extending and storage of sperm, and fertilization of eggs. Good overviews of the subject are provided by Scott and Baynes (1980) and Stoss (1983). Fish sperm are immotile in the testis and in undiluted semen and motility is induced upon discharge into the aqueous environment due to environmental factors which may include osmolality, ion concentrations, or pH. Changes in osmotic pressure are often cited in inducing motility. Dilute salt solutions can induce and prolong motility (Billard 1978, Piper et al. 1982, Billard et al. 1995, Brown and Mims 1995, Lahnsteiner et al. 1997) and improve fertilization rate (Heidinger and Kayes 1986, Brown and Shrable, 1995, Tan-Fermin et al. 1999). Solutions of 6.0 to 7.49 g/L NaCl also act to hold albumin from broken eggs in solution and prevent it from clogging the micropyle of unfertilized eggs, thus improving fertilization rates in salmonids (Carl 1941, Leitritz and Lewis 1976, Piper et al. 1982). Both eggs and sperm are rapidly incapacitated in fresh water, so fertilization within 20 seconds is recommended (Scott and Baynes 1980, Heidinger and Kayes 1986).

Storage of semen can be accomplished by reducing the temperature to just above freezing (Hulata and Rothbard 1979, DiLauro et al. 1994). Oxygen must be present so storage in containers with pure oxygen added and semen depths less than 3mm are recommended (Moore 1996). Water will activate the semen so care must be taken to keep water out of the storage container (Satterfield and Flickinger 1995a, Koupal 1996). Fecal matter must be removed immediately as it reduces shelf life and duration of motility (Satterfield and Flickinger 1995b, Koupal 1996).

Semen can be extended with a salt solution isotonic to the seminal plasma (Stoss 1983, Yao et al. 1999). Extending the semen keeps it from dessicating, dilutes it to permit fertilization of more eggs for a given volume of semen, and permits collection of semen when males are abundant for use when males are scarce (Stoss 1983). Many extenders have been tested including some which attempted to duplicate the ionic composition of seminal plasma (Moore 1987, Ohta and Izawa 1996, Yao et al. 1999). Others have achieved good results with a simple NaCl solution which mimics the osmolality of seminal plasma (Brown and Mims 1995, Brown and Moore 1996, see also Scott and Baynes 1980).

There are complicating factors to the above generalizations. For example, sperm of different species are activated in solutions of different osmotic pressures. Salmonid sperm are motile in NaCl concentrations exceeding that of seminal plasma (Morisawa et al. 1983a), while cyprinid sperm are not motile in NaCl concentrations equal to or higher than seminal plasma (Morisawa et al. 1983b). In general, higher concentrations of salt (5.0 to 7.9 g/L NaCl) are reported to activate salmonid sperm (Carl 1941, Leitritz and Lewis 1976, Piper et al. 1982, Brown and Shrable 1995), while lower concentrations (2.9 g/L NaCl) are reported to activate carp, muskellunge and *Cottus gobio* (Billard et al 1995, Lin and Dabrowski 1996, Lahnsteiner et al. 1997). Concentrations of NaCl which would activate salmonid sperm were found to inhibit motility in muskellunge (7.25 g/L, Lin and Dabrowski 1996) and walleye (8.8 g/L, Brown and Moore 1996). Thus, determination of concentrations of NaCl which activate sperm and those which inhibit sperm motility must be done on a species specific basis. There are no published reports of sperm activitation, motility, osmolality or diluents for Alosids.

The role of K+ ions in activation and extending sperm is complicated. In salmonids, very low concentrations of K+ permit full activation of sperm, but increasing K+ concentrations inhibits activation. Addition of divalent cations (Ca++ or Mg++) results in full activation in solutions of K+ that would normally inhibit motility (Morisawa et al. 1983a, Boitano and Omoto 1992). This contrasts to cyprinids where K+ accelerates motility.

As might be expected, freshwater and saltwater fish differ in their sperm motility characteristics. Linhart et al. (1999) found that freshwater tilapia sperm exhibited optimal motility at 70-333 mOsmol/kg, while tilapia acclimated to saltwater exhibited optimal sperm motility at 333-645 mOsmol/kg.

Cryopreservation for long term storage of semen is possible, but is beyond the scope of the present study.

Review of egg collection operations on the Delaware River has revealed several potential problems which may account for the unusually low egg viabilities. First, because of the swift and shallow nature of the habitat, small john boats must be used to set the gill nets used to collect spawners. This prohibits using the boat as a spawning platform as is done on the Hudson River (Mark Plummer, The Wyatt Group, pers. comm.). It also prohibits carrying a live tank to keep the spawners alive until stripping, as is done on the Pamunkey River (Tom Gunter, Virginia Department of Game and Inland Fisheries, pers. comm.). Instead, shad are removed from the gill nets, placed in square plastic tubs with water and taken to a site on shore where strip-spawning takes place. The delay between capture in the gill net and actual stripping can be 20 to 35 minutes. As a result, most shad are dead or dying when stripped. The use of good, live males for fertilization is thought to be an important factor in egg viability (Mark Plummer, The Wyatt Group, pers. comm.).

I propose several solutions to this problem. First, holding of male shad in a 35ppt salt solution (seawater), chilled to near freezing with de-chlorinated ice may keep the fish alive and act to slow degeneration of the sperm, while imposing minimal disruption to the normal fish collection routine. Second, I propose collection of sperm from males immediately upon capture and storage in a chilled container until use (Hulata and Rothbard 1979, Stoss 1983, DiLauro et al. 1994). Third, sperm collected immediately upon capture can be extended and used hours or even days later (Stoss 1983; Moore 1987,1996; Brown and Moore 1996; Koupal 1996). This third alternative has another application. Semen can be collected when males are abundant and stored for later use when males are scarce.

A second potential problem is the presence of broken eggs in the stripping dishpan. Albumin from broken eggs can clog the micropyle and prevent fertilization (Carl

1941, Leitritz and Lewis 1976, Piper et al. 1982). This problem can be easily rectified by the use of a dilute salt solution during sperm activation. The salt solution keeps the egg albumin in solution and prevents it from clogging the micropyle (Carl 1941, Leitritz and Lewis 1976, Piper et al. 1982). Another potential benefit of the use of saline solutions in sperm activation is an increase in the duration of sperm motility (Rieniets and Millard 1985, Brown and Shrable 1995).

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

This study investigates 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 and extended sperm, use of isotonic salt solutions during sperm activation, and use of calcium chloride during water hardening and transport.

Materials and Methods

Preliminary work was conducted in Virginia on March 25 and 26, 2000, to determine (1) the osmolality of American shad seminal fluid, (2) the response of shad sperm to activation in NaCl and NaCl/KCl solutions, (3) the motility of sperm collected from dead or dying shad, and (4) the motility of stored, whole and extended semen over time.

Male shad were collected by gill nets and delivered alive to a central location where spawning took place. Males were thoroughly dried with towels and semen stripped into dry dishpans or sandwich containers. A 1 ml sample was collected from each male and stored in microcentrifuge tubes. The remaining semen was used to fertilize production lots of eggs on site. Fourteen semen samples were stored overnight by pressing the microcentrifuge tubes into a piece of open-cell foam to keep them upright. The lids were kept open and the foam put in a plastic container. Oxygen was added to the container and the container sealed and kept on ice until delivery to Virginia Commonwealth University the following day where the osmolality of the semen was measured with a vapor pressure osmometer.

Whole semen was collected, stored in sandwich containers with oxygen, and transported on ice to the King and Queen Fish Hatchery. Sperm was activated with concentrations of NaCl from 0 to 12 g/L (0 -1.2%) at intervals of 1g/L. Solutions of 20, 30 and 40 g NaCl/L were also tested. Motility was observed under a microscope at 400X by putting a 1mm diameter drop of semen on a microscope slide and adding a large drop of the activating solution (Brown and Mims 1995). Motility was scored 0 to 6, following the methods of Brown and Moore (1996), with 0 being no motility and 6 being 100% motility. A stopwatch was used to score motility at 30 sec intervals.

Three shad were placed in tubs with water as is standard practice on the Delaware. One shad was stripped after 20 minutes, one after 40 minutes and one after 110 minutes. Semen was activated and motility observed to assess motility of sperm collected from dead or dying shad.

Motility of stored whole and extended semen was assessed by collecting semen from 2 males in a sandwich container. One ml of semen was put in another container and diluted with 4 ml of extender. The remaining semen was stored whole. The experiment was repeated two times. Motility of sperm was checked within several hours and again at 2 day intervals. Whole and extended semen was stored on ice in plastic sandwich boxes (Satterfield and Flickinger 1995b) with a maximum of 4mm fluid depth. Oxygen was added to the boxes daily.

Based on the preliminary work done in Virginia, the remainder of the study was conducted on the Delaware River in Pennsylvania and consisted of five treatments and a control (Table 1, Figure 1). American shad were collected by gill net using standard methods. The first male captured was put in a solution of 35ppt salt solution (approximating seawater) which had been chilled to approximately 32F by the addition of de-chlorinated ice. The second male captured was put in a tub with water, as per standard practice. The third male captured was stripped immediately upon capture. The fish was thoroughly dried with a towel prior to stripping to remove any water and prevent water from activating the sperm. Semen from the third male was stripped into a cup and 2 ml of the semen was measured and put in plastic sandwich container C' (Satterfield and Flickinger 1995b). Total depth of liquid in the container did not exceed 4mm. The containers were labeled, sealed and kept on ice until the sperm was used for fertilization. When all nets had been checked the fish were taken to the beach where strip-spawning operations began.

Whole, chilled semen from the third shad was checked for motility. Semen from the second male shad (held in water) was stripped into a cup and checked for motility. Two milliliters were measured and put in sandwich container A'. Semen from the first male shad (kept in chilled salt solution) was stripped into a cup and checked for motility. Two milliliters were measured and put in sandwich container B'. All motility observations were video taped to provide a permanent record and reduce the subjectivity of motility scoring.

Eggs from three ripe female shad were stripped into a dry plastic dishpan. Feces were removed immediately with a dry spoon. The eggs were thoroughly mixed and divided equally between 4 dry dishpans (dishpans labeled A through C).

Semen from containers A' through C' were thoroughly mixed with eggs in dishpans A through C, respectively. The contents of dishpan A were equally divided between dishpans labeled A1 and A2. Dishpans A1, A2, B, and C were activated simultaneously. Dishpan A1 was activated by addition of a solution of 6 g/L NaCl (treatments 1 and 2), while dishpans A2(treatment 3 and control), B, and C were activated with river water.

Each of the four dishpans were given a few minutes for fertilization and the eggs were washed with river water to remove remaining sperm. At this point, eggs from dishpan A1 were divided equally and poured into two labeled 5 gallon buckets for water hardening. One lot was water hardened in river water (treatment 1) and the other in 200 mg/L $CaCl_2$ (treatment 2). Dishpan A2 was also be divided equally and poured into two labeled 5 gallon buckets. The first lot was water hardened in 200 mg/L $CaCl_2$ (treatment 3) and the other in river water (control). Eggs from dishpans B and C were poured into labeled 5 gal buckets and water hardened in river water. The experiment was not replicated due to a lack of additional fish in spawning condition.

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. 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 samples (at least 100 eggs each) of each egg lot and counting the number of live and dead eggs. The three samples were pooled and the percent live was compared.

Results and Discussion

Thirteen measurements of osmolality were obtained, ranging from 375 to 642 milliosmols/Kg , with a mean of 492 and standard deviation of 73.6. Our measurements of osmolality were higher than those reported in the literature. Morisawa et al. (1983a) reported osmolality of 270 to 300 milliosmols/Kg for rainbow trout, masu salmon and ayu. Morisawa et al. (1983b) reported osmolality of 317 milliosmols/Kg for goldfish and 302 milliosmols/Kg for carp. Linhart et al. (1999) reported osmolality of 337 milliosmols/Kg for freshwater tilapia and 351milliosmols/Kg for seawater tilapia. Tan-Fermin et al. (1999)

reported osmolality of 269 milliosmols/Kg for Asian catfish. These researchers used seminal fluid, not whole semen, while our measurements were taken with whole semen since a centrifuge was not available to extract seminal fluid. As a result, our measurements may be inaccurate.

Motility scores for semen activated with NaCl solutions from 0 to 1.2% are reported in Table 1. Initial motility was scored 6 (explosive with 100% sperm motility) for all concentrations of NaCl between 0 and 1.2%. As the literature indicates, sperm motility is both explosive and short-lived. Motility was essentially zero within 60 seconds, although vibratory motion persisted after 60 seconds. Motility scores at 30 seconds ranged from 1 to 4, with higher scores at lower NaCl concentrations, however, this may not represent a real difference. I found the motility scoring system of Brown and Moore (1996) to be very subjective, perhaps due to my in-experience with the method. The explosive nature of the sperm movement created a confusing image in the field of view, making estimating the percent motile very difficult. Placing too much semen on the slide resulted in delayed motility as the activating solution mixed slowly with the semen. Clumping and dessication of semen, as observed with stored semen, exacerbated this problem.

Motility of shad sperm activated with solutions of 2.0 to 4.0% NaCl , 1.48% KCL, and 0.818% NaCl + 1.48% KCl is reported in Table 2. These solutions were tested in the hope of developing a storage medium which would dilute and hold semen in an un-activated state for later activation. These solutions all inhibited motility. Initial motility of sperm activated with these solutions was rated 1 or 0 for all trials except replicate 1 of the combination NaCl/KCl solution which had an initial motility score or 3. Some vibratory motion was present in each of the trials. Addition of river water successfully induced motility in all solutions.

Results of experiments using a semen extender are recorded in Table 3. A wide array of extenders have been used for fish semen. I chose an extender used for cryopreservation (Ott and Horton, 1971;cited in Scott and Baynes, 1980) in order to keep that option open, if the experiment was successful over the short term. Semen activated with river water after dilution in the extender exhibited motility comparable to that of whole semen, except that in one replicate there was some vibratory motion prior to activation. Sperm motility declined at 46h post collection and was absent at 91h post collection in both extended and whole semen. This may have been due to higher than desirable storage temperatures. Too many samples were collected to store in a single layer on ice. Temperatures were taken several days after the samples were collected when it was discovered that samples stored on the uppermost of 2 layers were stored at 58F. Storage layer was not recorded for each sample container and containers were repositioned daily after addition of oxygen, making it impossible to determine the storage temperature for any sample.

Motility of sperm stripped from dead American shad is recorded in Table 4. Fish 2 was stripped 20 minutes after removal from the water. The shad was still gilling and sperm motility was comparable to that taken from fresh specimens. Fish 3, stripped 40 minutes after removal from the water, also had sperm motility comparable to that of fresh specimens. Sperm from fish 1, which had been out of the water for approximately 110 minutes, was not motile. Sperm taken from Pacific salmon 1 1/2 to 5h after death is still viable, providing the sperm is exposed to air for 10-15 min before activation (Scott and Baynes, 1980). Unfortunately, I attempted to activate the sperm from fish 1 immediately after stripping, without exposure to air. These results suggest that use of dead males is not responsible for the egg viability problems on the Delaware River.

Results of egg viability experiments using Delaware River shad eggs are reported in Table 5. A total of six treatments were proposed, with three replicates per treatment. Lack of fish, due to high water conditions, prevented completion of the experiment as designed. Only 3 ripe males and 3 ripe females were collected. A single replicate was completed with five of the six proposed treatments. 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%. These results must be viewed with caution since the treatments were not replicated. In addition, treatments 4 and 5 used different males which could account for differences in viability when compared to treatments 1 through 3 and the control, which all used the same male. The high egg viability of treatments 2 and 3, suggests that use of $CaCl_2$ in water hardening and transport shows promise and should be examined further. Use of ice and salt to hold males (treatment 4) also resulted in high egg viability. There appeared to be no advantage to activation in 6g/L NaCl. This was confirmed by experiments conducted by the Virginia Department of Game and Inland Fisheries, in which activation in 4.5g/L NaCl (four trials) resulted in consistently lower survival at hatch when compared to controls activated in river water (Dave Hopler, pers. comm.).

Viewed as a whole, this experiment was not very successful. The schedule proved to be too ambitious and resulted in problems encountered, including a faulty microscope, unavailability of a centrifuge, inadequate refrigeration of samples and lack of sufficient fish for replication of trials. The results do suggest that American shad semen cannot be extended with a simple salt solution matching the osmolality of seminal fluid as is the case with paddlefish (Brown and Mims 1995) and walleye (Brown and Moore 1996). It appears that development of an extender will be contingent upon mimicking the ionic composition of seminal fluid. Our results also suggest that use of dead males is not a major problem on the Delaware River, unless the condition of sperm after the death of the male varies from fish to fish. Use of calcium chloride in water hardening and transport shows promise in increasing egg viability.

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Figure 1. Egg viability study, 2000

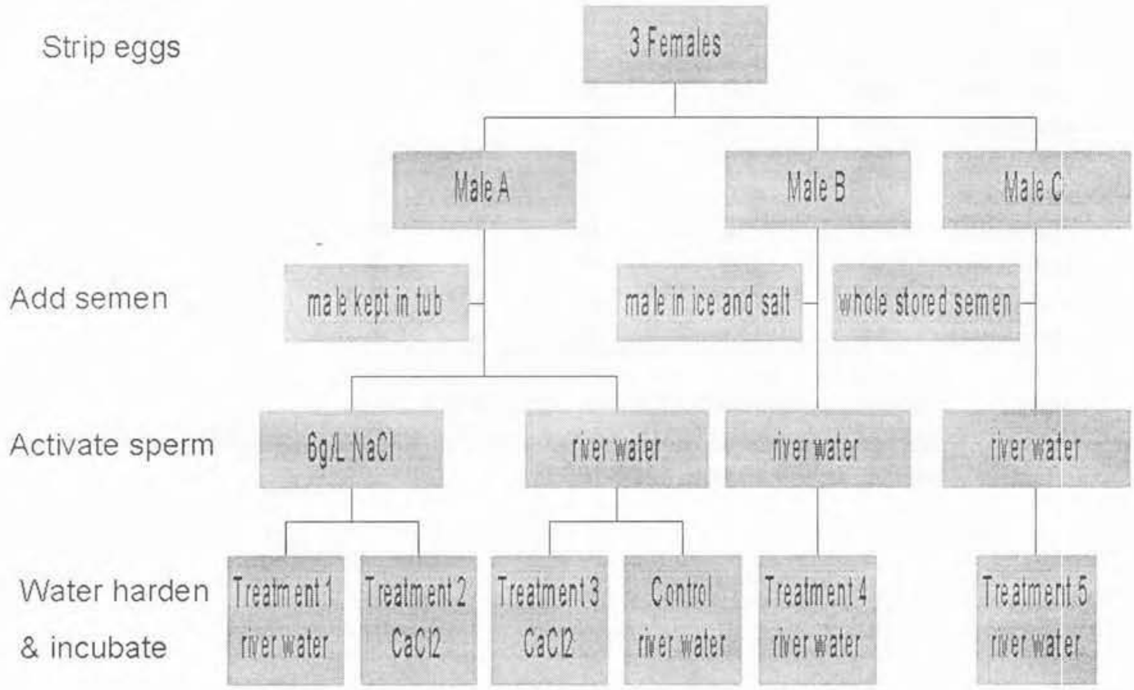

Table 1. Motility of American shad sperm when activated with 0.0 to 1.2% NaCl solutions, 25 May, 2000.

Activation solution			Initial motility		
Solvent	NaCl (%)	NaCl (g/L)	score	30 sec	60 sec
well water	0	0.0	6	4	1
well water	0.1	1.0	6	4	1
well water	0.2	2.0	6	4	1
well water	0.3	3.0	6	4	1
well water	0.4	4.0	6	1	0
well water	0.5	5.0	6	1	0
well water	0.6	6.0	6	1	0
well water	0.7	7.0	6	1	0
well water	0.8	8.0	6	1	0
well water	1.2	12.0	6	1	0
river water	1.2	12.0	6	4	1

Note: All tests performed with semen from a single male.
Semen collected at 1645h, stored on ice, in sandwich container with oxygen
Motility tested approx. 1800-1830h.

T1-eggres00

Table 2. Motility of American shad sperm when activated with 2.0 to 4.0% NaCl solutions and NaCl/KCl solutions, 26 May, 2000.

	Activation solution		Initial motility		
Replicate	NaCl (%)	KCl (%)	score	30 sec	60 sec
1	0.0	0.0	6	1	
2	0.0	0.0	6	1	
1	2.0	0.0	1	1	0
2	2.0	0.0	1	1	0
1	3.0	0.0	0*	0	
2	3.0	0.0	1**	0	
1	4.0	0.0	0*	0	
2	4.0	0.0	0*	0	
1	0.818	1.48	3	1	
2	0.818	1.48	1	1	
1	0.0	1.48	1	0*	
2	0.0	1.48	1	0*	

* some vibrating

**less activity than at 2%

In all trials, some sperm were vibrating even if no motility was observed.

After viewing with saline extender all samples were fully activated by addition of water.

Note: Tests performed with semen from two males.
Semen collected at 1737h, stored on ice, in sandwich container with oxygen
Motility tested approx. 1920h.

Table 3. Motility of extended American shad semen, May 2000.

Replicate	Specimen collection	Extender ratio	Initial motility score (1945h)	30 sec	46h post collection Initial motility score	30 sec	60 sec	91h post collection Initial motility score
1	3/26/00 1710h	0	6	1	3***	3	1	0****
1	3/26/00 1710h	1:4	6	1*	3	3	2	0****
2	3/26/00 1710h	0	6	3	2***	2	1	0****
2	3/26/00 1710h	1:4	6**	1*	3	4	3	0****

* clumps were present with no motility

** some vibratory motion present before addition of water

*** dried out clumps present with no motility

**** some vibratory motion present, whole semen very thick and dessicated.

Note: Sandwich containers stored 2 deep on top of ice, top container 58F

Extender: 7.3g/L NaCl, 0.38g/L KCl, 0.23g/L CaCl2(2H20), 5.0 g/L NaHCO3, 0.23 g/L MgSO4(7H2O), 0.41g/L NaH2PO4(1H2O), 1.0 g/L Fructose, 7.5 g/L Lecithin, and 1.0 g/L Manitol (Ott and Horton 1971, cited in Scott and Baynes 1980)

Table 4. Motility of sperm from dead American shad, 26 May, 2000.

Fish	Date	fish put in bucket	semen collected	Time fish in bucket	Condition of fish when semen collected	Initial motility score	30 sec
2	3/26/00	1642h	1702h	20 min	alive	6	4
3	3/26/00	1653h	1733h	40min	dead	6	4
1	3/25/00	not recorded	not recorded	~110 min	dead	0	0

all samples on 3/26 viewed 1900- 1945h

Table 5. Egg viability experiments for Delaware River American shad eggs, 2000.

Treatment	Male handling	Semen	Dishpan	Sperm activation solution	Water hardening & transport	Number of eggs	Number Live eggs	Percent Live eggs
1	wet tub (dead?)	whole, used immediately	A1	6 g/L NaCl	river water	2,088	1,225	58.7%
2	wet tub (dead?)	whole, used immediately	A1	6 g/L NaCl	200mg/L CaCl2	1,774	1,286	72.5%
3	wet tub (dead?)	whole, used immediately	A2	river water	200mg/L CaCl2	1,598	1,250	78.2%
control	wet tub (dead?)	whole, used immediately	A2	river water	river water	1,244	820	65.9%
4	ice and salt (live?)	whole, used immediately	B	river water	river water	5,420	3,936	72.6%
5	stripped immediately	whole, chilled	C	river water	river water	4,999	3,182	63.7%

Notes: Eggs from 3 females were pooled, mixed and used for all 5 treatments and control.
Semen from male A was used for treatments 1-3 and the control.
Semen from male B used in treatments 4 and male C used in treatment 5.
Proposed treatment 6 (semen stored in extender) not tested due to lack of a fourth male.

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 2000 spring migration, Conowingo East Lift passed a record 153,546 American shad while lifts at Holtwood and Safe Harbor passed 29,421 and 21,079, respectively. Fish passage facilities were completed at York Haven Dam in 2000. During its inaugural season, 4,675 adult shad were counted passing the fishway at York Haven - additional shad may have passed through the open channel portion of the fishway and went uncounted. For the first time in nearly a century, American shad had free 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 and West Conewago creeks, York County; Conestoga River and Little Conestoga Creek, Lancaster County; Conodoguinet Creek, Cumberland County and Swatara Creek, Dauphin/Lebanon County are now accessible with the completion of main stem fishways.

Of the 9,785 adult shad collected by the Conowingo West Lift during 2000, 1,351 were transported and stocked in the main stem Susquehanna at Columbia(856) and in the Conestoga River(495). Observed transport and delayed mortalities of shad amounted to less than 5%. Overall sex ratio (SR) in these transfers was about 2 to 1 favoring males. Of the river herring collected, 2,026 alewives were stocked in the Little Conestoga. Blueback transports included 4,783 adults stocked in the Conestoga (2,983) and at Muddy Creek Access (1,800). Mortality for river herring transports was very low.

During the 2000 production season, the PFBC Van Dyke Research Station for Anadromous Fish released 9.46 million shad larvae in the Susquehanna Basin, Pennsylvania. Most larvae were released between 19 May to 14 June in the following locations, numbers, and days(d) of age (tetracycline marks by days of age in parentheses):

Juniata R.(various sites)	6,249,719 age 6-13d (3)
Susq. R. (various sites)	1,119,141 age 9-13d (3)
W. Br. Susq. R.	632,386 age 21d (3,6,9,15)
N. Br. Susq. R.	974,614 age 19d (3,6,12,15,18)
Conodoguinet Ck.	111,017 age 15d (3,9,12)
Conestoga R.	231,178 age 23d (3,9,12,15)
W. Conewago Ck.	109,352 age 18d (9,12,15)
Swatara Ck.	33,321 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 and 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

Haul seining was conducted at Columbia by RMC/Normandeau Associates, Incorporated (RMC) once each week on 15 dates during the period 12 July through 17 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 (Lancaster County), West Conewago Creek (York County), Swatara Creek (Dauphin/Lebanon County), and Conodoguinet Creek (Cumberland County) were sampled by seine on a weekly basis from 24 July through 23 August. A total of 288 hauls were conducted at 30 stations in five tributaries (six stations per tributary) using a seine measuring 30-ft X 6-ft with 3/8 in stretch mesh. All tributaries were sampled on five dates with the exception of Swatara Creek, which was sampled on four dates.

Push-netting

Push-netting for juvenile alosids was conducted by RMC at various sites in the upper portion of Conowingo pool between 1 June and 7 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 a 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 four 15 minute 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. In addition, upon the request of the PFBC, ten additional sampling events were conducted in the lower Susquehanna River in the vicinity of Muddy

Run Pump Storage Station and Peach Bottom Atomic Power Station, and in the York Haven Hydroelectric Station forebay.

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 8 December (30 total). Sampling began at sunset and consisted of 10 lifts with 10 minute intervals between lift cycles. After 12 October, modifications were made to the sampling method in an effort to meet lift-net program objectives. These modifications included moving the lift-net from the south side of the coffer cell to the north side, and the use of a lighting system to illuminate the water over the lift-net. Additional sampling with a cast-net was conducted on 30 October.

RMC conducted intake screen sampling for impinged alosids at PECO's Peach Bottom Atomic Power Station three times per week from 18 October to 8 December. SECO's Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosids twice weekly from 9 October to 8 December.

Susquehanna River Mouth and Flats

Maryland DNR sampled the upper Chesapeake Bay using haul seines and by electrofishing 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 principal purpose for haul seine sampling in the Columbia reach of the lower river during summer and fall months was to document the occurrence and relative abundance of both naturally produced juvenile shad and hatchery stocked fish. A total of 31 juveniles American shad were collected in 90 hauls for an overall Geometric Mean Catch-Per-Unit-Effort (GM CPUE) of 0.26 (Table 1). Daily Catch-Per-Unit-Effort (D CPUE) ranged from zero on seven sampling dates to 1.83 shad per haul on 10 October (Table 2). Of the total 31 juveniles captured, 11 (35%) were taken during on 10 October (Table 3). The length of juvenile shad ranged from 33 mm on 12 July to 137 mm on 10 October (Table 4). A total of 25 taxa was collected by seine.

Haul Seining - Tributaries

No American shad or blueback herring were collected or observed in 294 seine hauls in selected tributaries. A total of 25 taxa was collected by seine in tributaries.

Push-netting

No juvenile American shad were collected in approximately 1493 minutes of push-netting. A total of 10 taxa was collected during push-netting.

Electrofishing

The two upper river reaches on the Susquehanna and Juniata rivers were sampled for a total of 996 minutes of shock time resulting in the capture of no juvenile American shad. Lower river sites were sampled from 13 September to 31 October for a combined total of 766 minutes of shock time resulting in the capture of 148, 58, and 2 juveniles at York Haven, Muddy Run, and Peach Bottom, respectively (Table 5). Additional juvenile shad were observed at lower river sites but eluded capture (Table 5). Daily CPUE for lower river sites ranged from zero to 48.39 shad/hour (Table 6). Nearly 95% of shad that were captured or observed occurred between 23 and 31 October at a water temperature of 12.0 to 15.0 degrees C. Juvenile American shad ranged from 100 to 191 mm TL; most were between 150 and 179 mm TL (Table 7) Mean length of captured juveniles was 153.6 mm TL. CPUE was highest on 23 October and exceeded 15 fish per hour between 23 and 31 October.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner forebay resulted in the capture of 405 juvenile American shad in 292 lifts for an overall GM CPUE of 0.66 (Table 8). Thirteen additional shad were captured on 30 October by cast-net. Highest daily catch by lift-net (146) occurred on 17 November at a water temperature of 10.0 degrees C and a river flow of 14,600 cfs (Table 9) resulting in a D CPUE of 20.86 fish per lift (Table 10). All shad were captured between 18 October and 29 November following modifications to the sampling method. The last juvenile shad collected occurred on 29 November at a water temperature of 4.0 degrees C and a river flow of 13,200 cfs (Table 9). Over 79% of juvenile American shad were captured between 8 and 29 November when the river temperature was less than 11.0 degrees C. Total length of juveniles ranged from 114 to 186 mm; 82% were 121 to 150 mm TL (Table 11). A total of six taxa was captured by lift-net with American shad being the most numerous. A single blueback herring was also captured by lift-net.

Peach Bottom intake screens produced 100 juvenile American shad, 6 juvenile blueback herring, and 2 juvenile alewife. A total of 1,742 fish of 14 taxa was collected at Peach Bottom. Cooling water strainers at Conowingo produced 63 juvenile American shad and a single juvenile blueback herring. A total of 2,165 fish of 8 taxa was collected at Conowingo.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 551 juvenile American shad in the upper Chesapeake Bay during summer and fall 2000 (Table 15 and Figure 5).

Otolith Mark Analysis

Results of otolith analysis is outlined in Table 12. Otoliths from 536 juvenile American shad taken in the summer and fall collections were analyzed for hatchery marks. A total of 84 juvenile shad otoliths from seine and electrofishing collections above Holtwood Dam was successfully processed. All juvenile shad collected above Holtwood were marked and of hatchery origin.

Otoliths from 452 juvenile American shad collected at Holtwood, Peach Bottom, and Conowingo Dam were successfully processed. Overall, 439 (97%) of the fish were marked and the remaining 13 fish (3%) were wild. Wild fish were captured at Holtwood, Muddy Run, Peach Bottom, and Conowingo. The total percentage of hatchery fish above Conowingo was 97% with 3% being wild. Recapture of shad from various stocking sites is discussed in Job III.

Of the 551 juvenile American shad collected by Maryland in the upper Bay, 135 were processed by Maryland DNR for otolith analysis, with 125 wild and one hatchery (day 3 mark). An additional 182 otoliths were processed by PFBC with all readable otoliths wild.

DISCUSSION

In-Stream Movements and Outmigration Timing

Spring river conditions for most of the Susquehanna River basin during 2000 could be characterized by highly variable and above normal flows. Flows measured at Holtwood Hydroelectric Station exceeded 90,000 cfs on sixteen dates in April and two dates in May. Water temperatures were also highly variable. Unseasonably warm weather in early May caused rapid increases in water temperatures in the lower Susquehanna Basin. River temperatures at Holtwood jumped over twenty degrees Fahrenheit in a eleven day period from 28 April to 10 May. Temperatures peaked (75.9 F) on 10 May and dropped steadily, in conjunction with a prolonged cold spell, until reaching a monthly low (61.0 F) on 24 May. Temperatures rebounded in June and remained in the high 60's and low to mid 70's until lift operations at Conowingo was suspended for the season. Summer flows in the most of the basin were normal excluding August which had above normal flows. A notable exception was the North Branch of the Susquehanna which maintained above normal flows throughout most of the summer. Fall river flows in lower basin were normal with the exception of November which had below normal flows. Water clarity was very high in the lower Susquehanna Basin in summer and fall.

Haul seine collections during 2000 were lowest on record (Table 1) and never exceeded eleven juveniles captured for a given month from July through October (Table 2). Catches of juvenile shad by month were well below the ten-year average of 177.4, 123.7, 110.7, and 29.1 for July, August, September, and October, respectively (Table 13). Monthly seine catches during 2000 were insufficient in number to detect any apparent outmigration pattern although the catch at Columbia seemed to correlate with river flow (Figure 1). Low numbers of juveniles collected by seine may be related to lack of wild reproduction, low survival, or unfavorable river conditions - high water clarity during the seining period may have influenced catch rates.

The first marked fish collected at Columbia by seine occurred on 12 July. These included four shad stocked in the Juniata River suggesting a movement of approximately 60-80 miles in 55 days or less. All American shad collected by seine at Columbia were of hatchery origin with 88% originating from Juniata River stockings.

Based on lift-net catches, outmigration of juvenile American shad occurred in late October and November with 100% of those collected occurring between 24 October and 26 November (Table 9). The first American shad collected by lift-net occurred on 18 October at a water temperature of 14.0 C and a river flow of 8,680 cfs. Two distinct peaks in catches (Figure 2) occurred during late October through early November, and mid November through late November. These peaks apparently corresponded to increased outmigration behavior brought about by increased river flow and decreased water temperature following fall freshets (Figure 2 and 3). The mid to late November peak accounted for 79.4% of the total juveniles captured by this gear type. During this period thousands of shad were observed in the Holtwood forebay.

All juvenile shad captured occurred after modifications to the sampling method were implemented. However, it is not known what impact modifications had on the ability to capture juvenile shad. Increased catches may be in response to overall increases in juvenile abundance corresponding with the outmigration period and not related to enhanced success due to sampling modifications. It was felt that modifications were necessary to salvage what was fast becoming one of the poorest seasons on record.

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. In 2000, the outmigration occurred in a six week period when water temperatures were between 14.0 C and 4.0 C, and river flow ranged from 8,680 cfs to 15,100 cfs (Figure 2 and 3). This pattern is consistent with previous years but somewhat later than the 16 September through 25 October outmigration period observed in 1999 (Table 14). Delays could be attributed to the lack of significant precipitation and stable water temperatures during the month of September.

As in 1999, juvenile shad catches by haul seine and lift-net appeared to correspond with decreasing river flows following elevated flows in association with a precipitation event (Figure 1,2 and 3). No wild shad were captured by seine during the 2000 sampling season.

Abundance

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, 2000 GM CPUE by seine of 0.26 is the lowest on record since Columbia became the primary sampling site and well below the long-term average of 2.49 (Table 1). GM CPUE for lift-netting in 2000 was 0.66, ranking fourth lowest out of the last fifteen years of sampling by this method and well below the long-term average of 1.97 (Table 8). Based on the data collected to date there is no apparent relationship between GM CPUE by lift-net and adult recruitment to Conowingo lift (Figure 4). There does appear to be a relationship between lift net GM CPUE and river flow (Figure 3) suggesting that catches of shad at Holtwood may be more influenced by river flow than juvenile abundance. Low catches by seining and lift-net are probably associated with poor reproduction success and survival of shad fry in response to highly variable flows and dramatic fluctuations in river temperatures observed during spring.

As in 1999, tributary seining efforts failed to capture any juvenile shad despite the fact otolith analysis determined survival of shad stocked in tributaries. Sampling effort may have been of insufficient intensity to capture juveniles (i.e. shad are not present at sites sampled), or juveniles may have remained in tributaries for only a short time before migrating downstream to utilize large river habitat in the Susquehanna; this movement may have occurred before tributary sampling began. Low abundance resulting from poor survival of stocked fry and limited natural reproduction may also have attributed to the inability to capture juveniles by seine in tributaries. In both 1997 and 1998, seining was successful at collecting juvenile shad in major tributaries.

Despite the stocking of over 9.4 million American shad fry upstream of sampling sites on the Juniata and Susquehanna, electrofishing river reaches between Amity Hall and Huntingdon and Clarks Ferry and Sunbury failed to capture juvenile American shad. Electrofishing at York Haven, Muddy Run, and Peach Bottom resulted in the highest CPUE (16.25) for this gear type to date (Table 6). Observed differences in upper river and lower river electrofishing catches are unknown. Few spawning adults above York Haven and reduced survival associated with environmental conditions most likely contributed to decreased abundance and poor catches of juveniles in upper river areas. Enhanced water clarity may have also played by making juvenile shad less susceptible to capture by this gear type. 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.

Despite success in collecting juvenile alosids in Virginia, push-netting in the lower Susquehanna impoundments has failed to produce even modest numbers of fish. However, push-netting remains one of the only methods of collecting juvenile alosids in Conowingo pool prior to the onset of the outmigration. It is hoped that continued modifications to the sampling method and increased alosid abundance associated with stock restoration may increase the effectiveness of push-netting in the future.

During its first three operating seasons, the fish lift at Holtwood Dam lifted an average of less than 30% of the American shad passed at Conowingo Dam. In 2000, the Holtwood lift passed less than 20% of those passed at Conowingo. Reproductive success of the adults which passed Conowingo but not Holtwood may be substantial, however poor catches of wild alosids by push-net in Conowingo pool fail to substantiate this hypothesis. It is hoped that low catches by push-net are a function of unrefined design and sampling techniques rather than low abundance.

Only 14,963 blueback herring and 2 alewife were passed by the Conowingo East Lift in 2000. This compares to 130,625 bluebacks and 14 alewife passed in 1999. Decreases in numbers of bluebacks passed is most likely attributed to high river flows and disruption of lift operations during early spring when numbers of returning bluebacks at Conowingo is highest. Of the blueback herring passed at Conowingo, only 27 were counted passing Holtwood. Additional sources of river herring above Conowingo Dam, albeit few in number, include those captured at Conowingo West Lift and transported upriver and released. The lack of substantial numbers of spawning herring above Conowingo Dam resulted in poor production of blueback herring and alewife with only eight bluebacks and two alewives collected during juvenile alosid sampling. During 1999, herring reproduction above Conowingo was more successful with over 200 blueback herring collected during juvenile alosid sampling.

If the susceptibility of hatchery and wild juvenile shad to capture by all current sampling methods are the same, hatchery fish were more than 20 times more abundant (97% hatchery verses 3% wild) than wild fish during 2000. If restorations efforts are going be successful at reaching target population goals, substantial increases in wild juvenile abundance will be required in the future.

Growth

Juvenile hatchery shad collected with seines at Columbia averaged 54.5 mm total length (TL) from 12 July to 19 July (range 34 - 72 mm) and grew to an average 131.1 mm (range 129 - 135 mm) by 10 October (Table 4). Since no wild shad were captured by seine at Columbia in 2000, comparison of growth between hatchery and wild juveniles was not possible.

Juvenile American shad captured by lift-net from 18 October to 29 November ranged from 114 - 186 mm with 84% of those captured measuring 121 - 150 mm TL (Table 11). In comparison, juvenile American shad captured by lift-net from 16 September to 25 October, 1999 ranged from 70 - 150 mm with 81% of those captured measuring 101 - 130 mm TL. Juvenile American shad captured in 2000 appeared to be slightly larger than those captured in 1999. Reasons for this may include a longer growing season associated with the delay in the outmigration period, less competition among individuals due to a weak year-class, or increased food abundance associated with favorable river conditions during the growing season. Growth of wild fish was difficult to assess due to few individuals captured, but growth of hatchery and wild fish appeared to be similar. Growth of the 2000 cohort does fall within ranges observed in previous years.

Stock Composition and Mark Analysis

Of the 536 otoliths analyzed from collections above Conowingo Dam, 13 (2%) were unmarked (Table 12). This compares to 5% wild fish in 1999 collections, and 5 - 58% from 1991 to 1998. No wild shad were captured above Holtwood Dam suggesting natural reproduction may be limited to the lower Susquehanna River basin. The high percentage of hatchery juveniles observed in 2000 may be due, in part, to the large numbers of fry stocked, or improvements in stocking procedures first implemented in 1998. Fry were stocked at numerous sites throughout the Juniata drainage rather than one or two sites. Spreading the fish out may have reduced predation by eliminating conditioned response behavior in piscivorous fishes attuned to sustained stocking at a single site. Reduced numbers of pre-spawn adult shad trucked and released above dams, stress associated with these transfers, and unfavorable river conditions during early spring may have also contributed to low natural reproduction.

During the 2000 spawning migration, over 29,000 American shad were passed at Safe Harbor Dam. This compares to approximately 34,000, 6,000 and 20,000 passed at Safe Harbor in 1999, 1998 and 1997, respectively. These fish had access to a 25 mile section of free flowing main stem river between Safe Harbor and York Haven. York Haven fish passage facilities, which began operation in 2000, passed a minimum of 4,588 Adult American shad. Additional shad may have passed York Haven through the fishway's open channel configuration and went uncounted. These fish had access to a 168 miles of free flowing river until encountering other migratory barriers on the Juniata and Susquehanna. It is difficult to assess the contribution of spawning habitat above Safe Harbor Dam had to the overall production of wild fish. The low contribution of wild fish at Holtwood, Peach Bottom, and Conowingo suggests that larvae spawned above Safe Harbor were not abundant, were swamped by high survival of hatchery fish, or drifted below Conowingo before sampling began.

Electrofishing in the York Haven forebay on 26 October resulted in the capture of 40 juvenile American shad all of which possessed the North Branch mark. The probability of this occurring by chance is remote, and suggests that schooling behavior during outmigration may be stronger than originally thought. The episodic nature of sampling for juveniles may have limitations when trying to determine relative survival of juvenile American shad and the production of wild fish.

Survival of the 2000 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 with the exception of Swatara Creek were represented in the Holtwood collections.

SUMMARY

- Juvenile American shad were successfully collected by haul seine, electrofisher, and lift-net.
- Haul seining GM CPUE of 0.26 was the lowest recorded for that gear since sampling at Columbia was standardized in 1992.
- Electofishing upper river sites on the Susquehanna and Juniata failed to capture juvenile shad.
- Electrofishing for juvenile shad in the lower Susquehanna resulted in a mean CPUE of 16.25 fish per hour.
- Lift-netting at Holtwood resulted in a GM CPUE of 0.66, the fourth lowest on record since 1985.
- Push-netting catches in Conowingo pool failed to capture any juvenile alosids.
- No juvenile alosids were collected in major tributaries.

- Peak out-migration based on lift-net catches occurred during October/November and were associated with increased river flows and decreased water temperatures in association with fall freshets.
- Otolith analysis determined that only 2% of the juveniles collected above Conowingo Dam were of wild origin as compared to 5% observed in 1999.
- Several factors may have impacted ability to catch juveniles in 2000 including: 1) low juvenile abundance 2) ineffective sampling due to environmental conditions.
- Juvenile production in the Susquehanna River basin appeared to be low and may have been impacted by: 1) limited natural reproduction 2) poor survival of stocked fry.

ACKNOWLEDGMENTS

RMC/Normandeau and Associates (Drumore, PA) were contracted by the PFBC to perform juvenile collections. Many individuals supplied information for this report. For their contributions, appreciation is extended to George Nardacci and Mike Hendricks. Gina Russo-Carney and Lee Rumfelt processed shad otoliths.

Figure 1. River flow and catch of juvenile American shad by seine at Columbia, PA, 2000.

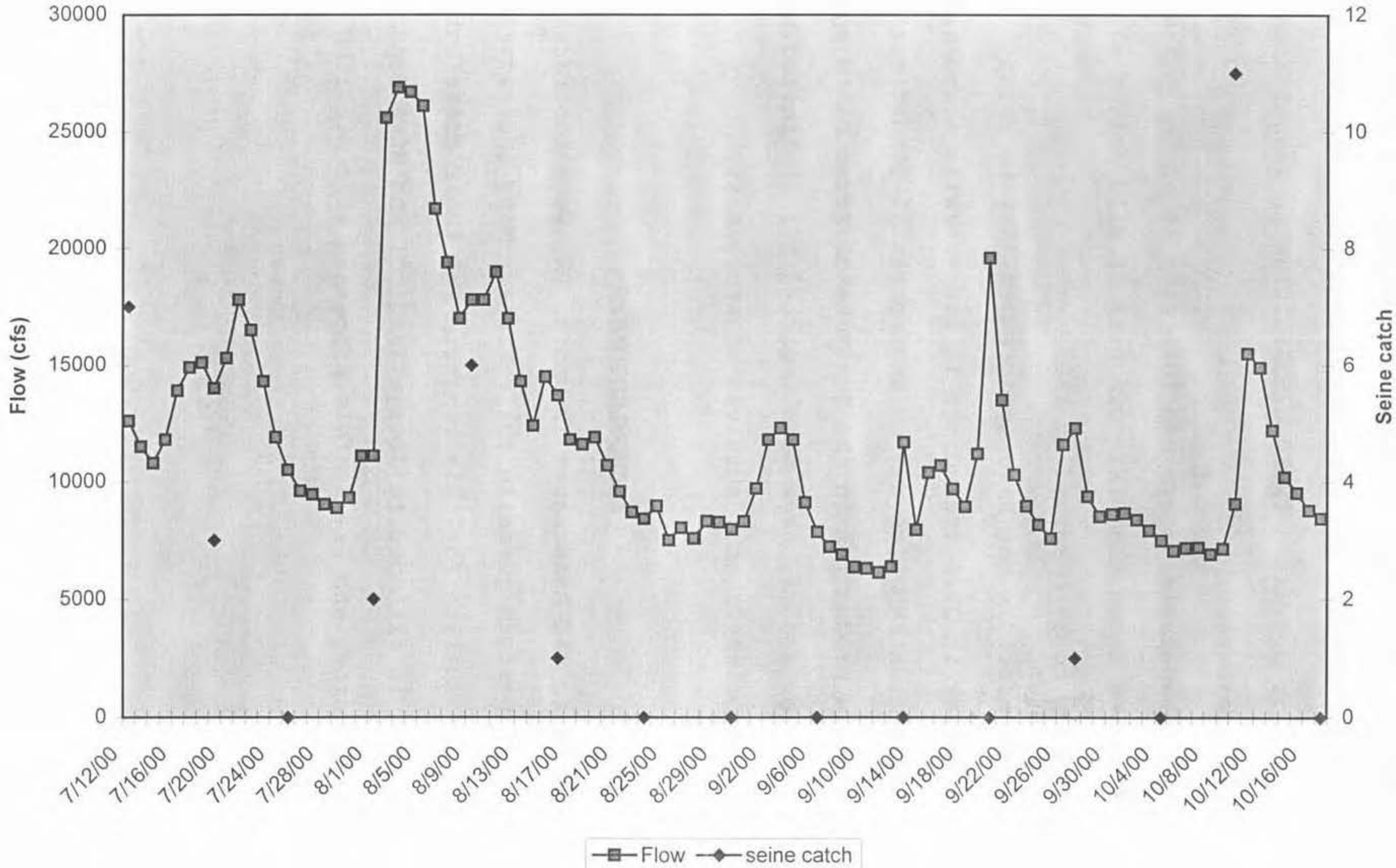
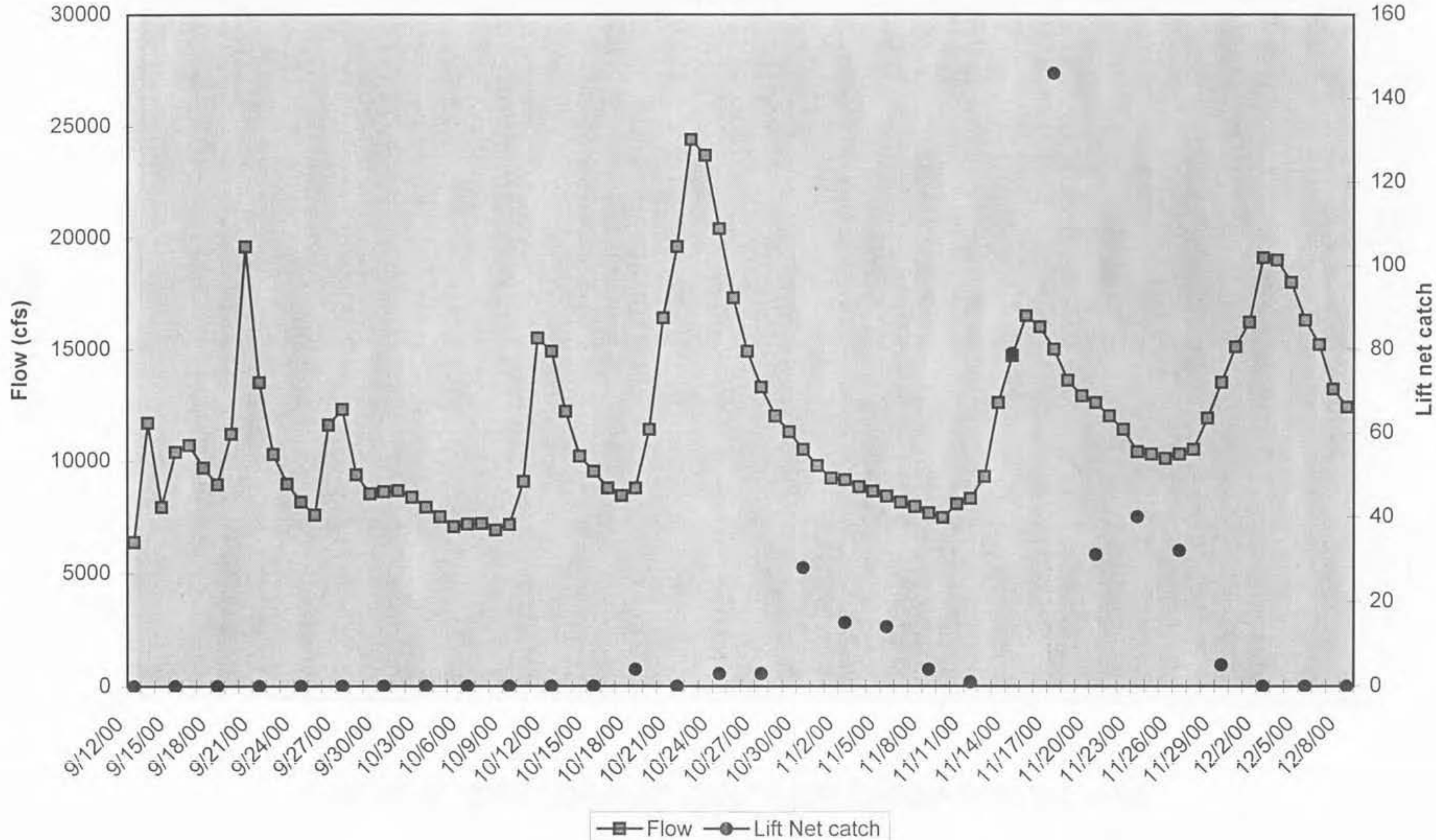


Figure 2. River flow and collection of juvenile American shad by lift net at Holtwood Dam, 2000.



4-25

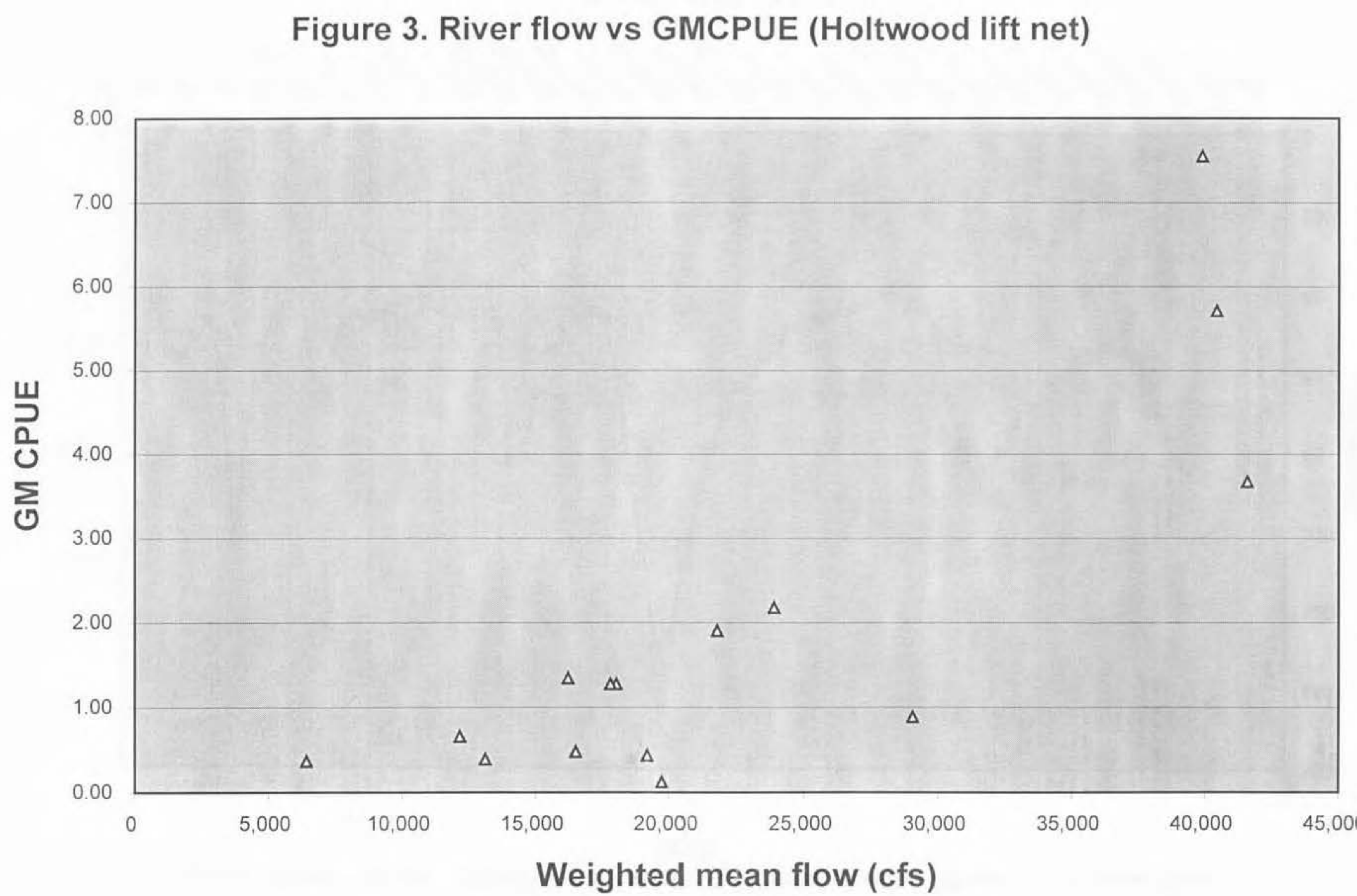


Figure 3. River flow vs GMCPUE (Holtwood lift net)
GM CPUE
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Weighted mean flow (cfs)

Figure 4. GMCPUE (Holtwood lift net) vs recruitment to Conowingo fish lifts

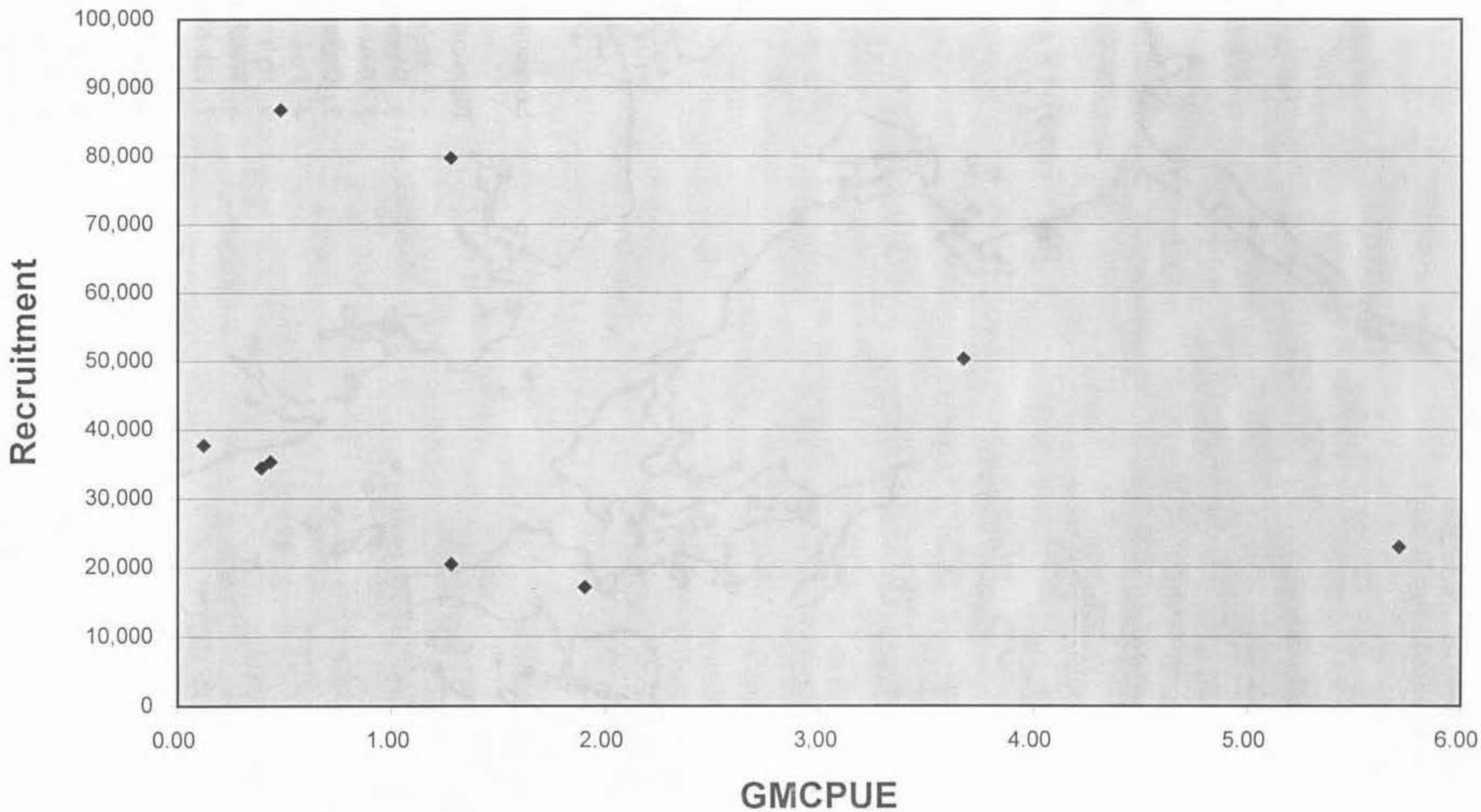
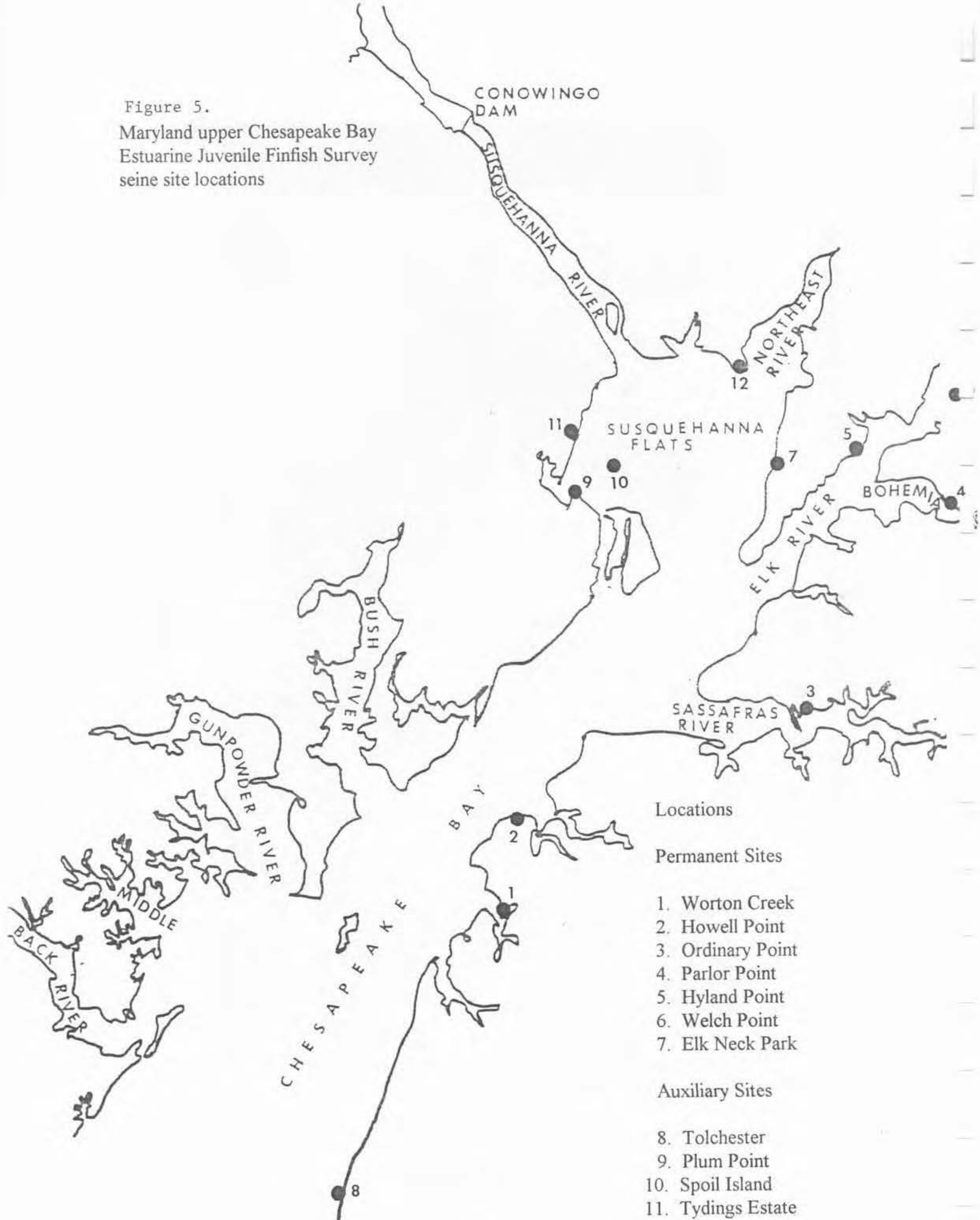


Figure 5.
Maryland upper Chesapeake Bay Estuarine Juvenile Finfish Survey seine site locations



Locations

Permanent Sites

1. Worton Creek
2. Howell Point
3. Ordinary Point
4. Parlor Point
5. Hyland Point
6. Welch Point
7. Elk Neck Park

Auxiliary Sites

8. Tolchester
9. Plum Point
10. Spoil Island
11. Tydings Estate
12. Carpenter Point

Table 1. Index of abundance for juvenile American shad collected by haul seine in at Marietta, Columbia and Wrightsville, 1985-2000.

Year	No. Hauls	No. Fish	CPUE	GM CPUE	Migration Duration (days)	Weighted Mean Flow (cfs)*	Recruitment to Lifts
1985							
1986							22,897
1987							17,096
1988							20,466
1989	-	1597	-		45	22,061	35,307
1990	73	285	3.90	1.23	55	17,489	50,323
1991	137	170	1.24	0.54	104	4,986	34,448
1992	92	269	2.92	1.45	89	21,943	37,740
1993	111	218	1.96	0.45	98	7,692	79,692
1994	110	390	3.55	2.29	108	23,168	86,708
1995	48	409	8.52	7.891	91	5,741	
1996	105	283	2.70	2.053	92	25,632	
1997	90	879	9.77	6.765	98	7,472	
1998	94	230	2.45	1.026	98	5,960	
1999	90	322	3.58	1.16	100	10,336	
2000	90	31	0.34	0.26	98	11,666	

* mean flow during successful collections

Table 2

Summary of catch per unit effort (CPUE) of juvenile American shad from the lower Susquehanna River near Columbia, Pennsylvania in 2000.

Date	Number of Hauls	Number of American Shad	CPUE	Standard Deviation	Variance	Confidence Interval
12 Jul	6	7	1.17	2.40	5.77	1.92
19 Jul	6	3	0.50	1.22	1.50	0.98
25 Jul	6	0	0.00	0.00	0.00	0.00
1 Aug	6	2	0.33	0.82	0.67	0.65
9 Aug	6	6	1.00	1.26	1.60	1.01
16 Aug	6	1	0.17	0.41	0.17	0.33
23 Aug	6	0	0.00	0.00	0.00	0.00
30 Aug	6	0	0.00	0.00	0.00	0.00
6 Sep	6	0	0.00	0.00	0.00	0.00
13 Sep	6	0	0.00	0.00	0.00	0.00
20 Sep	6	0	0.00	0.00	0.00	0.00
27 Sep	6	1	0.17	0.41	0.17	0.33
4 Oct	6	0	0.00	0.00	0.00	0.00
10 Oct	6	11	1.83	4.49	20.17	3.59
17 Oct	6	0	0.00	0.00	0.00	0.00

Table 3

Summary of juvenile American shad collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2000.

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
12 Jul	27.0	12,400	75	2033-2156	0	0	0	0	6	1	7
19 Jul	24.5	14,400	80	2026-2215	0	3	0	0	0	0	3
25 Jul	24.5	10,700	95	2026-2155	0	0	0	0	0	0	0
1 Aug	27.0	9,790	80	2020-2158	0	0	0	0	2	0	2
9 Aug	27.0	18,300	75	2010-2125	0	0	0	3	2	1	6
16 Aug	26.0	13,300	62	2000-2059	0	0	0	0	1	0	1
23 Aug	23.5	8,310	80	1950-2115	0	0	0	0	0	0	0
30 Aug	25.5	7,920	60	1935-2048	0	0	0	0	0	0	0
6 Sep	24.0	7,370	64	1930-2031	0	0	0	0	0	0	0
13 Sep	25.0	13,300	100	1915-2030	0	0	0	0	0	0	0
20 Sep	20.5	20,000	18	1904-2010	0	0	0	0	0	0	0
27 Sep	17.5	11,000	31	1855-2030	0	0	0	1	0	0	1
4 Oct	20.0	7,370	120	1835-1938	0	0	0	0	0	0	0
10 Oct	12.5	11,000	120	1835-2014	0	0	0	0	11	0	11
17 Oct	15.5	8,000	120	1830-1920	0	0	0	0	0	0	0
TOTAL					**0**	**3**	**5**	**4**	**22**	**2**	**31**

Table 4

Length frequency distribution of juvenile American shad collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania in 2000.

TL (mm)	12 Jul	19 Jul	25 Jul	1 Aug	9 Aug	16 Aug	23 Aug	30 Aug	6 Sep	13 Sep	20 Sep	27 Sep	4 Oct	10 Oct	17 Oct	Total
31-35	1															1
36-40																0
41-45	1															1
46-50	2															2
51-55	2			1												3
56-60																0
61-65		1														1
66-70	1	1			1											3
71-75		1			1											2
76-80																0
81-85					2											2
86-90				1		1										2
91-95																0
96-100																0
101-105																0
106-110					2											2
111-115																0
116-120																0
121-125														1		1
126-130												1		5		6
131-135														4		4
136-140														1		1
TOTAL	7	3	0	2	6	1	0	0	0	0	0	1	0	11	0	31

Table 5

Summary of the electrofishing catch of juvenile American shad in the Susquehanna River at selected sites, 2000.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi Disk (in)	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Number of Shad Captured	Shad Observed
				York Haven Hydroelectric Station Forebay					
13 Sep	6,640	24.0	72	100	250	7.0	No	4	2
16 Oct	8,890	15.0	100	75	200	5.5	Yes	10	30
23 Oct	23,100	14.0	55	70	380	6.5	Yes	84	1000
26 Oct	14,200	15.0	65	62	330	6.5	Yes	50	500
				Above Muddy Run Pumped Storage Station					
26 Sep	14,100	17.0	26	80	200	6.0	Yes	10	12
17 Oct	8,670	13.5	50	76	250	6.0	No	3	20
24 Oct	19,700	15.0	50	63	320	6.0	Yes	27	30
31 Oct	9,220	12.0	38	63	380	6.5	Yes	18	12
				Peach Bottom Atomic Power Station					
19 Sep	12,800	22.5	28	110	200	6.0	No	0	0
19 Oct	13,900	13.8	60	69	260	6.0	No	2	1
Total				***768***				***208***	***1,607***
Mean	***13,122***	***16.2***	***54.4***		***277.0***	***6.2***			

Table 6

Catch per unit of effort (CPUE), standard deviation, variance, and confidence interval for juvenile American shad collected with a boat-mounted electrofisher from the Lower Susquehanna River, August through October 2000.

Date	Number of Shad	CPUE (No./hour)	Total Length (mm)			Standard Deviation	Variance	Confidence Interval
			Mean	Minimum	Maximum			
13 Sep	4	3.33	102.50	100	105	2.38	5.67	2.33
26 Sep	10	7.50	129.40	113	142	8.75	76.49	5.42
16 Oct	10	6.00	156.50	140	171	8.75	76.50	5.42
17 Oct	3	2.37	140.67	120	162	21.01	441.33	23.77
19 Oct	2	1.74	148.50	144	153	6.36	40.50	8.82
23 Oct	84	72.00	162.70	135	183	7.41	54.96	1.59
24 Oct	27	25.71	132.19	110	169	13.85	191.93	5.23
26 Oct	50	48.39	163.00	143	191	8.86	78.57	2.46
31 Oct	18	17.14	143.22	118	176	15.79	249.36	7.29
Total	*208*			*100*	*191*			
Mean		*16.25*	*153.62*			*17.39*	*302.39*	*2.36*

Table 7

Length frequency distribution of juvenile American shad captured with a boat-mounted electrofisher from the Susquehanna River at selected sites, September and October 2000.

Total Length (mm)	13 Sep[1]	26 Sep[2]	16 Oct[1]	17 Oct[2]	19 Oct[3]	23 Oct[1]	24 Oct[2]	26 Oct[1]	31 Oct[2]	Total
100-109	4	1								5
110-119		5					5		1	11
120-129		2		1			8		3	14
130-139		2				1	8		4	15
140-149			2	1	1	1	2	3	3	13
150-159			5		1	24	3	15	4	52
160-169			2	1		43	1	22	2	71
170-179			1			14		8	1	24
180-189						1		1		2
190-199								1		1
Total	*4*	*10*	*10*	*3*	*2*	*84*	*27*	*50*	*18*	*208*

[1] York Haven Hydroelectric Station forebay.

[2] Muddy Run Pumped Storage Station.

[3] Peach Bottom Atomic Power Station.

Table 8. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2000.

Year	No. Lifts	No. Fish	CPUE	GM CPUE*	Migration Duration (days)	Larvae stocked	Weighted Mean Flow (cfs)*	Cohort Recruitment to Lifts
1985	378	3626	9.59	7.55	65	5,415,400	39,882	
1986	404	2926	7.24	5.71	64	9,899,430	40,423	22,897
1987	428	832	1.94	1.90	72	5,179,790	21,756	17,096
1988	230	929	4.04	1.28	51	6,450,685	18,025	20,466
1989	286	556	1.94	0.43	35	13,464,650	19,170	35,307
1990	290	3988	13.75	3.67	72	5,619,000	41,570	50,323
1991	370	208	0.56	0.39	71	7,218,000	13,105	34,448
1992	240	39	0.16	0.12	43	3,039,400	19,726	37,740
1993	240	1095	4.56	1.27	56	6,541,500	17,804	77,991
1994	250	206	0.82	0.48	71	6,420,100	16,490	
1995	230	2100	9.13	1.34	44	10,001,000	16,200	
1997	160	1372	8.58	0.88	51	8,019,000	29,051	
1998	230	180	0.78	0.37	67	11,757,000	6,420	
1999	140	490	3.50	2.18	40	13,501,000	23,871	
2000	292	405	1.39	0.66	43	9,460,728	12,155	

*Geometric mean values required by ASMFC.

Table 9

Summary of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 12 September through 8 December 2000.

Date:	*12-Sep*	*15-Sep*	*18-Sep*	*21-Sep*	24-Sep	*27-Sep*	*30-Sep*	*3-Oct*	*6-Oct*	*9-Oct*	*12-Oct*	*15-Oct*	*18-Oct*	*21-Oct*	*24-Oct*	*27-Oct*
Water Temp (C):	*24.5*	*24.0*	*23.0*	*20.0*	*19.5*	*18.0*	*17.5*	*17.5*	*17.5*	*16.5*	*15.0*	*14.0*	*14.0*	*16.0*	*15.5*	*15.0*
Secchi (in):	*47*	35	*28*	*NA*	*37*	*30*	*42*	*NA*	*39*	*30*	*38*	*47*	*47*	*53*	*60*	*60*
River Flow (cfs):	*6,110*	*10,700*	*8,630*	*12,200*	*8,000*	*11,000*	*8,680*	*7,770*	*7,220*	*7,440*	*13,500*	*9,390*	*8,680*	*19,900*	*20,000*	*12,600*
Start Time (hr):	*1910*	*1900*	*1910*	*1910*	*1902*	*1845*	*1830*	*1818*	*1755*	*1806*	*1840*	*1808*	*1750*	*1750*	*1805*	*1730*
End Time (hr):	*2027*	*2022*	*2021*	*2035*	*2010*	*2002*	*1946*	*1936*	*1917*	*1918*	*1930*	*1916*	*1920*	*1912*	*1950*	*1911*
American shad	-	-	-	-	-	-	-	-	-	-	-	-	4	-	3	4
Blueback herring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Comely shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-
Spottail shiner	-	1	-	11	1	-	-	-	36	9	-	-	11	3	1	-
Bluegill	-	-	-	1	3	-	7	1	-	-	1	-	-	-	-	-
Walleye	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
TOTAL	***0***	***1***	***0***	***12***	***4***	***0***	***7***	***1***	***36***	***9***	***1***	***0***	***15***	***4***	***13***	***5***

Date:	*30-Oct*	*2-Nov*	*5-Nov*	*8-Nov*	*11-Nov*	*14-Nov*	*17-Nov*	*20-Nov*	*22-Nov*	*26-Nov*	*29-Nov*	*2-Dec*	*5-Dec*	*8-Dec*	
Water Temp (C):	*13.5*	*12.0*	*11.5*	*11.0*	*11.5*	*10.5*	*10.0*	*7.0*	*5.5*	*4.5*	*4.0*	*4.0*	*4.0*	*2.0*	
Secchi (in):	*40*	*43*	*40*	*65*	*35*	*67*	*55*	*70*	*70*	*105*	*100*	*80*	*90*	*90*	
River Flow (cfs):	*10,500*	*8,720*	*8,450*	*8,300*	*8,180*	*15,100*	*14,600*	*12,200*	*11,500*	*10,400*	*13,200*	*17,900*	*16,400*	*12,400*	
Start Time (hr):	*1653*	*1712*	*1720*	*1640*	*1635*	*1630*	*1630*	*1620*	*1636*	*1610*	*1630*	*1635*	*1630*	*1620*	
End Time (hr):	*1826*	*1830*	*1850*	*1800*	*1755*	*1805*	*1724*	*1726*	*1715*	*1750*	*1745*	*1754*	*1750*	*1800*	***TOTAL***
American shad	41*	15	14	4	1	79	146	31	40	32	5	-	-	-	**419**
Blueback herring	-	-	-	-	-	-	1	-	-	-	-	-	-	-	**1**
Comely shiner	-	-	2	-	-	-	-	-	-	-	-	-	-	-	**10**
Spottail shiner	4	2	5	1	-	3	-	-	-	-	-	-	-	-	**88**
Bluegill	-	1	-	-	-	-	-	-	-	-	-	-	-	-	**14**
Walleye	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3**
TOTAL	***45***	***18***	***21***	***5***	***1***	***82***	***147***	***31***	***40***	***32***	***5***	***0***	***0***	***0***	***535***

NA - Not Available

* 13 of the shad were caught via cast net.

Table 10

Catch per unit effort (CPUE), standard deviation, variance, and confidence interval of juvenile American shad collected by an 8 x 8 ft lift net at the Holtwood Power Station inner forebay, 12 September through 8 December 2000.

Date	Number of Shad	CPUE	Standard Deviation	Variance	Confidence Interval*
18 Oct	4	0.40	0.97	0.93	0.60
24 Oct	3	0.30	0.95	0.90	0.59
27 Oct	4	0.40	1.26	1.60	0.78
30 Oct	28	2.80	5.53	30.62	3.43
2 Nov	15	1.50	4.09	16.72	2.53
5 Nov	14	1.40	1.96	3.82	1.21
8 Nov	4	0.40	0.70	0.49	0.43
11 Nov	1	0.10	0.33	0.11	0.22
14 Nov	79	7.90	18.00	324.10	11.16
17 Nov	146	20.86	46.17	2,131.60	28.62
20 Nov	31	3.88	8.80	77.43	5.45
22 Nov	40	8.00	12.65	160.00	7.84
26 Nov	32	3.20	10.12	102.40	6.27
29 Nov	5	0.50	1.58	2.50	0.98

* 95 percent confidence level.

Table 11

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, 18 October through 29 November 2000. Only dates when American shad were caught are presented.

Total Length	October				November										
(mm)	18	24	27	30	2	5	8	11	14	17	20	22	26	29	Total per Length
111-120		1		3	1	2			1	14					**22**
121-130				15	3	4		1	26	62	6		3		**120**
131-140	1			18	8	1	1		44	53		17	10		**153**
141-150	2		1	3	2	3	2		7	14	16	19	9	1	**79**
151-160	1	1	2	2		4	1		1	3	7	4	8	2	**36**
161-170					1						1		2	1	**5**
171-180		1												1	**2**
181-190			1												**1**
Total	*4*	*3*	*4*	*41**	*15*	*14*	*4*	*1*	*79*	*146*	*30*	*40*	*32*	*5*	418

* 13 shad were caught via cast net.

Table 12. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2000.

Collection Site	Coll. Date	Immersion marks: Day 3 — Jun. R./ Susq. R.	Days 3,9,12 — 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.	Hatchery Total	Wild	Total
Three Mile I.	9/13/00	4							4		4
York Haven	10/16/00						1	9	10		10
forebay	10/26/00							40	40		40
Columbia	7/12/00	7							7		7
	7/19/00	3							3		3
	8/1/00	2							2		2
	8/9/00	3		2					5		5
	8/16/00	1							1		1
	9/27/00			1					1		1
	10/10/00	10						1	11		11
Above Holtwood		30	0	3	0	0	1	50	84	0	84
Percent		36%	0%	4%	0%	0%	1%	60%	100%	0%	

(continued on the next page)

Table 12. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2000.

Collection Site	Coll. Date	Immersion marks: Day 3 Jun. R./ Susq. R.	Days 3,9,12 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.	Hatchery Total	Wild	Total
Holtwood	10/18/00	4							4		4
	10/24/00	1						1	2	1	3
	10/27/00	4							4		4
	10/30/00	36					3		39	2	41
	11/02/00	14					1		15		15
	11/05/00	13						1	14		14
	11/08/00	4							4		4
	11/11/00	1							1		1
	11/14/00	25		1			2	2	30		30
	11/17/00	34	1				1	4	40		40
	11/20/00	28		1				1	30		30
	11/22/00	27	1				1	1	30		30
	11/26/00	28		1				2	31	1	32
	11/29/00	3						2	5		5
Muddy Run	9/26/00	8				2			10		10
Power Station	10/17/00	3							3		3
	10/24/00	24						2	26	1	27
	10/31/00	16						1	17	1	18
Peach Bottom	9/12/00								0	1	1
Impingement	10/19/00	1				1			2		2
	10/20/00								0	1	1
	10/25/00	6							6	1	7
	10/30/00	1							1		1
	11/3/00	1							1		1
	11/13/00								0	1	1
	11/15/00	2							2		2
	11/17/00	6		1					7		7
	11/20/00	13		1				1	15		15
	11/22/00	12							12		12
	11/27/00	16						1	17		17
	11/29/00	8						1	9		9
	12/4/00	5							5		5
	12/6/00	10	1					2	13	1	14
	12/8/00	6							6		6
Conowingo	10/16/00	1							1		1
Strainers	11/3/00	1							1		1
	11/17/00	1							1		1
	11/20/00	4						1	5		5
	11/27/00	1							1		1
	12/2/00	9					2		11	1	12
	12/4/00	14						2	16	1	17
	12/8/00	2							2		2
Holt./P. Bot./Con.		393	3	5	0	3	10	25	439	13	452
Percent		87%	1%	1%	0%	1%	2%	6%	97%	3%	
Total		423	3	8	0	3	11	75	523	13	536
Percent		79%	1%	1%	0%	1%	2%	14%	98%	2%	

Table 13

Historic weekly catch of juvenile American shad by haul seine from the Lower Susquehanna River, 1989 through 2000.

Week of:	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
4 Jul				0		2							**2**
11 Jul	1,048		0	120	0	27		2	44	10	0	7	**1,251**
18 Jul			0	6		70	53	18	28	14	0	3	**189**
25 Jul	45	31			0	60	24	15	22	144	1	0	**342**
1 Aug		0	0	20	0	24	29	32	14	30	1	2	**150**
8 Aug	61	0	0	2	8	13	35	56	20	0	0	6	**195**
15 Aug	7	69	0	16	0	46	40	43	171	9	0	1	**401**
22 Aug					13		42	39	120	10	8	0	**232**
29 Aug		25	12		20		43	34	129	3	2	0	**268**
5 Sep		4			15	50	31	3	46	3	*	0	**152**
12 Sep		93	16		26	25	34	1	89	3	264	0	**551**
19 Sep		28	30		27	14	46	12	59	1	17	0	**234**
26 Sep		0	73		11	5	15	15	32	0	20	1	**171**
3 Oct		0	69	2	22	5	19	10	91	3	1	0	**222**
10 Oct		0	7		0	2	31	3	0	0	3	11	**46**
17 Oct			5			10			14	0	5	0	**34**
24 Oct			0	0			0	0					**0**
TOTAL	**1,161**	**250**	**212**	**166**	**142**	**353**	**442**	**283**	**879**	**230**	**322**	**31**	**4,440**

* No sampling this week due to high river flows.

Table 14

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 1985-2000*.

	Historical Years											Year			
Week	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	1997	1998	1999	2000
Aug 13-19	-	-	-	-	-	-	*0.0*	-	-	-	*0.0*	-	-	-	-
Aug 20-26	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-
Aug 27-Sep 2	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-
Sep 3-9	-	-	-	*0.0*	-	*0.8*	*0.0*	*1.4*	*0.0*	*0.5*	*0.0*	-	-	-	-
Sep 10-16	-	-	*1.3*	-	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.0*	0.0	0.0	0.4	**0.0**
Sep 17-23	-	-	*0.7*	-	*2.3*	*0.0*	*0.0*	*0.5*	*0.0*	*0.0*	-	0.0	0.0	9.7	**0.0**
Sep 24-30	-	-	*0.3*	-	-	*7.5*	*0.0*	*0.0*	*0.3*	*0.1*	*0.0*	0.0	0.0	0.3	**0.0**
Oct 1-7	-	-	*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**
Oct 8-14	-	*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**
Oct 15-21	*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**
Oct 22-28	*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**
Oct 29-Nov 4	*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**
Nov 5-11	*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**
Nov 12-18	*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**
Nov 19-25	*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**
Nov 26-Dec 2	*15.1*	-	-	*0.3*	-	*0.0*	*1.6*	-	*0.0*	*0.0*	*0.0*	0.5	0.0	0.0	**1.2**
Dec 3-9	*62.8*	*14.2*	*0.0*	*0.0*	-	-	-	*0.9*	-	*0.0*	-	0.0	0.0	0.0	**0.0**
Dec 10-16	*4.3*	*0.1*	-	-	-	-	*1.2*	-	-	-	-	-	0.6	-	-
Dec 17-23	*0.5*	*0.0*	-	-	-	-	*0.0*	-	-	-	-	-	-	-	-
											Total number of shad for season	1372	180	490	**406****
											Total number of lifts for season	300	300	300	**290**
											CPUE for entire season	4.6	0.6	1.6	**1.4**

* Lift net was not operated in 1996 due to flood damage to the platform.

** In 2000, total American shad caught solely with lift net was 406; the 13 caught by cast net were not included in CPUE data.

Table 15.

Catch, effort, and catch-per-unit-of-effort of juvenile American shad by location from the upper Chesapeake Bay during the 2000 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.	37	2	11	2	11	2	59	6	9.8
Parlor Pt.	8	2	4	2	0	2	12	6	2.0
Elk Neck Pk.	11	2	9	2	21	2	41	6	6.8
Welch Pt.	59	2	207	2	4	2	270	6	45.0
Hyland Pt.	13	2	1	2	13	2	27	6	4.5
TOTALS	128	14	232	14	49	14	409	42	
CPUE	9.14		16.57		3.50		9.74		
B. Auxiliary									
Carpenter Pt.	7	1	22	1	5	1	34	3	11.3
Plum Pt.	30	1	5	1	2	1	37	3	12.3
Spoil Is.	4	1	10	1	15	1	29	3	9.7
Tydings Est.	15	1	18	1	9	1	42	3	14.0
Tolchester	0	1	0	1	0	1	0	3	0.0
TOTALS	56	5	55	5	31	5	142	15	
CPUE	11.20		11.00		6.20		9.47		
C. GRAND TOTALS	184	19	287	19	80	19	551	57	
CPUE	9.68		15.11		4.21		9.67		

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

With the completion of York Haven fish passage facilities in 2000, American shad and other migratory alosids gained access to hundreds of miles of potential spawning habitat in the Susquehanna and Juniata rivers as well as numerous large tributaries. Access and utilization of this habitat is essential if target restoration goals of two million adult American shad and 15 million river herring above Conowingo Dam is going to be reached. 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 imprinting behavior, prioritize blockages for fish passage, and refine strategies for restoring extirpated populations of American shad and river herring to specific watersheds.

METHODS

Since 1995, uniquely marked American shad fry were stocked in Muddy Creek, York County; West Conewago Creek, York County, Conestoga River, Lancaster County; Conodoguinet Creek, Cumberland

County; Swatara Creek, Dauphin/Lebanon counties; Juniata River; West Branch of the Susquehanna River; and North Branch of the Susquehanna River (Table 1). To monitor abundance and distribution of adult alosids in 2000, daytime electrofishing surveys were conducted using various gear types in the Susquehanna River and selected tributaries at or near the base of first upstream blockage to migration. Sampling locations during the 2000 spawning migration was as follows:

Susquehanna River - Fabri-dam (*Sunbury*);

Tributaries *(Lancaster Co.)* - Conestoga R., Little Conestoga Ck. Fishing Ck. (*Lancaster Co.*); Peters Ck., Muddy Ck., West Conewago Ck.(*York Co.*); Conodoguinet Ck.(*Cumberland Co.*); Swatara Ck.*(Dauphin/Lebanon Co.)*.

Five surveys were conducted between 8 June and 20 June at the base of the Fabri-dam. Tributary surveys were conducted between 9 May and 21 June. Five surveys each were conducted on Muddy Creek, West Conewago Creek, Little Conestoga Creek, and the Conestoga River. Fishing Creek and Peters Creek were surveyed on three dates each. Two surveys each were conducted on Conodoguinet Creek and Swatara Creek. Tributary sampling frequency was base on number of alosids passed at the main stem hydroelectric projects.

RESULTS

Boat electrofishing at the base of the Fabri-dam (r.m. 125.5) on the Susquehanna River resulted in the capture of four adult American shad in 600 minutes of shock time (Table 2). Daily CPUE ranged from zero to 1.00 shad per hour of electrofishing (Table 3). All shad collected were partially spent males ranging in size from 422 to 517 mm TL and weighed 580 to 860 g (Table 2). Shad were captured at water temperatures from 17.0 to 22.0 degrees C and flows from 27,300 to 32,300 cfs (Table 2). Three additional adult shad were observed during sampling but eluded capture (Table 3).

Three American shad were collected from tributaries, two from the Conestoga River, and one from West Conewago Creek, in approximately 2030 minutes of shock time (Table 4). American shad collected were partially spent males in good condition. Shad ranged from 432 to 447 mm TL and weighed 710 to 740g. American shad were captured at water temperatures from 14.0 to 20.5 degrees C. Daily CPUE ranged from zero to 0.017 fish per hour in tributaries where shad were captured (Table 4). Adult shad from the Conestoga River and West Conewago Creek were captured at the base of the Lancaster Water Works Dam (r.m. 32.8) and Detter's Mill Dam (r.m. 27.7), respectively. No American shad were captured in the other tributaries sampled.

Results of adult American shad otolith analysis are summarized in Job V, Task 2, Table 1. Of the adult shad captured at the Fabri-dam, two were wild fish, and two where hatchery with a day 3 or 5 mark indicating they were stocked in the Juniata or Susquehanna River. Both adult shad captured at the base of the Lancaster Water Works Dam were hatchery, with one having a day 5 mark and the other a day 3, 9, 12, 15 mark indicating they were stocked in the Juniata or Susquehanna River and the Conestoga River, respectively. The single adult captured in West Conewago Creek had a day 5 mark indicating it was stocked in the Juniata or Susquehanna river. No adult river herring were collected during the survey.

DISCUSSION

Adult American shad and river herring in the Susquehanna River Basin are derived from two sources: 1) those using the fishway at the main stem dams 2) those captured by the Conowingo West Lift, transported and released above dams. In 2000, Conowingo East Lift passed a record 153,546 American shad while lifts at Holtwood (r.m. 24.3), Safe Harbor (r.m. 31.9), and York Haven (r.m. 56.7) passed 29,421 and 21,079, and 4,675, respectively. Additional shad may have passed through the open channel portion of the York Haven fishway and went uncounted. During 2000, 9,785 adult American shad were collected by the Conowingo West Lift. Of these, 1,351 were transported and stocked in the main stem

Susquehanna at Columbia (856) and in the Conestoga River (495). Observed transport and delayed mortalities of shad amounted to less than 5%. Overall sex ratio (SR) in these transfers was about 2 to 1 favoring males.

Numbers of river herring passed by the main stem fishways were smaller with counts at Conowingo, Holtwood, and Safe Harbor being 23,515, 27, and 816, respectively. Of the river herring collected, 2,026 alewives were stocked in the Little Conestoga. Blueback herring transports included 4,783 adults stocked in the Conestoga (2,481), Little Conestoga (502) and at Muddy Creek Access (1,800). Mortality for river herring transports was very low.

The Fabri-dam (r.m. 125.5) is located just downstream of where the North Branch and West Branch connect to form the main stem Susquehanna River. Captured adult American shad could have reached the base of the Fabri-dam by two avenues: 1) using fish passage facilities at the four downstream hydro-projects, or 2) transport by truck and released at Columbia. Either would have required an additional upstream migration of approximately 70 miles to reach the base of the dam. The two hatchery adults collected at the base of the Fabri-dam originated from fry stockings in the Juniata River or main stem Susquehanna near Montgomery Ferry. Wild adult shad captured at the base of dam could have originated from two sources 1) progeny of fish transported and released above York Haven Dam, or 2) progeny of fish spawned below York Haven Dam.

Despite the presence of adult shad in the river reach between Clemson Island and the Fabri-dam, production of wild shad was low in the upper Susquehanna without a single wild juvenile shad collected during sampling on the Juniata River and Susquehanna main stem above Clemson Island. Wild production in the entire Susquehanna Basin appears to have been limited with only 3% of the juvenile shad collected above Conowingo Dam being wild. Planned construction of a fishway at the Fabri-dam will provide passage for migratory alosids in the future. However, fish passage efficiency will need to improve to ensure American shad will reach upstream sections in sufficient time and numbers to reproduce.

The confluence of West Conewago Creek with the Susquehanna is located on the east shore below York Haven Dam. Based on fish counts at Safe Harbor Dam and numbers of shad released at Columbia, 21,935 American shad would have access to West Conewago Creek during the 2000 spawning migration. The presence of the Juniata/Susquehanna mark on the shad captured at Detter's Mill Dam suggests that this individual was a stray. This fish used the lifts at Conowingo, Holtwood, and Safe Harbor dams, or was released at Columbia, then traveled up Conewago Creek 27.7 miles to the base of the dam. Due to the episodic nature of adult sampling, additional American shad may have migrated up West Conewago and went undetected. Sampling by seine in West Conewago failed to capture any juvenile shad suggesting that if natural reproduction occurred, it was limited. Provisions for fish passage at Detter's Mill Dam should be implemented to ensure passage in the future.

The confluence of the Conestoga River with the Susquehanna is located on the west shore below Safe Harbor Dam. Based on fish counts at Holtwood Dam, 29,421 American shad would have access to the Conestoga River. An additional 495 adult shad were transported and released in the Conestoga River at Bridgeport, approximately one mile below the Lancaster Water Works Dam. It is not known if adult shad captured at the base of the Lancaster Water Works Dam were upstream migrants from the Susquehanna or transported individuals. Considering the limited number of fry stocked in the Conestoga, chances of a Conestoga marked shad being present in the load of transported adults were remote, but possible. Since fry with the Juniata/Susquehanna mark are stocked at much higher densities, chances of a Juniata/Susquehanna marked shad being present were much higher. If the two adult shad captured were migrants and not released transports, they 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. Stocking of pre-spawn adult American shad in tributaries should be suspended in the future to eliminate uncertainties with regard to the origin of adults.

Based on fish counts, Safe Harbor passed 657 blueback herring and 159 alewife. Considering that Holtwood only passed 27 bluebacks, a large proportion of the river herring counted at Safe Harbor could have only originated from fish transported to the Conestoga basin. These herring apparently moved out of the Conestoga after release and continued up the Susquehanna. It is not known if herring spawned prior to moving out of the Conestoga basin. Future releases of river herring in tributaries should be well upstream of their confluence with the Susquehanna, preferably above existing blockages, to discourage downstream movement. Sampling by seine in the Conestoga and Little Conestoga failed to capture any juvenile alosids suggesting that if natural reproduction occurred, it was limited.

It is largely accepted that transporting and release of pre-spawn alosids and stocking of shad fry is successful at establishing imprinted populations in the main stem Susquehanna River basin and elsewhere. It is too early to determine if the same strategy will be successful at establishing sub-populations in tributaries to the Susquehanna River. Information obtained in 2000 is limited, but suggests that straying by American shad into tributaries is occurring. In addition, the stocking of shad fry may be having success at establishing shad imprinted to the Conestoga River. Whether shad and river herring will return in the future in sufficient numbers to spawn successfully is not yet known. Habitat quality and quantity may also be limiting factors to establishing sub-populations in tributaries. Monitoring of main stem and tributary waters should continue in order to track adult alosid abundance, distribution, wild production, and success of the restoration effort.

SUMMARY

- Adult American shad were captured by electrofishing at the base of the Fabri-dam, Susquehanna River; Lancaster Water Works Dam, Conestoga River; and Detter's Mill Dam, West Conewago Creek.
- Straying of adult American shad into tributary waters which were stocked with larvae has been documented.
- Stocking shad fry may be useful in establishing sub-populations imprinted to tributary waters.
- American shad and river herring reproduction in tributaries was not detected during 2000.

- Releases of pre-spawn river herring should be above dams in upper portions of tributary watersheds.
- Stocking of pre-spawn American shad in tributaries should be suspended.
- Monitoring of 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 marked American shad stocked in the Susquehanna River, 1995-2000.

			Mark		Taggant		Mark Retention (%)		Hatchery			
Year	Number	Size	Immersion (days)	Feed	Immersion	Feed	Immers	Feed	Fry Culture	Fingerling Culture	Stocking Location	Egg Source
1995	8,339,000	Fry	5	-	200ppm OTC	-	-	-	Van Dyke	-	Juniata	Hud./Del.
	731,000	Fry	5	-	200ppm OTC	-		-	Van Dyke	-	Susq. (above Clarks Ferry)	Hud./Del.
	9,070,000	Fry	5	Subtotal			100					
	1044000	Fry	5	-	200ppm OTC	-	-	-	Van Dyke	-	Lehigh R.	Delaware
	220,000	Fry	12,15,18	-	200ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Hudson
	230,000	Fry	3,13,17	-	200ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr. (mouth)	Hudson
	198,000	Fry	3,7,15,19	-	200ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Hudson
	190,000	Fry	5,9,13,17	-	200ppm OTC	-	100	-	Van Dyke	-	Conestoga R. (mouth)	Hudson
	93,000	Fry	3,13,17,21	-	200ppm OTC	-	100	-	Van Dyke	-	Muddy Cr.	Hudson
	1,975,000											
1996	4,787,000	Fry	3	-	256ppm OTC	-	-	-	Van Dyke	-	Juniata	Hud./Del.
	943,000	Fry	3	-	256ppm OTC	-	-	-	Van Dyke	-	Susq. (above Clarks Ferry)	Delaware
	5,730,000	Fry	3	Subtotal			100					
	561,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	West Br. Susq. R.	Hud./Del.
	683,000	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	North Br. Susq. R.	Hudson
	172,000	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Delaware
	277,000	Fry	3,9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Delaware
	43,000	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Standing Stone Cr.	Delaware
	993,000	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.	Delaware
	1,736,000	Fry	Subtotal									
1997	236,000	Fry	5	-	256ppm OTC	-	-	-	Van Dyke	-	Juniata	Hud./Del.
	2,801,000	Fry	5	-	256ppm OTC	-	-	-	Van Dyke	-	Susq. (above Clarks Ferry)	Hud./Del.
	3,037,000	Fry	5	Subtotal			100					
	2,270,000	Fry	3,13,17	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata	Hud./Del.
	486,000	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Jun. R. (Huntingdon)	Hudson
	1,247,000	Fry	5,9,13	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.	Delaware
	622,000	Fry	5,9,13,21	-	256ppm OTC	-	100	-	Van Dyke	-	West Br. Susq. R.	Hudson
	1,199,000	Fry	5,9,13,17	-	256ppm OTC	-	100	-	Van Dyke	-	North Br. Susq. R.	Hud./Del.
	174,000	Fry	11,14,17	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Delaware
	231,000	Fry	3,13,17,21	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Hudson
	6,229,000		Subtotal									
	25,000	Fing.	various	single	256ppm OTC	40g OTC/# food	100	100	Van Dyke	Benner Spring	Swatara Cr.	Hud./Del.
1998	8,925,000	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Jun. & Susq. R.	Hud./Del.
	321,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	W. Conewago Cr.	Hudson
	948,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.	Delaware
	565,000	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata R.	Susq.
	305,000	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Hudson
	1,126,000	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	North Br. Susq. R.	Hudson
	229,000	Fry	3,9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Hudson
	230,000	Fry	3,6,9,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	Swatara Cr.	Hudson
	12,649,000	Fry	Subtotal									
	2,200	Fing.	various	double	256ppm OTC	40g OTC/# food	-	100	Van Dyke	Benner Spring	Standing Stone Cr.	Various
	56,000	Fry	3,6,9,15	-	200ppm OTC	-		-	Lamar	-	West Br. Susq. R.	Susq.

Table 1. Summary of marked American shad stocked in the Susquehanna River, 1995-2000.

Year	Number	Size	Mark Immersion (days)	Mark Feed	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers	Mark Retention (%) Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source
1999	10,229,000	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata R.	Hud./Del.
	410,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Schuylkill R.	Delaware
	501,000	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.	Delaware
	373,000	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Hudson
	984,000	Fry	3,6,9,15	-	256ppm OTC	-	100	-	Van Dyke	-	W. Br. Susq. R.	Hudson
	236,000	Fry	3,9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Hudson
	219,000	Fry	3,6,9,12,18	-	256ppm OTC	-	100	-	Van Dyke	-	W. Conewago Cr.	Hudson
	249,000	Fry	3,6,9,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	Swatara Cr.	Hudson
	1,211,000	Fry	3,6,12,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.	Hudson
	14,412,000		Subtotal									
2000	7,369,000	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata & Susq. R.	Hudson
	111,000	Fry	3,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Hudson
	109,000	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	W. Conewago Cr.	Hudson
	536,000	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Schuylkill R.	Delaware
	632,000	Fry	3,6,9,15	-	256ppm OTC	-	100	-	Van Dyke	-	W. Br. Susq. R.	Hudson
	329,000	Fry	3,6,9,15	-	200ppm OTC	-	100	-	Lamar	-	W. Br. Susq. R.	Susq.
	231,000	Fry	3,9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conestoga R.	Hudson
	447,000	Fry	3,6,9,12,18	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.	Delaware
	33,000	Fry	3,6,9,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	Swatara Cr.	Hudson
	975,000	Fry	3,6,12,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.	Hudson
	10,772,000		Subtotal									

Table 2

Summary of American shad collected in 2000 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
8 Jun	27,300	17.0	120	300	7.0	1	1
12 Jun	21,500	22.0	120	200	3.5	1	0
14 Jun	32,300	18.5	120	240	3.5	2	0
16 Jun	57,900	19.5	120	330	7.0	0	2
20 Jun	37,100	20.0	120	350	7.0	0	0
Total			*600*			*4*	*3*
Mean	*35,220*	*19.4*		*284.0*	*5.6*		

Table 3.

Catch per unit of effort (CPUE) of American shad collected in 2000 with a boat-mounted electrofisher downstream of the Shikellamy State Park inflatable dam on the Susquehanna River near Sunbury, Pennsylvania.

Date	No. of Shad	Total Length (mm)	Weight (g)	Sex	CPUE (No./hour)
8-Jun	1	501	860	Male	0.50
12-Jun	1	517	940	Male	0.50
14-Jun	2	422	580	Male	1.00
		465	680	Male	
16-Jun	0	NA	NA	NA	0.00
20-Jun	0	NA	NA	NA	0.00
TOTAL	*4*				
MEAN		*476*	*765*		*0.40*

NA = Not Applicable.

Table 4.

Summary of PFBC electrofishing surveys conducted in large tributaries to the Susquehanna River during spring 2000.

Date	Location	Water Temperature (°C)	Start Time (h)	End Time (h)	Number of American Shad	CPUE (No./h)
09 May	Muddy Creek	19.5	1025	1135	0	0.000
				Subtotal	***0***	***0.000***
16 May	Muddy Creek	15.0	1455	1600	0	0.000
16 May	West Conewago Creek	19.5	0900	1010	0	0.000
16 May	Little Conestoga Creek	15.0	1145	1255	0	0.000
17 May	Conestoga River	17.0	0905	1015	0	0.000
				Subtotal	***0***	***0.000***
22 May	Conestoga River	14.0	0900	1005	1	0.017
23 May	Muddy Creek	13.0	0825	0930	0	0.000
26 May	West Conewago Creek	17.0	0850	0955	0	0.000
26 May	Little Conestoga Creek	15.0	1125	1240	0	0.000
				Subtotal	***1***	***0.004***
01 Jun	Muddy Creek	13.0	1245	1350	0	0.000
31 May	West Conewago Creek	15.5	0905	1010	0	0.000
31 May	Little Conestoga Creek	13.0	1140	1255	0	0.000
01 Jun	Conestoga River	16.0	0915	1030	1	0.017
				Subtotal	***1***	***0.004***
05 Jun	West Conewago Creek	20.5	0905	1015	1	0.017
05 Jun	Little Conestoga Creek	16.7	0012	1245	0	0.000
06 Jun	Muddy Creek	15.0	1340	1445	0	0.000
07 Jun	Conestoga River	15.0	0845	0950	0	0.000
				Subtotal	***1***	***0.004***
12 Jun	Little Conestoga Creek	22.0	1245	1355	0	0.000
12 Jun	West Conewago Creek	27.0	1545	1658	0	0.000
13 Jun	Swatara Creek	21.0	1015	1125	0	0.000
13 Jun	Conodoguinet Creek	21.5	1240	1355	0	0.000
14 Jun	Conestoga River	19.0	0840	0950	0	0.000
				Subtotal	***0***	***0.000***
21 Jun	Swatara Creek	19.7	0925	1035	0	0.000
21 Jun	Conodoguinet Creek	22.7	1145	1250	0	0.000
				Subtotal	***0***	***0.000***
		Large Stream Surveys Total			***3***	***0.002***

Job V., Task 2. Analysis of adult American shad otoliths, 2000

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Abstract

A total of 197 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2000. Based on tetracycline marking and otolith microstructure, 54% of the 193 readable otoliths were identified as wild and 46% hatchery. Double marked fish (released below Conowingo Dam) represented 12.4% 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 318 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 0.86 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1994 and 1995 year classes are 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. The restoration approach consisted of two primary programs: 1) trapping of pre-spawn adults at Conowingo Dam and transfer to areas above dams; 2) planting of hatchery-reared fry and fingerlings.

In order to evaluate and improve the program, it was necessary to know the relative contribution of these programs 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 2000.

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 upon 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. Under white light, each otolith specimen was classified hatchery or wild based upon visual microstructural characteristics. After microstructure classification, the white light was turned off 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 approximately 195 otoliths whose age is known 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 1999. Age composition data was gathered as follows: for 1996 to 2000, 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. Stock/recruitment ratios were determined for each year class by dividing total recruitment into the number of fry stocked above dams for hatchery fish, the number of fingerlings stocked above dams for fingerlings, or the number of adults transported above dams for wild fish.

Results and Discussion

A total of 197 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 2000. No samples were collected from the East lift since it was operated in fish passage mode. For 4 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 193 readable otoliths (Table 1). A total of 104 (54%) otoliths exhibited wild microstructure and no tetracycline mark. Eighty-nine otoliths (46%) 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 4.1 years for males and 5.1 years for females. For wild fish, mean ages were 4.0 for males and 4.8 for females (Table 4). For hatchery fish, mean age was 4.3 for males and 5.4 for females. Overall sex ratio was 2.3 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. No consistent difference in length at age is apparent between wild and hatchery fish.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 9. The catch of adult shad at the lifts was partitioned into year classes using scale or otolith age data and tabulated according to origin based on otolith analysis (Tables 10-12). 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 1994 are not fully recruited, however, recruitment from the 1994 and 1995 year classes were above the long term average, and are included in the analysis. For the period 1986-1995, the number of hatchery larvae required to produce one returning adult ranged from 151 to

620, with a mean of 318 (Table 10). This is a maximum estimate since the 1994 and 1995 year classes are not fully recruited.

The number of hatchery larvae required to produce one returning adult was surprisingly low in comparison to 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 analysis was repeated for fingerlings stocked above Conowingo Dam (Table 11). For the period 1986-1994, the number of hatchery fingerlings required to produce one returning adult ranged from 42 to 386, with a mean of 134. Again, this is a maximum estimate since the 1994 and 1995 year classes are 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, 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.

A similar analysis was tabulated for wild fish (Table 12). For the period 1986 to

1995, transport of an average of 0.86 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.

From 1988 to 1994 American shad larvae reared at the Van Dyke Hatchery were uniquely marked according to egg source river. Since the majority of the fish returning to Conowingo Dam are ages 4 to 6, those cohorts are now fully recruited, and we can analyze adult returns based on egg source river. Prior to 1995, aging of adult American shad collected at Conowingo Dam was done using scale ages. Comparison of scale age vs. tetracycline mark revealed many cases where the age was not possible, given the mark present. This was not observed after 1995 when otolith ages were used. To minimize problems associated with mis-aging, I analyzed cohorts from 1991 to 1994 only.

I performed cohort analysis for adults originating from the Delaware, Hudson and Connecticut Rivers (Tables 13-15). This analysis was similar to the analysis used in Tables 9-12 except the actual numbers of fish returning at age are used instead of age frequency. For cohorts from 1991 to 1994, mean number of larvae required to return one adult to Conowingo Dam was 136 for the Delaware River, 228 for the Hudson River, and 843 for the Connecticut River. This corresponds to relative survival of 1.00 for the Delaware River, 0.59 for the Hudson River, and 0.16 for the Connecticut River (Table 16). This is in contrast to results from in-river recoveries of YOY. In-river recovery rates for Hudson River YOY were consistently higher than those for the Delaware River, with a composite relative survival of 1.00 vs. 0.29 for the Delaware River and 0.06 for the Connecticut River. There is no clear explanation for this. Potential explanations include; in-river catchability for juveniles varies between egg sources, ocean survival rates vary between egg sources, or catchability for adults (lift efficiency) varies between egg sources. For the latter explanation, one might hypothesize a genetic pre-disposition for Hudson River fish to spawn in tidal waters and therefore not enter the Conowingo lifts. If this were true, we might expect recovery rates of Hudson River origin fish to be higher than Delaware river origin fish in upper Chesapeake Bay. Table 17 (1995-2000 summary) provides no evidence for this, in fact, recovery rates for Delaware River origin fish in upper Chesapeake Bay are higher (43.8) than Hudson River origin fish (26.8).

Table 17 provides a detailed look at recoveries of marked American shad, by cohort, which were captured at Conowingo Dam and the upper Chesapeake Bay pound nets. The reader should keep in mind that this analysis relies heavily on accurate aging of otoliths, a science/art in which the writer has limited confidence. Recovery rates ranged from 0 for the 1994 cohort from the Connecticut River source to 2,286 for the 1991 cohort from the Connecticut River. The unusually high survival of the 1991 Connecticut River cohort is puzzling, given the overall poor performance of the Connecticut River source as a whole. It is tempting to explain this away based on mis-aging, however that is not likely. The 5,9,13,17,21 day mark applied to this cohort was first used in 1991, eliminating the possibility of over-aging these fish. Under-aging would have been possible, thereby assigning them to the 1992 cohort. Even if 50% were under-aged, the recovery rate would still have been 1143 $x10^{-7}$, or 1.4 times the next highest rate.

Recovery rates for the 1991 to 1994 cohorts combined, returning to Conowingo Dam from 1995 to 2000, were higher for the Delaware River (229 $\times10^{-7}$) than for the Hudson (175 $\times10^{-7}$)and Connecticut River (55 $\times10^{-7}$), as reported by cohort analysis above. All egg sources combined, recovery rates for the 1992 cohort were highest (303 $\times10^{-7}$), followed by 1991 (211 $\times10^{-7}$), 1994 (111 $\times10^{-7}$) and 1993 (106 $\times10^{-7}$). Recovery rates for the upper Chesapeake Bay were an order of magnitude lower, reflective of fewer samples collected. Detailed analysis of upper Bay samples is not warranted due to small sample size.

Recoveries of adults from the 1991 day-night stocking study showed that day stocking resulted in slightly higher recovery rates(115.3 $\times10^{-7}$) than night stocking(109.5 $\times10^{-7}$). In contrast, recovery rates for juveniles, collected prior to out-migration during 1991, were slightly higher for night releases (8.5 $\times10^{-5}$) than for daytime releases (7.54 $\times10^{-5}$, Hendricks et al. 1992). In either case, the differences may not be significant and night stocking would not be warranted, based on the significant logistical difficulties it would entail.

Recoveries of adults from the 1992 midstream-nearshore study indicated that nearshore stocked Hudson larvae were recovered at a much higher rate than midstream stocked larvae(820 $\times10^{-7}$ vs 373 $\times10^{-7}$), but the opposite was true for

Connecticut River larvae(144 $\times10^{-7}$ vs 168 $\times10^{-7}$). Recovery rates for juveniles (Hendricks and Bender 1993) were higher for larvae released nearshore for both egg sources (Hudson, nearshore- 264 $\times10^{-6}$, Hudson midstream- 174 $\times10^{-6}$, Conn., nearshore- 34 $\times10^{-6}$, Conn., midstream- 21 x 10^{-6}). Again, these results support our decision to continue to stock shad larvae at nearshore locations.

In 1993, two tanks of Connecticut River larvae were marked at 5 days of age and stocked at 7 days of age to avoid heavy mortalities which were occurring after 9 days of age. Juvenile recovery rate for this group was 13 $\times10^{-6}$, compared to 4 $\times10^{-6}$ for Connecticut River larvae stocked between 22 and 26 days of age (Hendricks and Bender, 1995). In a follow-up study in 1994, recovery rate of Hudson River larvae stocked at 7 days of age was 123 $\times10^{-6}$ vs a recovery rate of 17 $\times10^{-6}$ for larvae stocked at 20 days of age (Hendricks and Bender, 1995). Recovery rates for adults from these groups exhibited similar trends; a 10-fold increase in recovery rate for larvae stocked at 7 days of age compared to those stocked at 20-26 days of age (Table 17). These results do not necessarily agree with our more recent experience in stocking larvae in tributaries. Larvae stocked in tributaries at 13 to 22 days of age have often exhibited higher recovery rates than those stocked in the Juniata River or Susquehanna River at Montgomery Ferry at 7-10 days of age (see this report, job III, Appendix 1, discussion and Tables 1-1 to 1-7). This is a question that needs to be resolved, since other jurisdictions are currently prevented from stocking larvae at an earlier age due to the ASMFC requirement for unique marking of hatchery-reared shad.

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

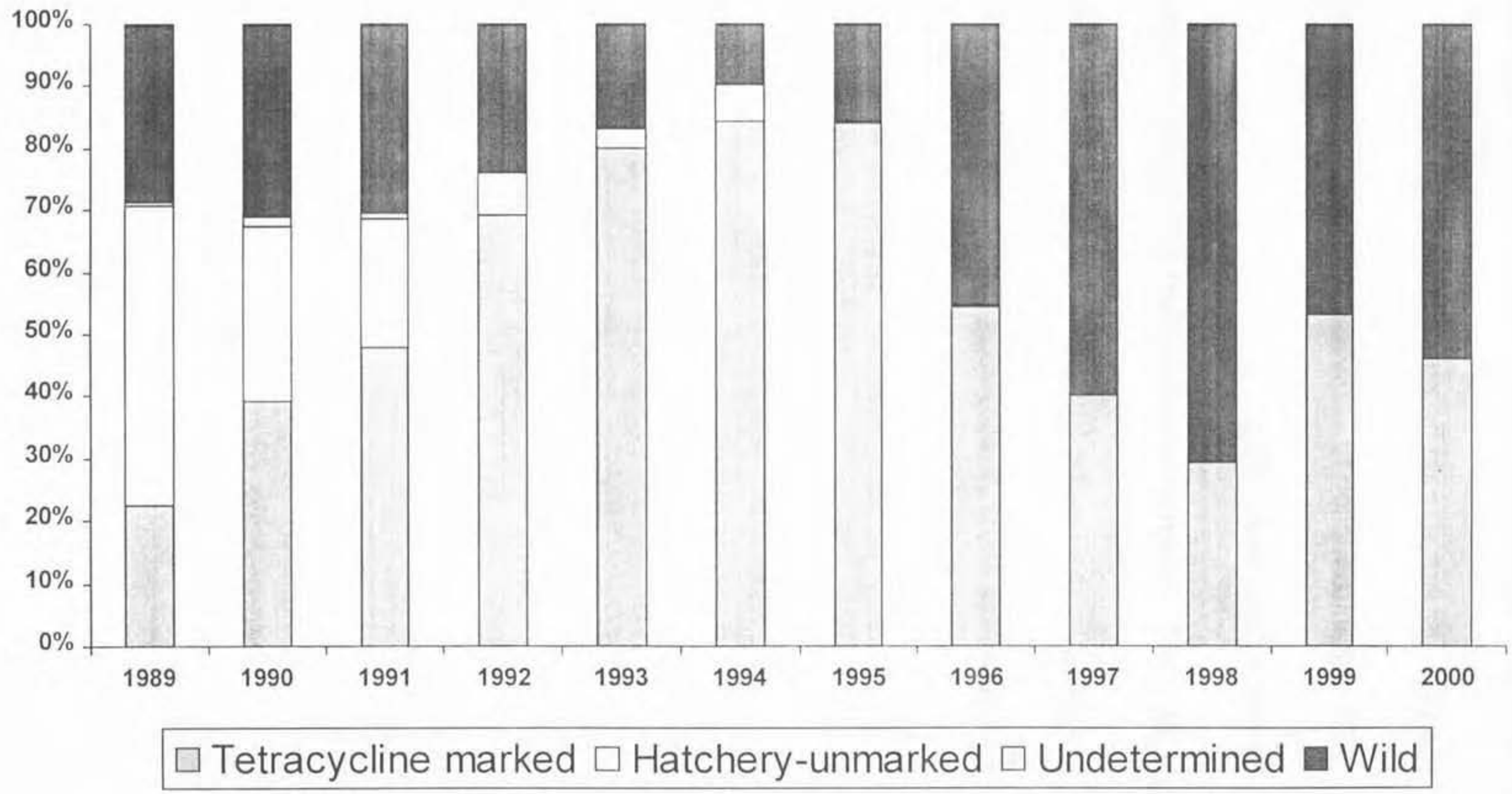

Figure 2. Catch of American shad in the Conowingo Dam Fish Lifts

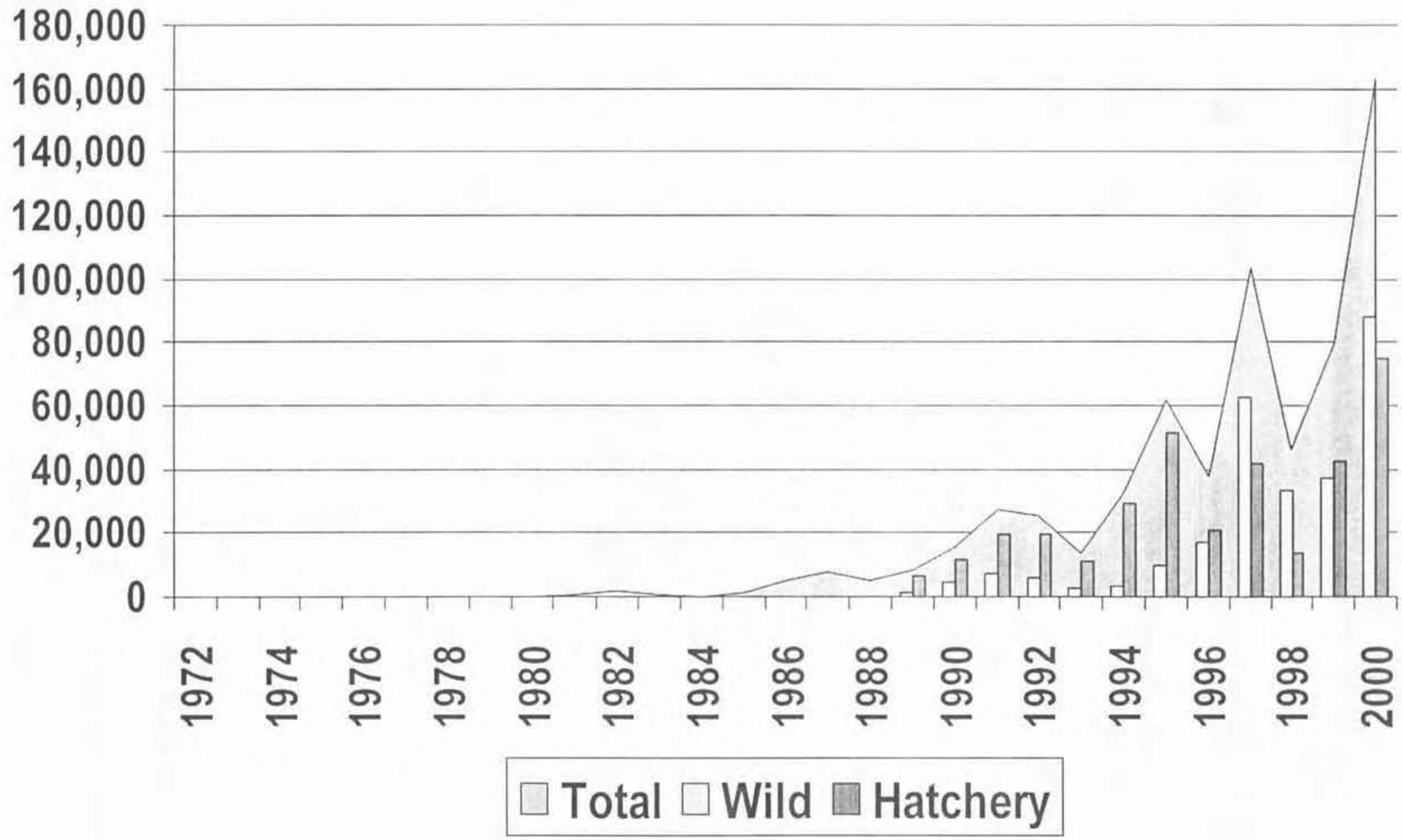

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2000.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

Conowingo Dam		N	%
Wild Microstructure, No TC Mark		104	54%
Hatchery Microstructure			
No TC Mark*		0	0%
Single TC Mark	Day 3 or 5	65	34%
Double TC Mark	Days 5,9, 3,6 or 3,7	9	5%
	Days 3,17	1	1%
	Days 7,11	1	1%
Triple TC Mark	Days 5,9,13	2	1%
	Days 3,13,17	4	2%
	Days 3,9,12	2	1%
	Days 11,14,17 or 12,15,18	2	1%
Quadruple TC Mark	Days 3,13,17,21	1	1%
	Days 3,6,9,12	1	1%
	Days 5,9,13,21	1	1%
	Total Hatchery	89	46%
	Total readable otoliths	193	
	Unreadable Otoliths**	4	
	Total	197	
Other sites			
Fabri-Dam	No mark	2	
	Day 3 or 5	2	
Conestoga R.	Day 5	1	
	Days 3,9,12,15	1	
W. Conewago Cr.	Day 5	1	
Big Chestnut I.	Days 3,9,12,15	1	

*Includes otoliths in which autofluoresence may obscure mark and poor grinds.
**Includes missing, broken and poorly ground otoliths.

Table 2. Origin of adult American shad collected at Conowingo Dam Fish Lifts, based on otolith analysis. 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
Totals	1,359	59	140	6	25	1	241	890	34	2,655

*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, 2000.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male		19	85	25	5			3	137	4.1
Female		1	13	27	14	2		2	59	5.1
Unknown				1					1	
Totals	0	20	98	53	19	2	0	5	197	4.4

Table 4. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2000.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male- Wild		12	48	8	2				70	4.0
Male- Hatc.		7	37	17	3				64	4.3
Female- Wild		1	11	13	6				31	4.8
Female- Hatc.			2	14	8	2			26	5.4
Totals	0	20	98	52	19	2	0	0	191	4.4

Table 5. Length frequency by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2000.

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			9	42	51	29	5						136
Female					6	16	18	14	7				61
Unknown													0
Totals	0	0	9	42	57	45	23	14	7	0	0	0	197

Table 6. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2000.

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			6	29	22	10	3						70
Male- Hatc.			3	13	29	19	2						66
Female- Wild					3	8	9	9	5				34
Female- Hatc.					3	8	9	5	2				27
Totals	0	0	9	42	57	45	23	14	7	0	0	0	197

Table 7. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2000.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male			394	(19)	408	(89)	433	(26)	466	(6)				
Female			405	(1)	441	(13)	465	(27)	479	(14)	485	(2)		

Table 8. Mean length at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2000.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male- Wild			389	(12)	404	(49)	431	(8)	478	(3)				
Male- Hatc.			402	(7)	413	(40)	434	(18)	453	(3)				
Female- Wild			405	(1)	445	(11)	479	(13)	486	(6)				
Female- Hatc.					420	(2)	452	(14)	473	(8)	485	(2)		

Table 9. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-2000.

									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	7.89	32.6	45.3	10.0	0.0	48%	1%	5%	47%
2000	163,331	0.0	1.0	9.90	27.6	51.0	10.4	0.0	40%	0%	6%	54%

*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- 1995.

			Cohort								
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
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
2000							0	688	6,532	18,221	33,692
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,957	15,819	25,730	32,030	35,883	37,492
al releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00	7.47
arvae to return 1 adult:	620	431	445	591	172	289	192	254	200	279	199

number of larvae to return 1 adult (1986-1995): 318

Table 11. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 1995.

	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
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
Number of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	166	0	0
Mean number of fingerlings to return 1 adult (1986-1995):				134							

Table 12. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986- 1995.

	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
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,816	21,390	48,872	49,467	42,383	48,638
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
ults transported to return 1 adult:	0.73	1.93	1.56	1.73	1.79	1.47	0.73	0.24	0.58	1.33	0.70

Mean number of adults transported to return 1 adult (1986-1995): 0.86

Table 13. Tetracycline marked, Delaware River egg source American shad captured at Conowingo Dam, 1995-2000.

Year	Fish lift catch	Return at age 8	7	6	5	4	3	2	No. Otoliths Processed	Cohort 1991	1992	1993	1994
1995	61,650					7			331	1,304	0	0	
1996	37,513				25	28	14		379	2,474	2,771	1,386	0
1997	103,945			4	10	14	6		250	1,663	4,158	5,821	2,495
1998	46,481			3	13	4			130	0	1,073	4,648	1,430
1999	79,370		1	4	10				188	0	422	1,689	4,222
2000	163,331		1	2					193		0	846	1,693
										5,441	8,424	14,390	9,839
									Number Stocked (millions)	1.09	0.80	2.50	0.79
									Number of larvae to return 1 adult:	199	95	174	80
									Mean number of larvae to return 1 adult (1991-19				136

Table 14. Tetracycline marked, Hudson River egg source American shad captured at Conowingo Dam, 1995-2000.

Year	Fish lift catch	Return at age 8	7	6	5	4	3	2	No. Otoliths Processed	Cohort 1991	1992	1993	1994
1995	61,650					47	1		331	8,754	186	0	
1996	37,513				54	21	4	1	379	5,345	2,079	396	99
1997	103,945			6	9	8	17		250	2,495	3,742	3,326	7,068
1998	46,481			1		3			130	0	358	0	1,073
1999	79,370	1		1	21				188	422	0	422	8,866
2000	163,331			7					193		0	0	5,924
										17,016	6,364	4,144	23,030
									Number Stocked (millions)	6.10	0.57	1.10	3.78
									Number of larvae to return 1 adult:	358	89	266	164
									Mean number of larvae to return 1 adult (1991-19				228

Table 15. Tetracycline marked, Connecticut River egg source American shad captured at Conowingo Dam, 1995-2000.

Year	Fish lift catch	Return at age 8	7	6	5	4	3	2	No. Otoliths Processed	Cohort 1991	1992	1993	1994
1995	61,650					4	7		331	745	1,304	0	
1996	37,513				4	10	2		379	396	990	198	0
1997	103,945				1	3			250	0	416	1,247	0
1998	46,481				2				130	0	0	715	0
1999	79,370			2					188	0	0	844	0
2000	163,331		1						193		0	846	0
										1,141	2,709	3,851	0
									Number Stocked (millions)	0.04	1.67	2.93	1.86
									Number of larvae to return 1 adult:	31	617	761	
									Mean number of larvae to return 1 adult (1991-19				843

Table 16. Recapture of marked American shad as YOY vs adults, Susquehanna River.

	Egg source	Cohort 1991	1992	1993	1994	Mean	Relative
Inriver recovery rate as YOY*	Delaware	0.56	0.51	0.34	0.10	0.38	0.29
(all gear types)	Hudson	0.68	2.67	1.16	0.65	1.29	1.00
	Connecticut	0.00	0.26	0.07	0.00	0.08	0.06
Number of larvae required to return	Delaware	199	95	174	80	136	1.00
1 adult to Conowingo lifts:	Hudson	358	89	266	164	228	0.59
	Connecticut	31	617	761		843	0.16

* Data from SRAFRC reports for 1991-1994.

Table 17. Recapture of marked adult American shad stocked as larvae in the Juniata and middle Susquehanna River and recaptured at Conowingo Dam or the upper Chesapeake Bay.

				Number recaptured Conowingo lifts							Recovery Rate	Number recaptured Upper Bay					Recovery Rate
Egg Source	Cohort	Mark (days)	Number Stocked	1995	1996	1997	1998	1999	2000	Total	(1/Exp7)	1996	1997	1998	1999	Total	(1/Exp7)
Delaware	1991	3,13,17	1,085,000	7	25	4				36	332	3	3			6	55
Hudson	1991	5,9,13	1,911,000	23	32	5		1		61	319	3	2			5	26
Hudson (day)	1991	5	2,081,000	11	13					24	115	2				2	
Hudson (night)	1991	18	2,106,000	13	9	1				23	109					0	-
Connecticut	1991	5,9,13,17,21	35,000	4	4					8	2,286		1			1	286
Total	1991		7,218,000	58	83	10	-	1	-	152	211	8	6	-	-	14	19
Delaware	1992	3,13,17	798,700		28	10	3	1		42	526	3	3			6	75
Hudson	1992	5,9,13	378,500	1	14	4	1			20	528	3	1			4	106
Hudson- (nearshore)	1992	5	109,700		4	5				9	820	1				1	91
Hudson- (midstream)	1992	18	80,500		3					3	373	2			1	3	373
Connecticut	1992	5,9,13,17,21	514,100							-	-					0	-
Connecticut- (nearshore)	1992	3,13,17,21	623,000	5	3	1				9	144					0	-
Connecticut-(midstream)	1992	3,7,11,21	534,900	2	7					9	168					0	-
Total	1992		3,039,400	8	59	20	4	1	-	92	303	9	4	-	1	14	46
Delaware	1993	3,13,17	2,499,400		14	14	13	4	1	46	184		5	1	4	10	40
Hudson	1993	5,9,13	1,104,200		4	8		1		13	118		3			3	27
Connecticut	1993	5,9,13,17,21	2,037,900					1		1	5					0	-
Connecticut	1993	5	891,700		2	3	2	1	1	9	101	1	2	1	2	6	67
Total	1993		6,533,200	-	20	25	15	7	2	69	106	1	10	2	6	19	29
Delaware	1994	3,13,17	785,000			6	4	10	2	22	280	1			5	6	76
Hudson	1994	5,9,13	2,004,000			6		10	2	18	90				1	1	5
Hudson (7-day)	1994	5	996,000		1	11	3	9	5	29	291		3	1	8	12	120
Hudson (20-day)	1994	18	779,000					2		2	26					0	-
Connecticut	1994	5,9,13,17,21	1,855,000							-	-					0	-
Total	1994		6,419,000	-	1	23	7	31	9	71	111	1	3	1	14	19	30
Summary 1995-2000																	
Delaware			6,387,100	7	67	34	20	15	3	146	229	7	11	1	9	28	44
Hudson			11,549,900	48	80	40	4	23	7	202	175	11	9	1	10	31	27
Connecticut			6,491,600	11	16	4	2	2	1	36	55	1	3	1	2	7	11
Total			24,428,600	66	163	78	26	40	11	384	157	19	23	3	21	66	27

Job V - Task 3
Tank Spawning Techniques : Relative Efficacy of Two Hormones for Inducing Spawning in American Shad

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Summary

Hormone Experiment: Trials were conducted (1) to assess the effectiveness of Luteinizing Hormone- Releasing Hormone analogue (LHRHa) and Salmon Gonadotropin Releasing Hormone analogue (sGnRHa) hormone implants for inducing tank spawning of American shad; (2) to determine whether the use of sGnRHa hormone implants in male American shad improves reproductive success; and (3) to test the suitability of a cross flow rectangular tank for tank spawning. Analysis of results utilizing t-tests revealed no differences between treatments for these trials. A number of modifications in transport and holding procedures were implemented in the course of the season to improve survival till spawning. Average percent survival of American shad during transport when utilizing a single 1000 gallon tank was greater (100 %) when compared to use of four 400 gallon tanks (78%). Seven-day survival of American shad held in recirculation system at the Northeast Fishery Center was greater (71 %) when salinity was maintained at 2 to 4 ppt when compared to fresh water (19 %).

Production Observations: Approximately 3 million eggs were collected of which 2 million were incubated. Viability of the incubated eggs was 83 %. Eggs harvested from freshwater were approximately twice the size of those collected from the 2 - 4 ppt saltwater. Problems were encountered with Gas Bubble Disease which resulted in a large number of fry being lost. Approximately 328,000 fry were stocked into the West Branch of the Susquehanna River.

Background

The U.S. Fish and Wildlife Service and the partners in the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) have been involved in the restoration of

American shad (AMS) to the Susquehanna River for a number of 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 production goals for NEFC were to provide 5 to 10 million fertilized shad eggs for PFBC's Van Dyke Shad Hatchery, and to stock one to two million oxytetracycline marked fry in the West Branch of the Susquehanna River.

Traditionally the egg source for AMS culture involves lethal collection and riverside spawning at considerable costs. An alternative technique using hormone implants to induce natural tank spawning of AMS has been under development since 1993 by Maryland Department of Natural Resources (MDNR), Manning Hatchery, and for the past several years at Waldoboro Shad Hatchery (both with and without hormone implants) in Maine. Beginning in1999, American shad restoration efforts for the Roanoke River by Edenton NFH and Watha Hatchery, North Carolina Wildlife Resources Commission, have employed tank spawning techniques. Results from the several tank spawning efforts have differed greatly based upon site location, year and specific transport loads.

A tank spawning work shop conducted at Lamar, Pennsylvania in September, 1999 reviewed and developed strategies to enhance egg and fry production. A number of variables were considered which influence survival and reproduction of American shad broodfish collected for NEFC-Lamar during late April through May from the West Lift of Conowingo Dam on the Susquehanna River. Principal 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 or cholesterol-cellulose implant binders. A more uniform release was obtained from EVAC as compared to the latter two. 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 results were observed by the NEFC when utilizing Luteinizing Hormone-Releasing Hormone analogue (LHRHa) 80 % cellulose implants at doses varying from 15 to 75 ug per fish.

As a result of the tank spawning workshop, two subject areas where modifications were feasible were selected for study: (1) reduction of post-capture handling and transport stress, and (2) hormone implant efficacy. Results of the first study area are included in this report at Job V, Task 2. The second subject area, efficacy of two hormones for inducing spawning is reported below. The highest priority in conducting this phase of the technology work was improving survival until spawning followed by performance evaluations of hormone and tank configurations. Additional observations and a summary of production are also presented.

Relative Efficacy of Two Hormones for Inducing Spawning in American Shad

Survival Until Spawning

During the month of May and first week of June, American shad were removed from the West Lift of the Conowingo Dam and transported 4 to 5 hours to the NEFC. Four hormone trial shipments and one production run are discussed below.

May 02 - (Trial). Several handling and transport considerations were placed into operation as a "best" approach. The NEFC flatbed tank transport unit with four 400 gal. circular tanks was operated in a flow through mode with ambient river water as American shad were collected. Upon removal from the West Lift sorting bin, shad were placed in a hopper and anesthetized with 5 mg/l metomidate, and hormone implants were administered to 22 of 30 female and 18 of 69 male shad. Equal numbers and sex ratios of shad, with appropriate hormone treatments, were netted into distribution units to facilitate placement upon arrival at NEFC. Following collection of the load, 4.5 ppt marine salts, 0.25 ppm medomidate as osmotic assist and sedative, respectively, were added to the transport unit which included 1/5th H.P. circulation pumps and 1 liter/min. oxygen supplementation. Transport survival (Figure 1) was determined to be 57 % for both male and female American shad. Presence or absence of hormone implant did not influence mortality rates. Upon arrival shad were distributed by net to three 3,000 gal. circular and one 2,800 gal. cross flow tanks configured together as a portion of a 27,000 gal. freshwater recirculation system which was operated with one water volume exchange per day (Figure 9). On day 7 survival rates were 52 % and 47 % for male and females, respectively.

May 16 - (Trial). Between the May 2 and 13, ambient river water temperatures increased from 60 F to 75 F. In an attempt to ameliorate the initial transport losses of the May 2 trial, protocol was modified by collection of broodstock (97 males, 64 females) on the day prior to transport; holding in flow through tanks at the lift, and utilizing river tempered spring water at 65° F for transport in the NEFC flatbed unit. Marine salts, metomidate sedative, and oxygen were employed during transport as previously described. As opposed to the May 2 trial, hormone implants were administered upon arrival at NEFC. Shad were then placed in the freshwater recirculation system in tanks previously described . Transport survival, 97% male and 83% female (Figure 2), was markedly improved over the May 2 trial; however, all shad died by day 5.

May 20 - (Production). Given the poor survival results obtained utilizing the NEFC transport unit, a production transport delivery to NEFC with 100 American shad was undertaken by Normandeau Associates with a 1000 gal. recirculation system which maintained much stronger flows than the NEFC unit. The shad were collected on the day prior to transport, placed in ambient river water flow through holding tanks at the lift, and transported the following day with marine salts and metomidate. Hormone implants were administered upon arrival to all, and shad were placed in a single 6,000 gal. tank within the freshwater recirculation system. Transport survival was 100 % (Figure 3), but all shad died by day 5. This load represented the only delivery which failed to produce any eggs.

May 30 - (Trial). Protocol for this date was much the same as that of the May 20 trial.

Tanks used were those described for the May 2 delivery. The primary modification on this trial date was that the NEFC recirculation system was converted from freshwater to 3 ppt (2-4 ppt) salinity. This was achieved by adding granular sodium chloride twice daily to the system and reducing the water exchange rate to once per 48 hours. Half of the 38 males and all 62 females received hormone implants upon arrival at NEFC. Transport survival was 100% (Figure 4). Survival to day seven was 97% for males and 48% for females.

June 5 - (Trial). Transport and treatment upon arrival was similar to that described for May 30. Metomidate was not employed during transport and sodium chloride at 5 ppt replaced marine salts used on previous dates. A total of 62 males and 45 females were placed in four 1500 gal. tanks in the NEFC recirculation system which was maintained at 3 ppt salinity as previously described. No losses occurred during transport (Figure 5), and seven day survival was 73% for males and 64% for females.

Average percent survival of American shad during transport when utilizing Normandeau Associates system was greater (100 %) when compared to NEFC experimental unit (78%). Average percent survival of American shad held to day seven at NEFC was greater (71 %) when salinity was maintained at 2 to 4 ppt when compared to fresh water recirculation survival (19 %).

Performance evaluations of hormone and tank configurations

Three lines of investigation were selected with the aim of refining tank spawning culture technology: (1) Assess the effectiveness of Luteinizing Hormone-Releasing Hormone analogue (LHRHa) and Salmon Gonadotropin Releasing Hormone analogue (sGnRHa) hormone implants for inducing tank spawning of American shad; (2) determine whether the use of sGnRHa hormone implants in male AMS improves reproductive success; and (3) test the suitability of cross flow tanks for spawning. <u>*Null hypotheses tested*</u>:

1. When compared to fish (both males and females) implanted with LHRHa, fish implanted with sGnRHa will exhibit no difference in terms of reproductive performance as measured by average number of viable eggs produced per female.

2. Reproductive performance of sGnRHa spawning groups will not be effected by the presence or absence of hormone implants for male fish as measured by average number of viable eggs produced per female.
3. Spawning success of American shad females implanted with sGnRHa as measured by average number of viable eggs produced per female will not reflect differences owing to spawning tank environment - 12 foot circular vs 15 x 5 foot cross flow rectangular tank.

Results

(1) *Both sexes injected with hormone implants - sGnRHa vs. LHRHa* - Both hormones have demonstrated effective timing of maturation onset for various species. Implants of 15 to 75 ug LHRHa as previously used for American shad egg production programs have yielded inconsistent reproductive responses given lack of selective screening of brood from the river, the asynchronous nature of spawning, and stress resulting from handling, transport, and rearing environment . Therefore we tested this hypothesis to determine which implant was more effective at stimulating the shad's reproductive system. Dr. James Powell of Syndel International, Inc., Vancouver, British Columbia, provided guidance in selection of application rates of the hormones which were fixed at 150 ug per implant.

Comparative results between these applications were obtained for shipments received on May 16, 30 and June 5, 2000 (Figure 6). The average number of viable eggs produced per female when male and female American shad received sGnRHa was 17,700 compared to 11,800 for LHRHa; t-test analysis did not reveal a treatment difference.

(2) *Both sexes implanted with sGnRHa vs. implants administered to females only* - Observations from 1998 and 1999 tank spawning efforts revealed that for the most part male shad transported from Conowingo Dam were sexually mature in that milt could readily be expressed. Hormone implants retail for as much as $13.00 per dose and represent a significant portion of production costs. We tested this hypothesis to determine whether effective egg production could be obtained without implanting male shad.

Comparative results between these applications were obtained for shipments received on May 2,16, 30 and June 5, 2000 (Figure 7). The average number of viable eggs produced per female when male and female American shad received sGnRHa was 17,700 compared to 13,400 when only females received sGnRHa; t-test analysis did not reveal a treatment difference.

(3) *Females only injected with sGnRHa, circular vs. cross flow tank design* - The Northeast Fishery Center American shad recirculating tank spawning system (Figure 9) utilizes for the most part a variety of circular holding tanks (20, 12, and 10 ft. diameters - 6,000, 3,000, 1,500 gal. respectively) as well as one 15 x 5 ft. cross flow rectangular tank. The 2,800 gallon cross flow tank uses a lateral manifold to inject water across the tank bottom and a lateral discharge along the opposing side for wastes or in this case eggs. Shad behavioral responses in the cross flow tank in terms of orientation have varied from alignment with the currents to corner crowding to wandering. Normal shad orientation within the circular tanks is into the current, although wandering is noted at times.

The influence of these behaviors and tank hydraulics upon reproduction were examined for shipment dates May 2, 16 and 30 (Figure 8). For this comparison females only were implanted with sGnRHa. Average production of viable eggs per female from the circular tanks totaled 13,400 compared to 6,300 for the cross flow design; t-test analysis did not reveal a treatment difference.

Additional Observations

Hormones:

- During the May 2 shipment, no hormone was applied to one tank of American shad and no eggs were produced by this group. No survival benefit from lack of implant was observed.

- Surviving day 13 shad from the May 30 shipment (32 males and 20 females) were injected with LHRHa implants and place into a 20 ft. diameter tank. The shad survived for a number of days but failed to produce viable eggs.

- On the June 5 shipment, ovurellin, a hormone used for maturation of sturgeon in Hungary, was applied to a small group of American shad. Number of viable eggs produced per female was 6,000.

Production (Table 1 provides a summary for the year):

- Approximately 3 million eggs were collected of which 2 million were incubated. Initially eggs collected on May 2 which were smaller than 2.8 mm were discarded owing to previous concerns relative to survivability of resultant fry.

- Viability of the incubated eggs was 83 %.

- Eggs harvested from freshwater were approximately twice the size of those collected from the 2 - 4 ppt saltwater (38,500 / L vs. 80,800 / L).

- In Figures 1, 2, 4 and 5, days when viable eggs were collected are noted by circles in the survival bars. Days which produced the maximum number of eggs for a shipment date were noted by two circles. A shift in peak egg collection from day three to day two was noted when the system moved from freshwater recirculation to that of low salinity. The change was also concurrent with early versus late season broodstock collection.

- Problems were encountered with Gas Bubble Disease which resulted in a large number of fry being lost. Nitrogen gas level of 102.5 % and total gas pressure of 101.3 % were measured in the head box which supplies tempered water to fry rearing tanks (Figure 10). The nature of the problem was intermittent in that it occurred when tanks were lowered to facilitate oxytetracycline (OTC) otolith marking. The reduced pressure resulted in the lethal release of air bubbles within the intestinal track and fins of the fry.

- Approximately 328,000 fry with 200 ppm OTC immersion marks on otoliths (days 3, 6, 9, 15) were stocked into the West Branch of the Susquehanna River.

Table 1: American Shad: Production Summary Year 2000

Shipment Date	Von Bauer (Range)	Size Eggs / Liter	Females	Viable Eggs	Fry Stocked
5/2	95 (85 - 133)	35,700	30	183,000	9,776
5/16	99 (94 - 101)	40,400	64	270,000	
5/30	125 (120 - 158)	80,800	46	584,000	
6/6	125 (113 - 171)	80,800	45	879,000	318,820
Totals			**185**	**1,916,000**	**328,596**

Figure 1. American Shad Survival: Load - Transport - Holding

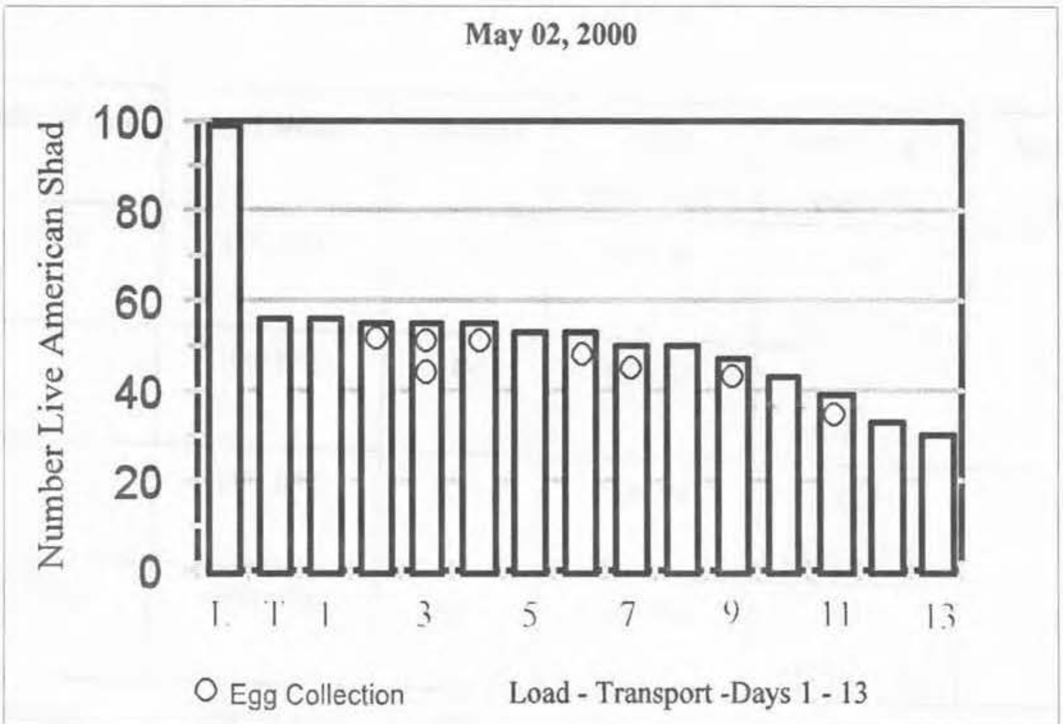


Figure 2. American Shad Survival: Load - Transport - Holding

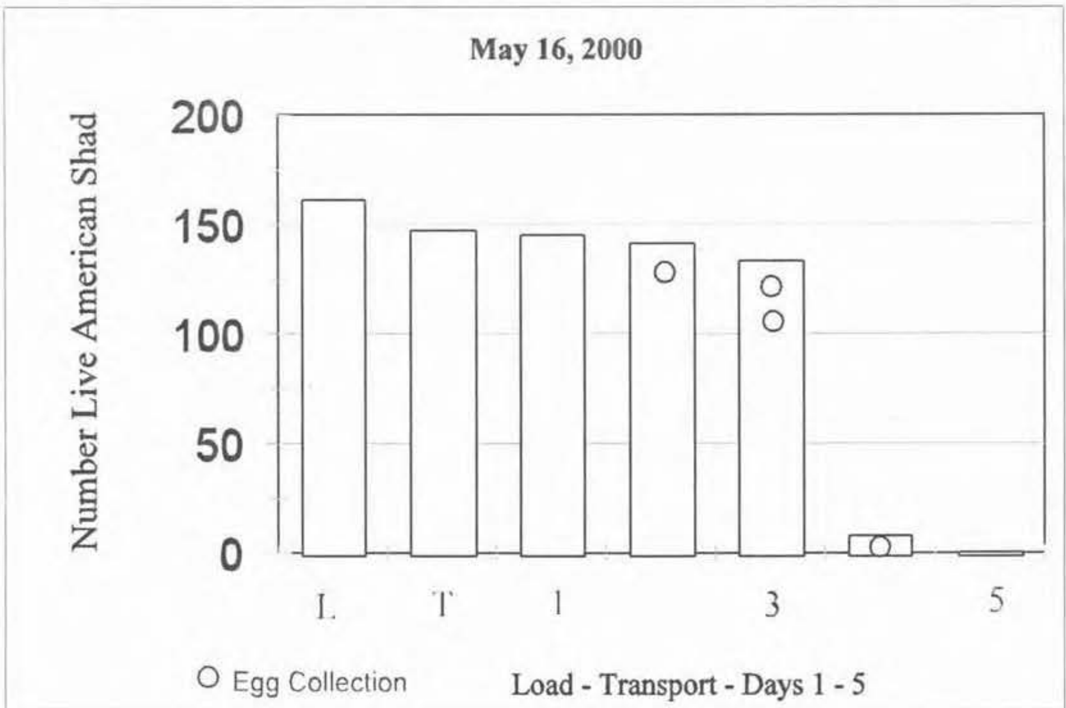


Figure 3. American Shad Survival: Load - Transport - Holding

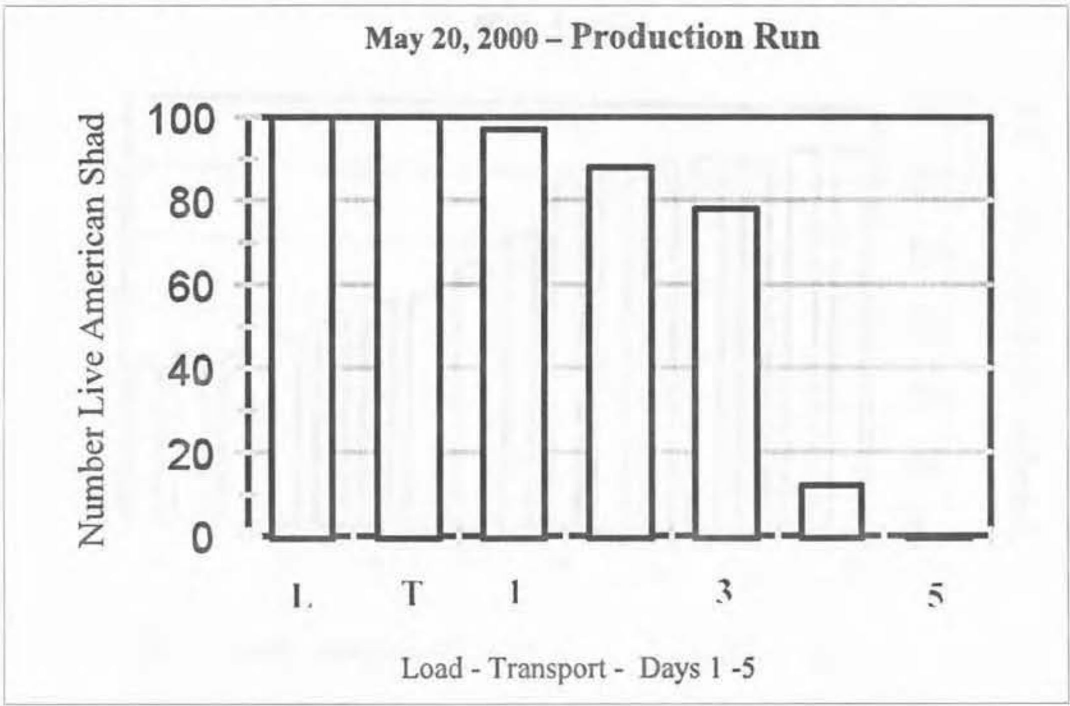


Figure 4. American Shad Survival: Load - Transport - Holding

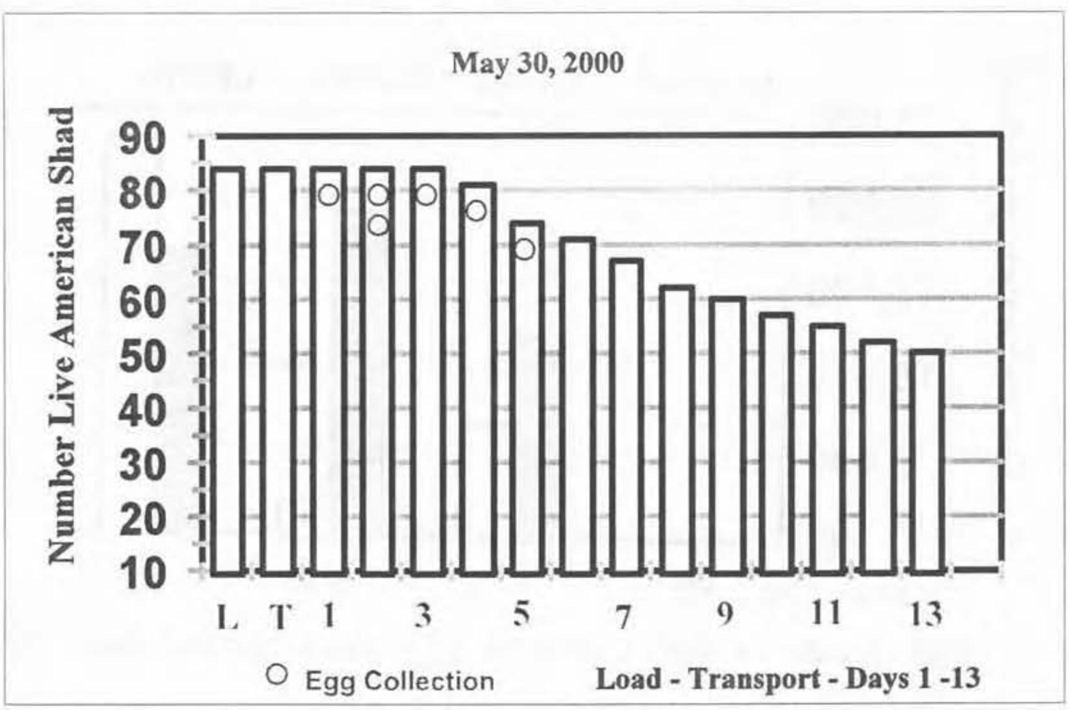


Figure 5. American Shad Survival: Load - Transport - Holding

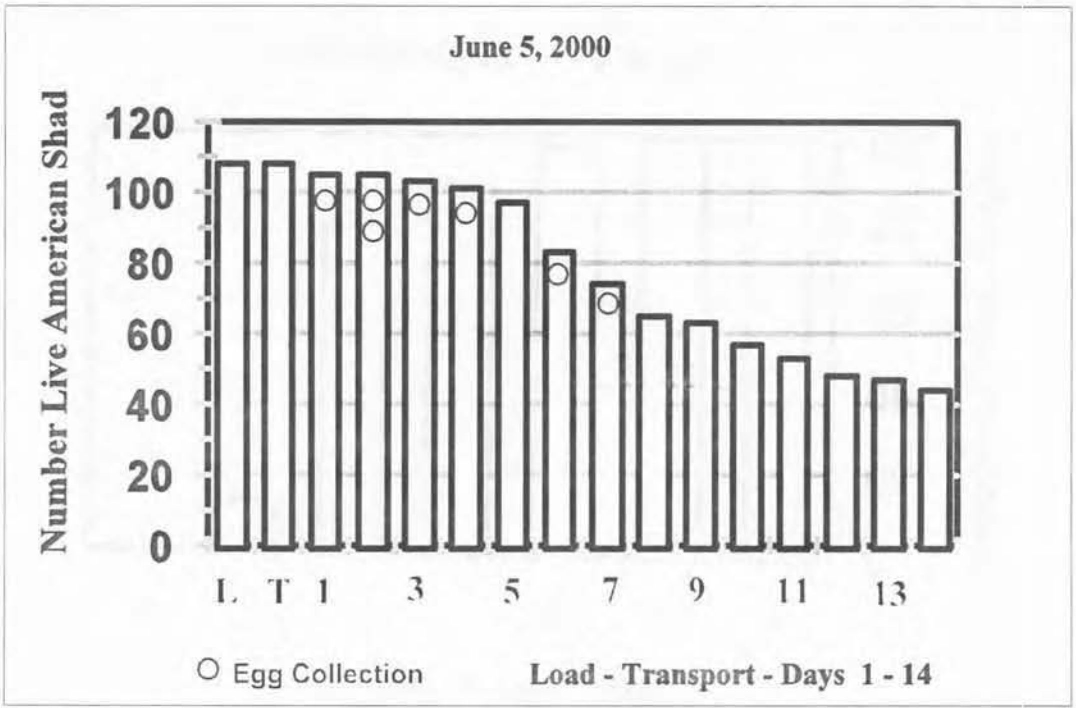


Figure 6. American Shad: Spawning Trial - 1 - Hormone Type

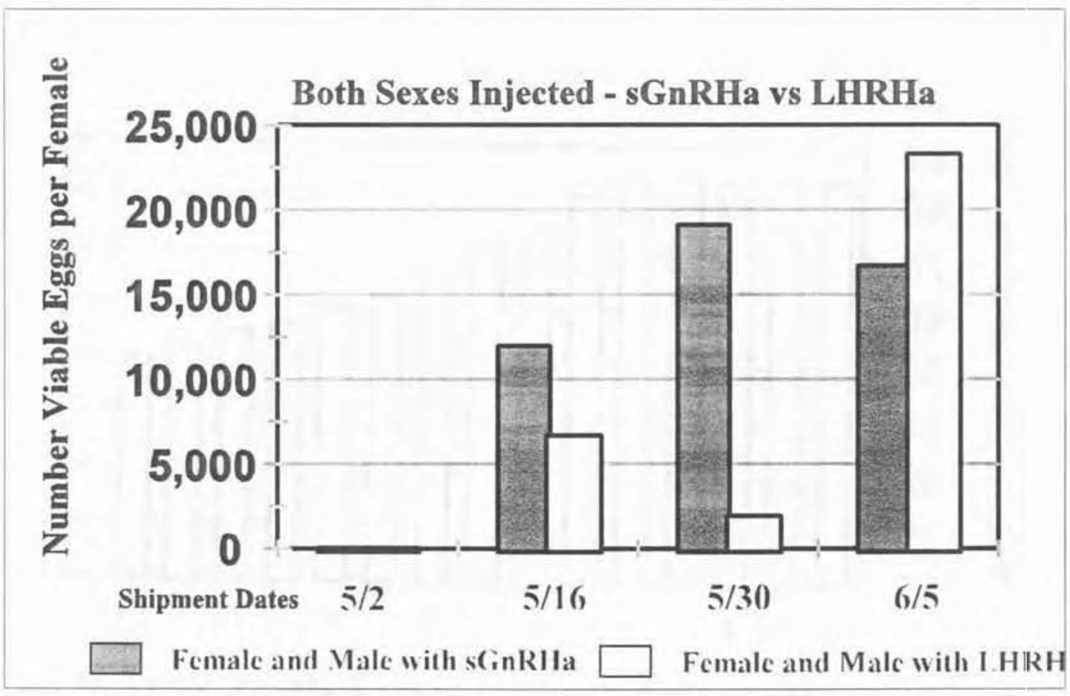


Figure 7. American Shad: Spawning Trial 2 - Male Implants

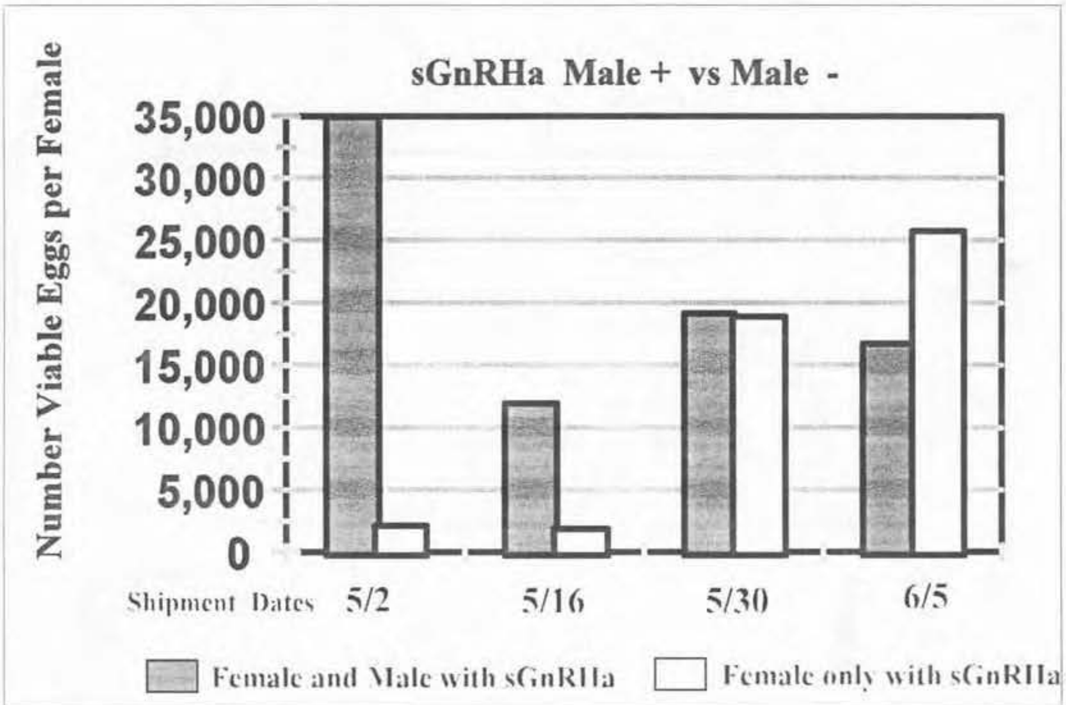


Figure 8. American Shad: Spawning Trial 3 - Tank Design

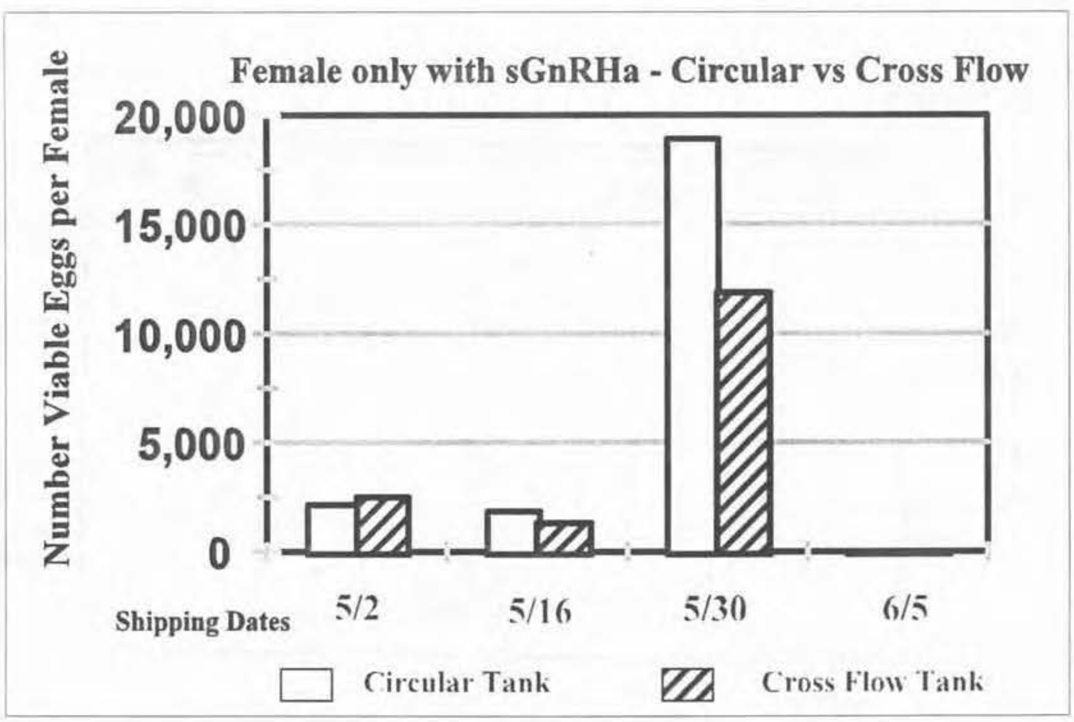


Figure 9. Northeast Fishery Center American Shad Recirculating Tank Spawning System

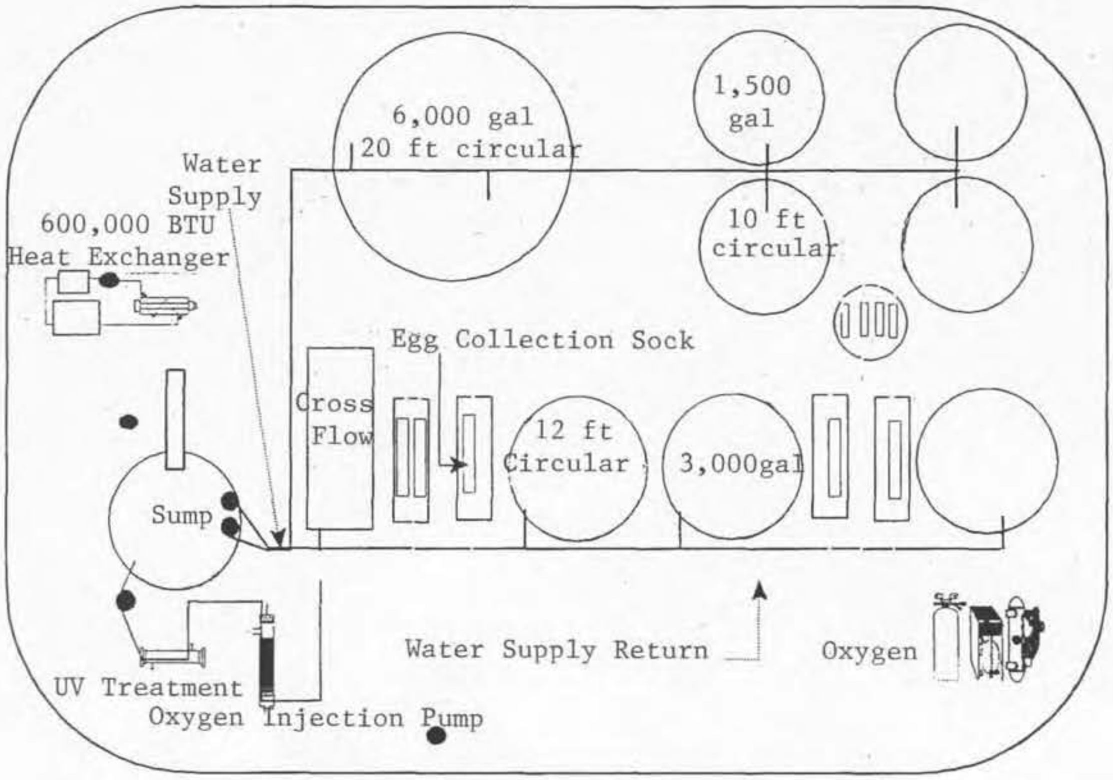
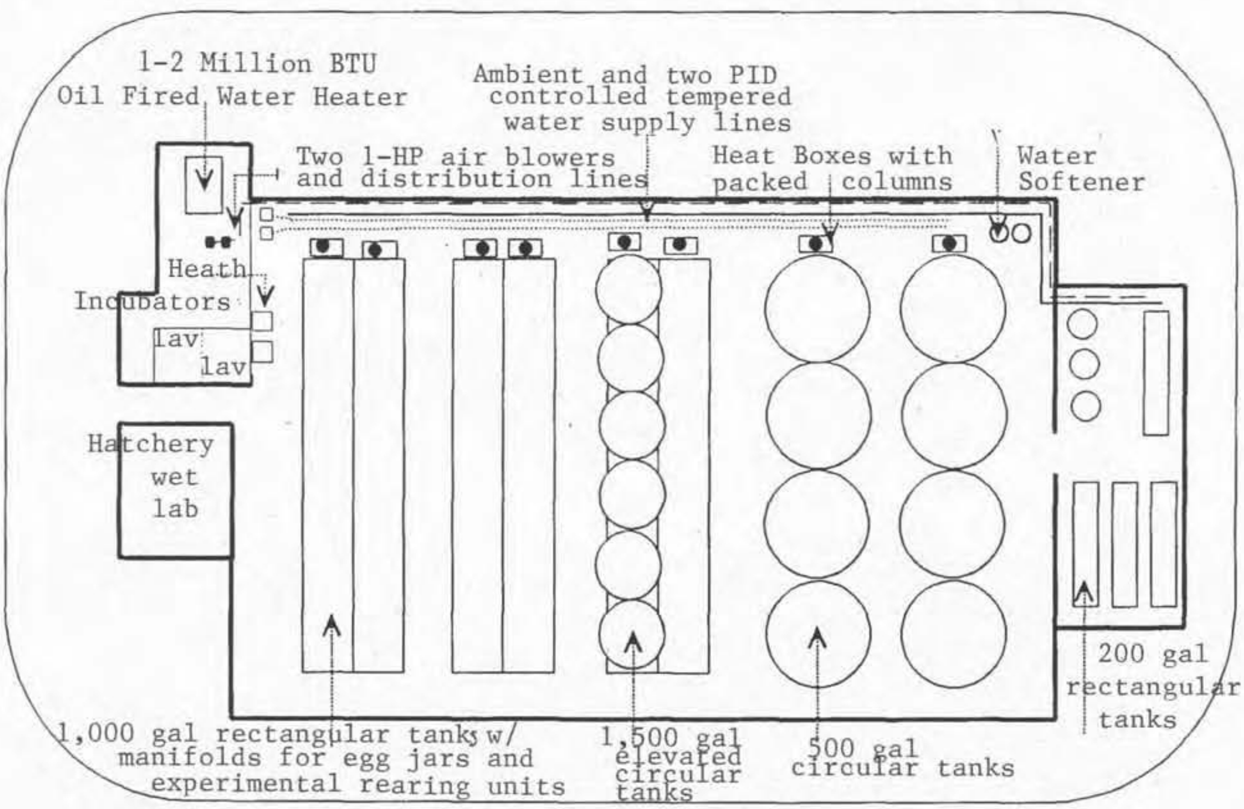


Figure 10. Northeast Fishery Center Hatchery Building



Job V - Task 4. Evaluating Sedation as a Means to Suppress the Stress Response Associated with Handling and Transport of American Shad

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Efforts to restore the American shad population in northeastern United States rivers have been expanding in response to declines in the mid-1900s due to overfishing, pollution, and construction of dams (Atlantic States Marine Fisheries Commission 2000). A component of restoration efforts in the Susquehanna River is the artificial spawning of wild adult fish and stocking of larvae in the upper watershed. Restoration programs that include the use of stocked progeny of wild fish are dependent upon reliably acquiring suitable brood stock and being able to spawn the fish either streamside or in a holding facility. Spawning in a holding facility requires transporting the fish in an efficient and least-stressful manner to minimize broodstock mortality and promote optimal egg production and fertilization rates.

Sedatives have been used to relieve stress in transported fish for many years. McFarland (1960) suggested that anesthesia-induced sedation is "*beneficial in fish transport since it reduces reactivity to disturbances met in transport and the possibility of physical damage and fatigue of fishes. Also it results in deceased oxygen consumption and accumulation of wastes from metabolism.*" Reduced temperature was one of the first 'anesthetics', and was used to successfully air-ship young white sturgeon to Japan in 1963 (Rodman 1963). Several investigations into the efficacy of tricaine methaneosulfonate (MS 222) as a stress suppressing sedative have occurred, with mixed results (Collins and Hulsey 1963; Harrell 1992; Swanson et al. 1996). Valium and quinaldine have also been explored as sedative agents (Murai et al. 1979; Davis et al. 1982; Limsuwan et al. 1983a).

Etomidate, an analog of propoxate, has shown promise for use with fishes (Amend et al. 1982, Guest and Prentice 1982). Metomidate (1H-Imidazole-5-carboxylic acid, 1-(1-phenylethyl)-, methyl ester, monohydrochloride) is an analog of etomidate and is an experimental, non-barbiturate hypnotic agent which has also been used to successfully sedate fish (Ross et al. 1993; Olsen et al. 1995). The use of metomidate in fishes is currently undergoing evaluation under the investigational new animal drug (INAD) process of the U.S. Food and Drug Administration (FDA), and use of metomidate is restricted to the terms of the existing INAD application.

Eugenol (4-allyl-2-methoxyphenol) is the active agent in clove oil and has also recently been used experimentally as an anesthesia for fish (Anderson et al. 1997; Peake 1998; Taylor and Roberts 1999). Eugenol is not currently accepted by the FDA for use as a fish anesthetic, and thus is also restricted to experimental use under existing INAD requirements.

The objective of our study was to examine the efficacy of metomidate and clove oil in suppressing the physiological stress responses associated with handling and transport of American shad. We hypothesized that a light sedation dose of either anesthetic in the transport tank water would suppress the suite of stress responses as monitored by selected blood chemistry variables. In particular, we compared the concentrations of glucose, lactate, K^+ ions, Na^+ ions, and Cl^- ions in the blood of sedated fish versus those of non-sedated, control fish which were otherwise handled and transported identically. We also assessed the temporal trends in physiological stress indicators as fish remained in captivity.

Methods

Source of fish and anesthetics.— American shad were removed from the west fish lift at the Conowingo Dam on the Susquehanna River during each Saturday in May, 2000. The fish lift attracts migrating fish into a channel, crowds the fish into a hopper, and the hopper is elevated and emptied into a 2.5m X 2m metal sorting tank approximately every 45 minutes. American shad were removed from the sorting tank and placed immediately into an anesthesia bath consisting of either 5 mg/l metomidate or 13 mg/l eugenol; this initial anesthesia matched the designated transport sedative each week (Table 1). The anesthesia tank was aerated with oxygen between fish lifts.

Metomidate was procured from Dr. H. Stoddard, Cross City, FL, under the authority and requirements of INAD application #4321. Eugenol, in the form of clove oil, was procured from Sigma Chemical Co., St. Louis, MO. To enhance solubility the eugenol was administered via a stock solution of 5% clove oil and 95% ethanol

Pre-transport baseline blood samples.— After narcosis (2-3 minutes) in the initial anesthesia, randomly selected fish were removed from the anesthesia and sampled for blood to provide a "pre-transport" baseline for blood chemistry parameters. Pre-heparinized syringes fitted with #20 needles were used to withdraw 1 cc of blood from the caudal vein at a point midway between the posterior insertion of the anal fin and the ventral origin of the caudal fin. Samples were placed on wet ice immediately and, within one hour, were centrifuged at approximately 3000g for five minutes. Two 0.5ml aliquots of plasma from each sample were placed in microcentrifuge tubes, kept on dry ice during transport, and stored in a deep freezer (-80° C) until processing. A total of eight "pre-transport" fish were sampled each Saturday. These baseline samples were taken from two fish at a time throughout the work day, from newly captured individuals, such that no fish resided in the anesthesia bath more than 4 minutes waiting for the previous fish to be sampled for blood. This was an attempt to sample only those fish which had not initiated a serological stress response. These fish were euthanized and thus removed from the experiment.

Additional experimental samples for assessing baseline blood chemistry parameters were collected during the May 13, May 20, and May 27 trials. In each case, American shad which had been captured in the fish lift the previous day were immediately placed in a 3.3m circular holding tank located on site at Conowingo Dam. The holding tank received flow-through ambient river water until the following day, when 10 fish were removed and sampled for blood. These samples were designed to assess whether an overnight "calming down" period, subsequent to the crowding and handling associated with capture, resulted in a different balance of blood chemistry parameters when compared to those of fish taken directly from the lift.

Treatment and control blood samples.— Fish not selected to provide "pre-treatment" blood samples were removed from the initial anesthesia after narcosis (2-4 minutes), administered an intramuscular hormone implant (females) or placebo (males), and placed immediately in tanks aboard the experimental transport truck. The transport tanks consisted of four circular 1500 l fiberglass tanks equipped to run on either flow-through or recirculated water. While parked at the fish lift receiving fish, the tanks received flow-through ambient river water. When sufficient fish had been placed in the tanks, or no later than 1600 hr each Saturday, the tanks were taken off flow-through and placed on a tank-specific re-circulating system. Prior to departure from the dam, each tank received ocean salt to bring salinity to 4.5ppt and two designated tanks received the sedative, while the remaining two tanks served as controls and received no sedative. Transport sedative doses consisted of either 0.25 mg/l metomidate or 4.0 mg/l eugenol. On the May 20 trial, all four tanks received the transport sedative (0.25 mg/l metomidate), and no control tanks were available. The treatment schedule and sample sizes are shown in Table 1. Oxygen was bubbled into the re-circulating systems at one l/min. Lids were secured on the tanks and the transport truck was driven approximately 4.5 hours to the Northeast Fishery Center (NEFC), a U.S. Fish and Wildlife Service holding and spawning facility in Lamar PA.

Immediately upon arrival at NEFC, eight randomly-selected American shad from each tank were anesthetized in either 5 mg/l metomidate or 14 mg/l eugenol and sampled for blood as described above. The remaining fish were placed into four 3.1-m diameter, 3,785-l tanks; each holding tank contained fish from a single transport tank. Bled fish were placed in a separate tank and removed from further experimentation. Twenty four hours after arrival at NEFC, up to eight fish from each holding tank were again selected for blood sampling. Anesthesia and blood sampling followed previous protocols. In all, blood samples were taken from 255 American shad.

Blood chemistry was analyzed at the U.S.Geological Survey Conte Anadromous Fish Research Center. Plasma glucose was measured by enzymatic coupling with hexokinase and glucose-6-phosphate dehydrogenase (Stein 1963). Plasma lactate was measured by reduction of nicotinamide adenine dinucleotide with lactate dehydrogenase (Marbach and Weil 1967). Both assays were run using duplicate 10 μl samples on a THERMOmax microplate reader using SOFTmax software (Molecular Devices, Menlo Park, CA., USA) with standard curves in each plate. Plasma sodium, chloride, and potassium were measured with ion-selective electrodes (AVL 9180, Roswell, GA, USA) using external standards.

Plasma cortisol levels were measured by a validated direct competitive enzyme immunoassay as outlined in Carey and McCormick (1998). Microtitre plates were coated with rabbit anti-cortisol antibody. Using a final dilution of 1:16,000 in coating buffer (0.05 M carbonate-bicarbonate, pH 9.6), 150μl were added to each well. Plates were incubated overnight at 4°C and then washed with a 0.15 M NaCl and 0.05% Tween 20 solution in a microplate washer. Plates were pounded dry by inverting them and snapping briskly against a towel. A blocking solution of EIA buffer (0.1 M phosphate, 0.15 M NaCl, pH 7.0, with 0.1% BSA) was added before the addition of 2.5μl of standard or sample (in duplicate) along with 100μl of cortisol-horseradish peroxidase conjugate (horseradish peroxidase linked to cortisol in the 3-position by a carboxymethyloxime bridge). Plates were incubated overnight at 25°C, washed as before and 200μl of 3,3',5,5'-tetramethylbenzidine containing 0.01% hydrogen peroxide was added to each well. Each plate was incubated at 25°C with shaking in a THERMOmax plate reader (Molecular Devices, Menlo Park, CA, USA) until the desired optical density was reached, usually 5-7 min. Then 0.5 M HCl, 50μl/well, was added to stop the color reaction and an endpoint reading was taken at 450 nm. Analysis of standards and samples was done on a 4-parameter logistic curve fit (SOFTmax 2.01, Molecular Devices). Sensitivity as defined by the dose-response curve was 1 to 400 ng/ml. The lower detection limit was 0.30 ng/ml. Using a pooled plasma sample, the average intra-assay variation was 5.5% (n=10) and the average inter-assay variation was 8.8% (n=10).

Data analysis.— Due to the temporally heterogeneous environmental conditions and the likely between–week variation in the physiologic condition of American shad entering the river and being captured at the lift, all analyses were done on a week-specific basis. That is, blood chemistry data from each week were analyzed separately as independent trials. For each trial, transport-related survival was compared for treatment versus control tanks with a chi-square analysis on the counts of dead and alive fish at the termination of the transport process. Blood chemistry parameters among treatment and control samples were compared for pre-transport, arrival, and 24-hour samples with analysis of variance. Chi square was used to test for dependence between sex and mortality rates for each trial. Statistical analyses were performed with SAS software (SAS Institute 1989).

Results

Eugenol.— Within a trial, mean survival during transport was virtually identical among tanks containing 4.0 mg/l eugenol and control tanks containing no sedative (Table 2). Overall mean survival generally increased as the season progressed. Survival during the May 13 and May 27 transport trials was 39.5 % and 96%, respectively. Few statistically significant differences in blood chemistry parameters were observed, either immediately after transport or 24 h after arrival at NEFC. Control fish exhibited a higher glucose level immediately post-transport on May 13 (Figure 1), and also showed a higher lactate level after transport on May 27 (Figure 2). Non-sedated fish also had a higher concentration of K^+ ion 24 h after arrival at NEFC.

Metomidate.— No significant differences in mean transport survival were observed between sedated and control fish during the May 6 trial (Table 2). Sedation with 0.25 mg/l metomidate during the May 6 transport trial provided no detectable difference in blood chemistry parameters, either at arrival or 24hr after arrival at NEFC (Figure 3). A comparison of results from the May 6 trial with those from the May 20 trial, for which no control fish were present, suggests that general the range and trends in physiological stress responses were similar (Figure 3).

Temporal trends.— Within a trial, notable temporal trends existed in key stress indicators. In particular, plasma glucose and lactate concentrations appeared to decrease slightly during transport (Figure 4a). Plasma glucose concentrations then increased markedly after arrival at NEFC, suggesting that fish were not stabilizing after being removed from the transport truck and placed into the receiving tanks (Figure 4a). Both plasma chloride and plasma sodium concentrations decreased after arrival at NEFC, providing further evidence that the fish were not recovering as time in captivity progressed (Figure 4b). Plasma potassium varied without trend.

Overall mortality was high (> 60%) during the first two trials, but decreased to 30% and 3% for the final two trials. With data pooled over treatment and control lots, females exhibited significantly higher mortality ($P < 0.05$) than males during three of the four trials (Figure 5).

Pre-transport holding period.— Fish which were removed from the fish lift and held in an on-site holding tank for 24-h prior to transport did not undergo a "recovery", as evidenced by blood chemistry parameters. To the contrary, these fish exhibited a larger stress signature than did fish just removed from the fish lift. Plasma glucose was higher in the fish held overnight, and plasma Na^+ and Cl^- concentrations were generally lower (Figure 6).

Discussion

Our results suggest that addition of a light sedative dose of eugenol or metomidate to transport tanks did not significantly influence mortality or suppress the serological stress response associated with capture, handling and transport of American shad. Our sedative doses (0.5 mg/l metomidate; 4.0 mg/l eugenol) were chosen based on published and anecdotal information regarding full anesthetic doses for these chemicals (Plumb et al. 1983; Peake 1998; Taylor and Roberts 1999; Ross et al. 1993). While we estimated the doses that might be effective for light sedation, it is possible that our doses did not induce sufficient narcosis to measurably suppress stress responses.

Our fish exhibited apparent slight drop in plasma glucose during the transport process, followed by a dramatic increase after arrival at NEFC. Limsuwan et al. (1983b) noted hyperglycemia and reduced plasma protein in channel catfish sedated with 0.6 mg/L etomidate, although they reported that plasma glucose levels returned to normal after 48 h of exposure. Our fish did not show any recovery during the one trial on which a 72h sample was analyzed. The plasma glucose levels in this study exhibited similar values and a similar pattern of increase as those reported by May and Koch (1991), who looked at a time series of blood chemistry from unsedated American shad captured and transported from Conowingo Dam (Figure 7). The plasma chloride levels observed by May and Koch (1991) are also very similar in magnitude and pattern to our results (Figure 7). This congruence may be a result of our sedative doses being insufficient for suppressing stress symptoms.

The transported fish in this study were effectively stressed to a point from which they did not recover. The specific event or procedure which initiated the physiological decline is difficult to identify. Glucose levels appeared to decrease during the transport process, and then increase dramatically after arrival at the holding facility. Hyperglycemia in fishes can result from increased physical activity in response to a disturbance (Nakano and Tomlinson 1967) or as a secondary response to some stressor, such as hypoxia or handling (Mazeaud et al. 1977). Plasma chloride levels decreased somewhat during transport, but the decline sharpened after arrival at NEFC. We hypothesize that the cumulative impacts of capture, handling, transport, and confinement on American shad results in a fatal progression of stress-related effects, e.g. impaired osmoregulatory function, depressed immunological functions, fungal attacks, and ultimately death. Females appeared to be more susceptible to stress-induced mortality, possibly due to elevated initial physiological stress levels associated with gonad maturation and migration demands.

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Table 1. Sedation treatment schedule and number of fish sampled for blood. met = metomidate; cl = clove oil/eugenol. * designates no control fish were present in this trial. Metomidate dose = 0.5 mg/l; eugenol dose = 4.0 mg/l.

				Arrival at NEFC		24-hour after arrival	
Trial	Transport date	Sedative	Pre-transport	with sedative	without sedative	with sedative	without sedative
1	May 6	met	10	16	16	13	10
2	May 13	cl	10	15	16	8	5
3	May 20	met	10	32	0*	32	0*
4	May 27	cl	10	16	16	11	9

Table 2. Survival during transport of sedated and non-sedated (control) American shad. met = metomidate; cl = clove oil/eugenol. * designates no control fish were present in this trial. Metomidate dose = 0.5 mg/l; eugenol dose = 4.0 mg/l.

			DO (mg/l)		No. fish transported		Mean survival during transport (%)	
Transport date	Sedative	Water temp C	dam departure	NEFC arrival	with sedative	without sedative	with sedative	without sedative
May 6	met	17.8	10.8	11	70	69	44.3	39.2
May 13	cl	24.1	5.3	10.6	58	53	39.6	39.5
May 20	met	20.0	8.0	6.7	161	*	73.3	*
May 27	cl	18.2	9.4	15.5	27	28	96.2	96.2

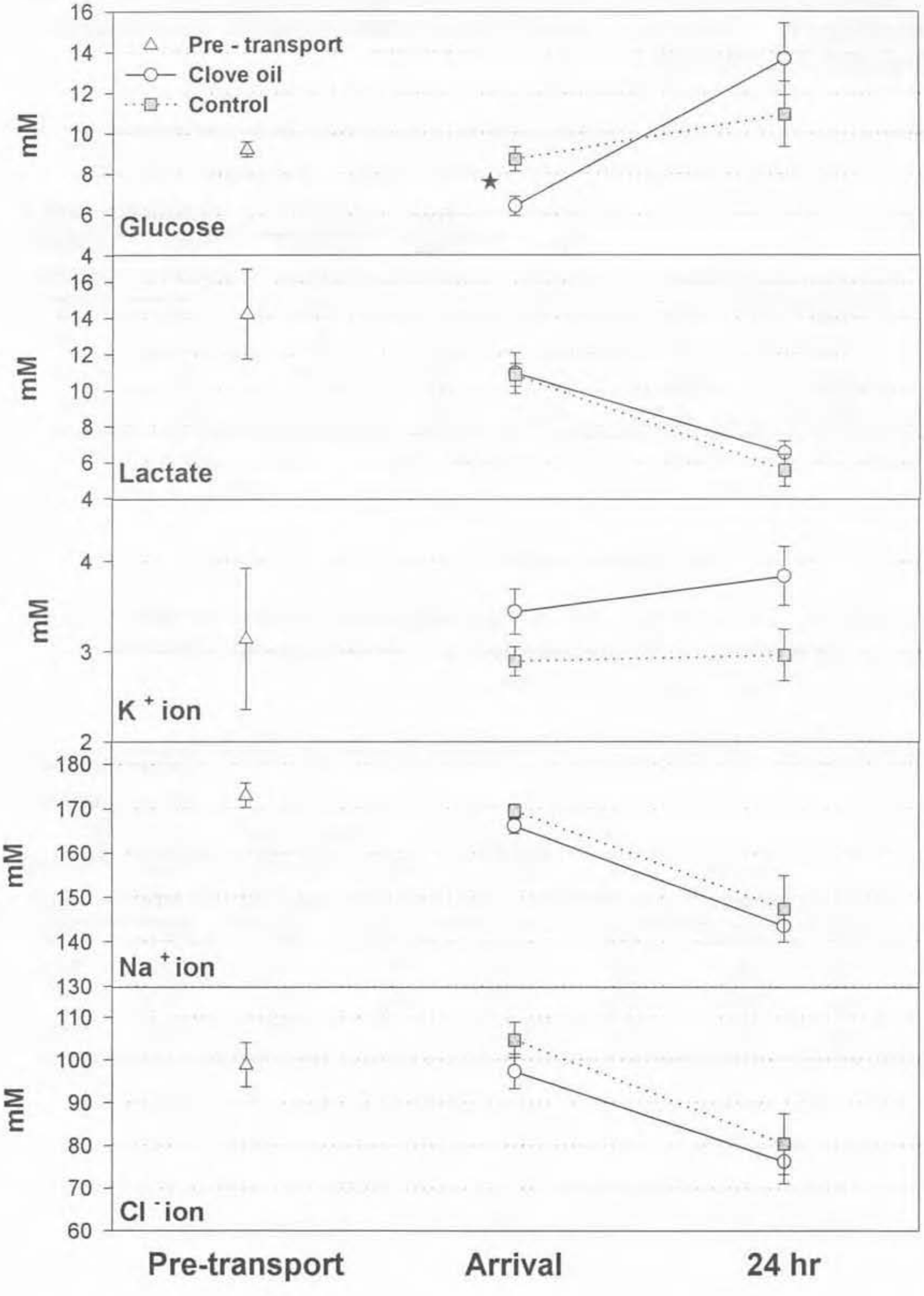

Figure 1. May 13-14 trial. Concentrations of blood chemistry variables in American shad before and after transport with sedative (clove oil) and without sedative (control).

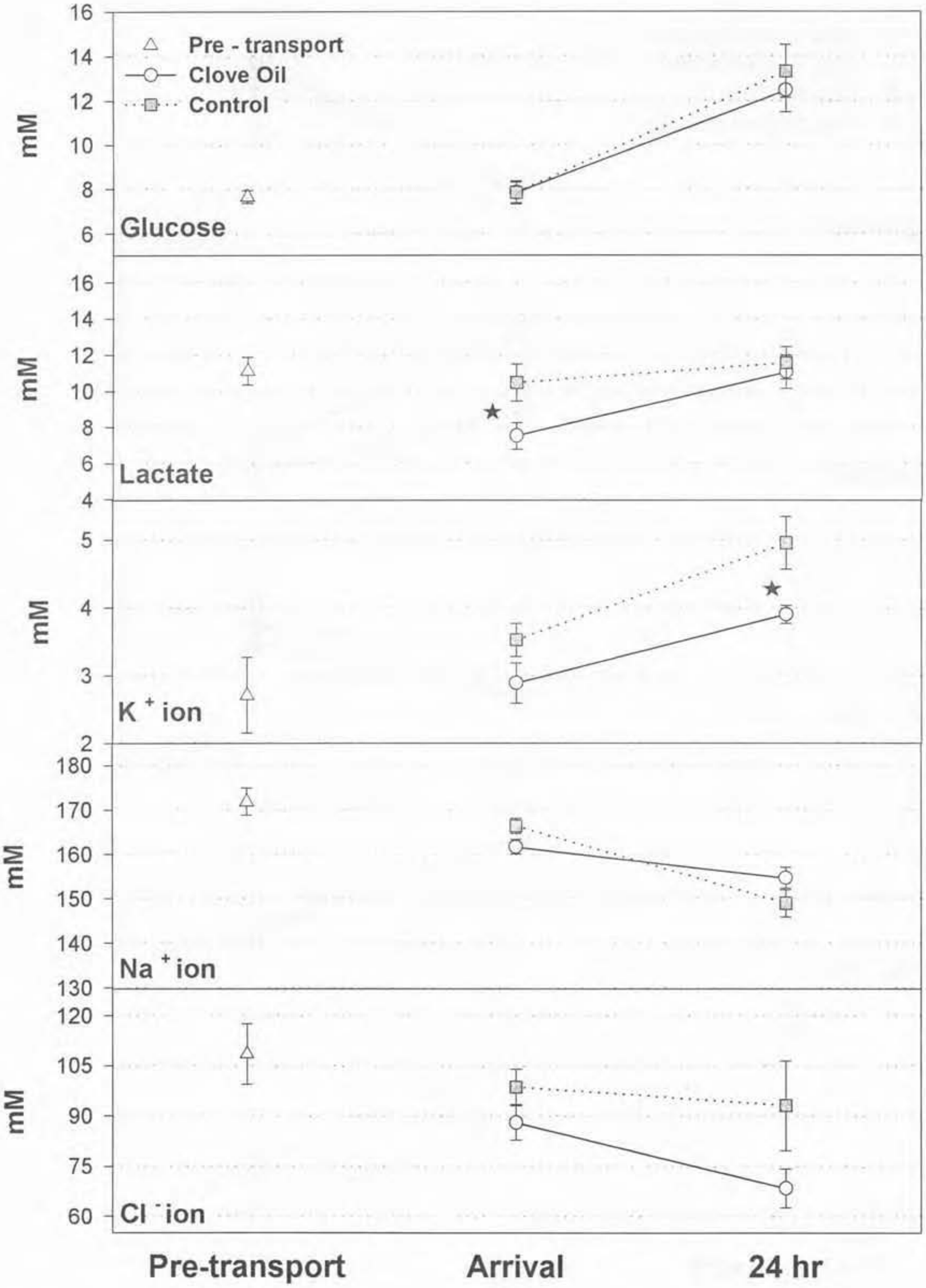

Figure 2. May 27-28 trial. Concentrations of blood chemistry variables in American shad before and after transport with sedative (clove oil) and without sedative (control).

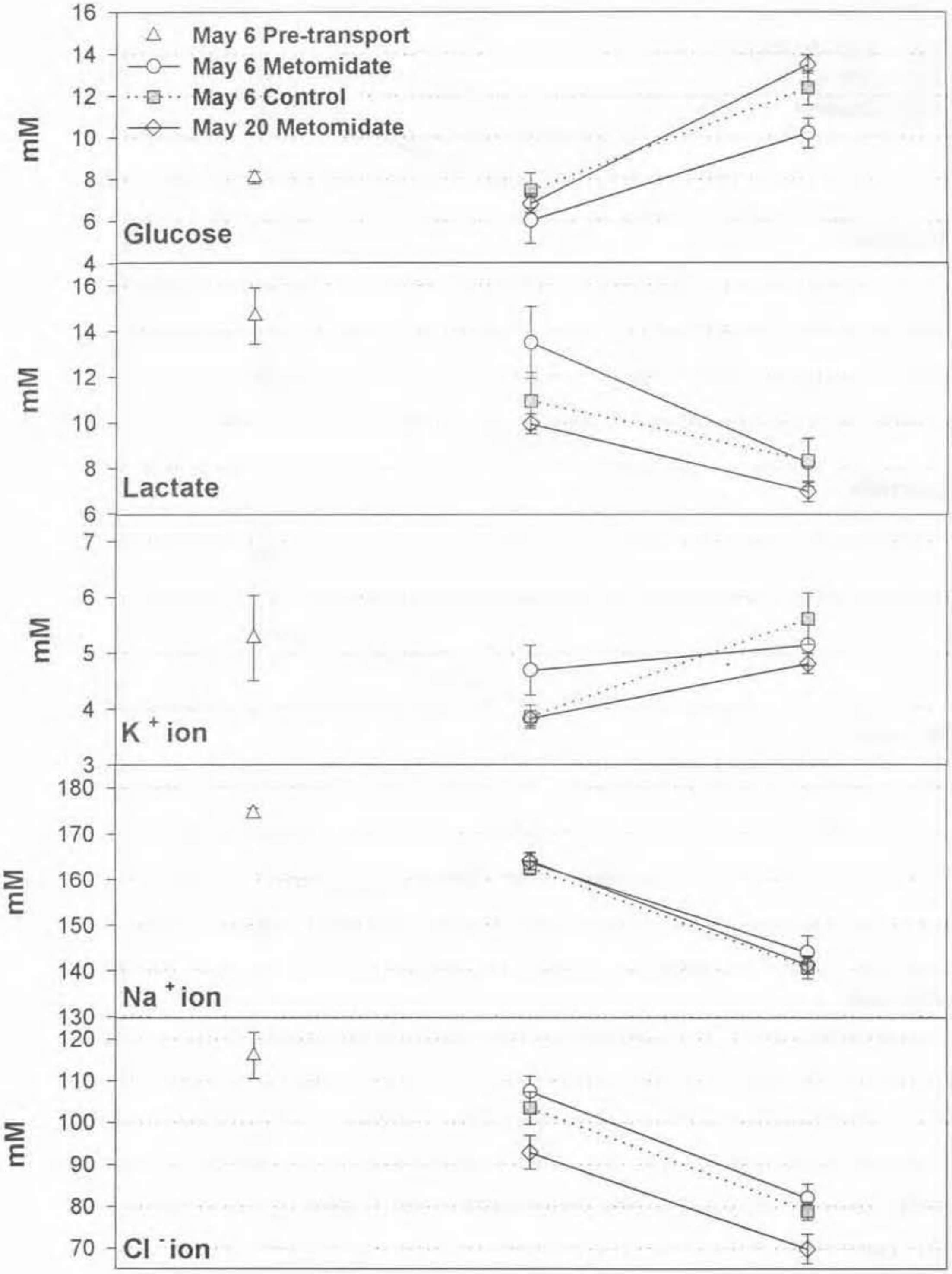

Figure 3. May 6-7 trial. Concentrations of blood chemistry variables in American shad before and after transport with sedative (metomidate) and without sedative (control).

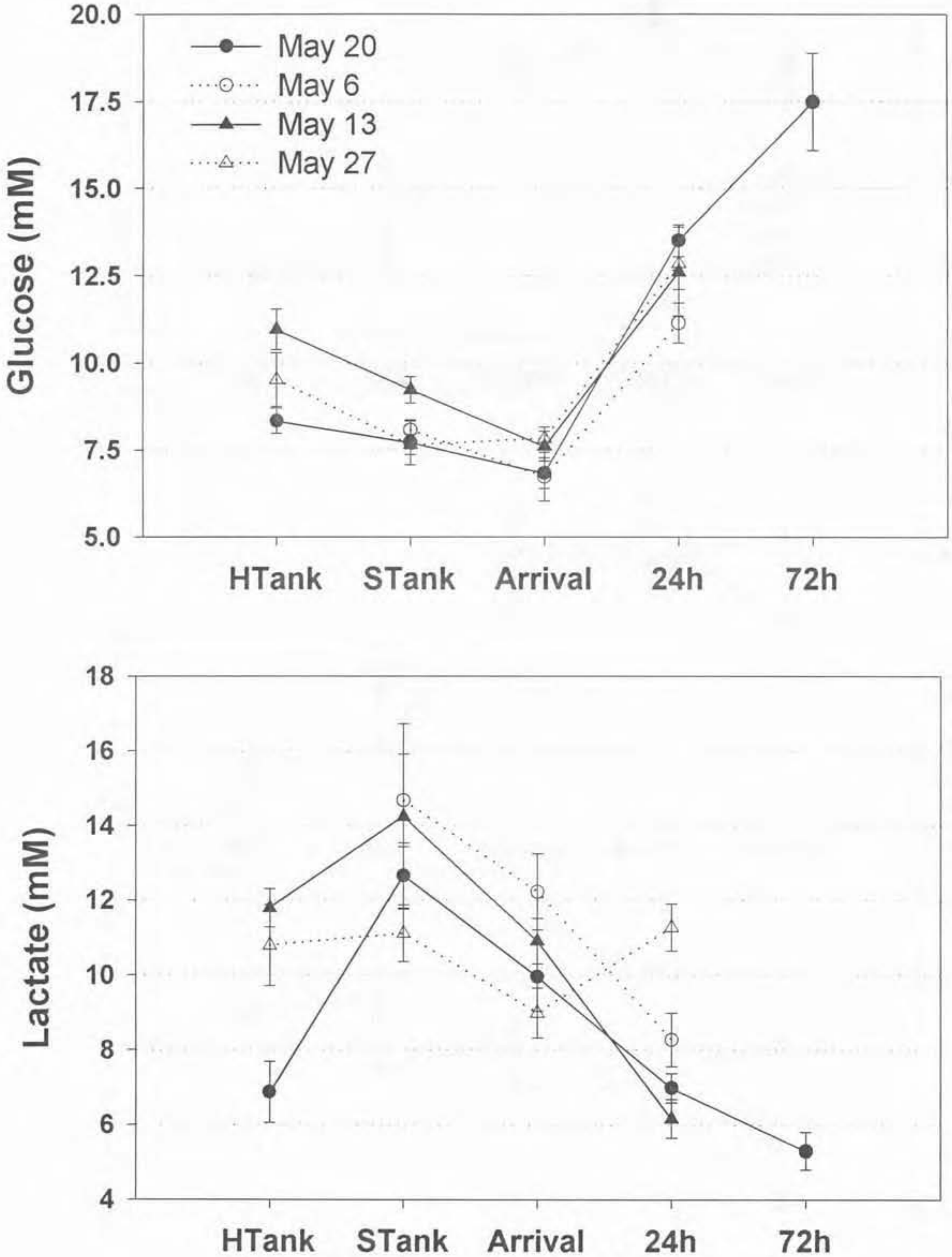

Figure 4a. Temporal trends in concentrations of blood chemistry variables in American shad before and after transport. Data pooled over control and sedated units.

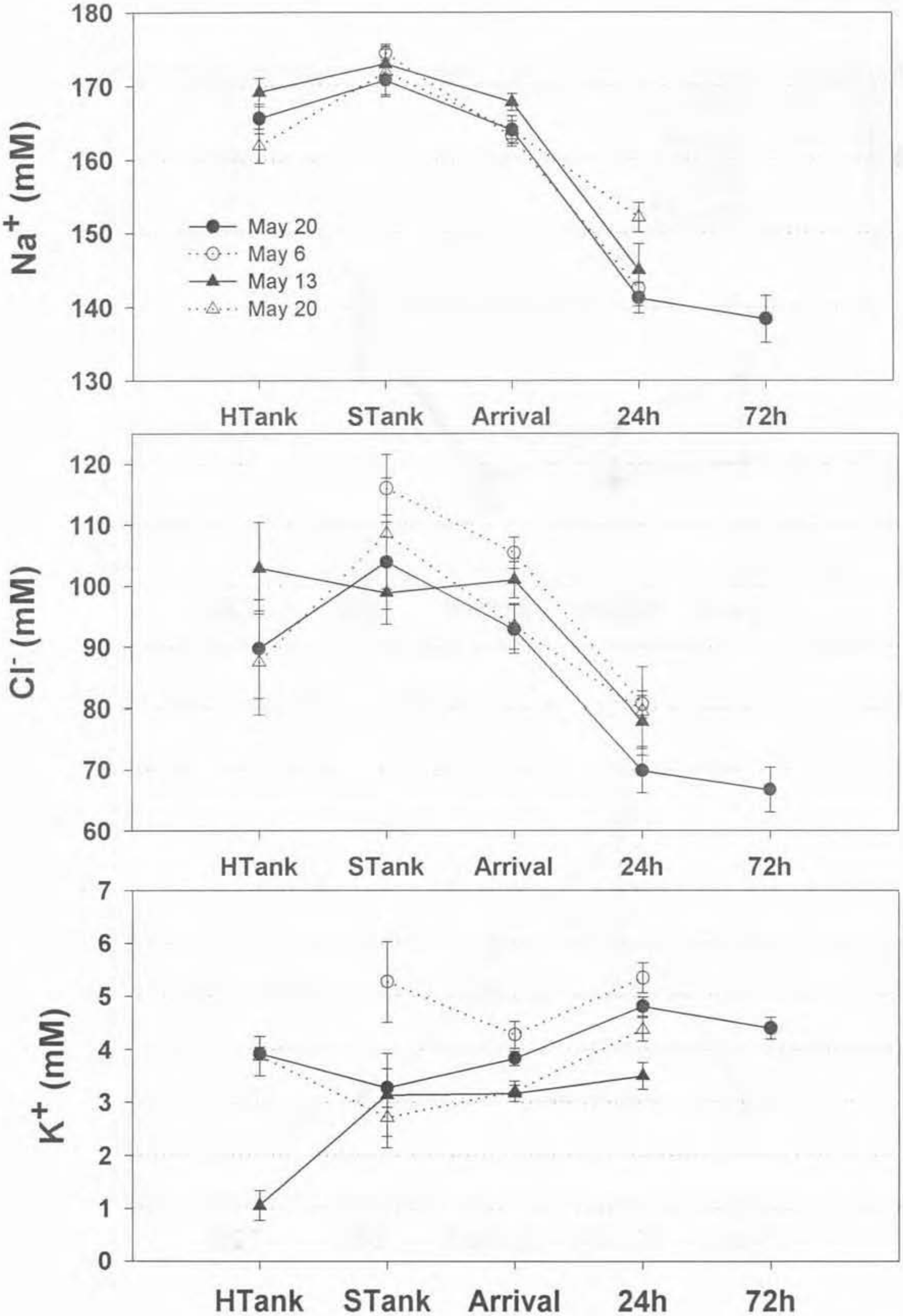

Figure 4b. Temporal trends in concentrations of blood chemistry variables in American shad before and after transport. Data pooled over control and sedated units.

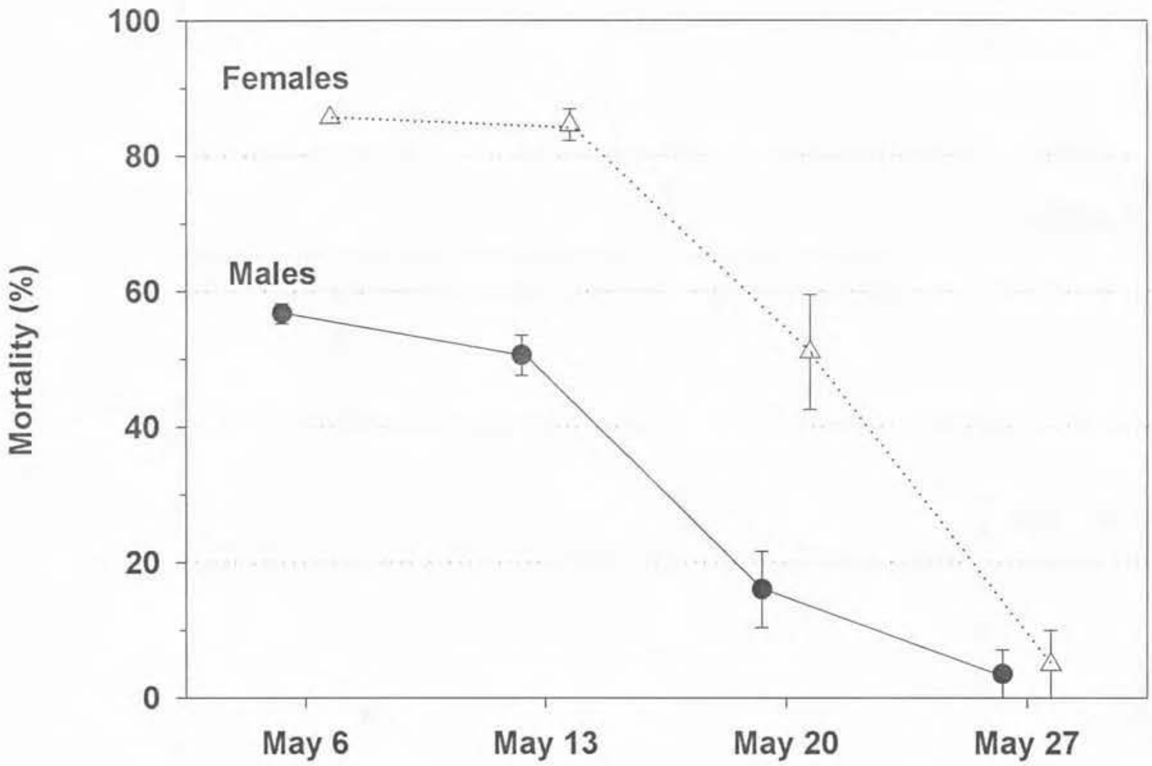

Figure 5. Overall mortality, by sex, of American shad during and after transport. Data pooled over control and sedated units.

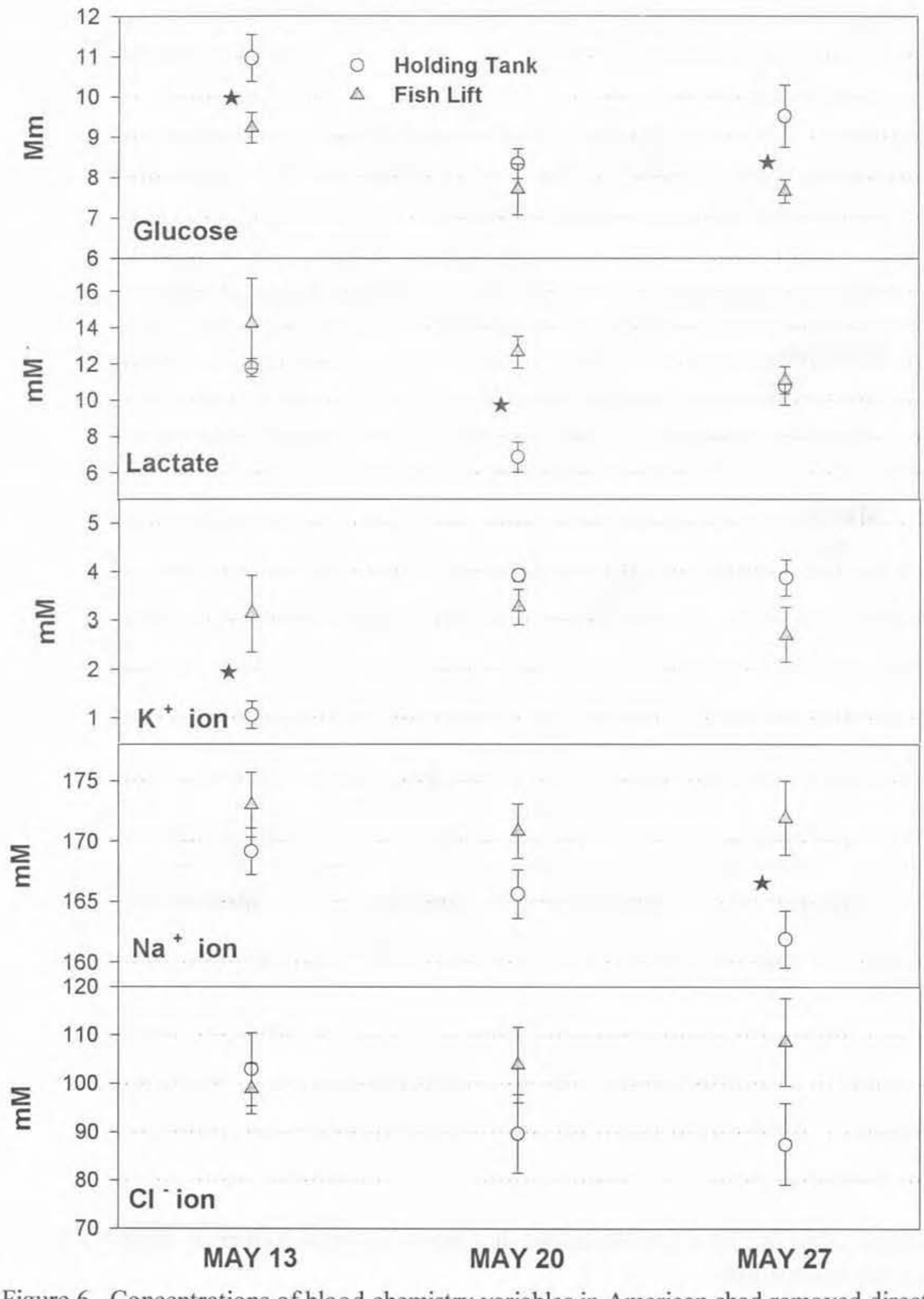

Figure 6. Concentrations of blood chemistry variables in American shad removed directly from fish lift and from American shad removed from lift and held overnight at Conowingo Dam site.

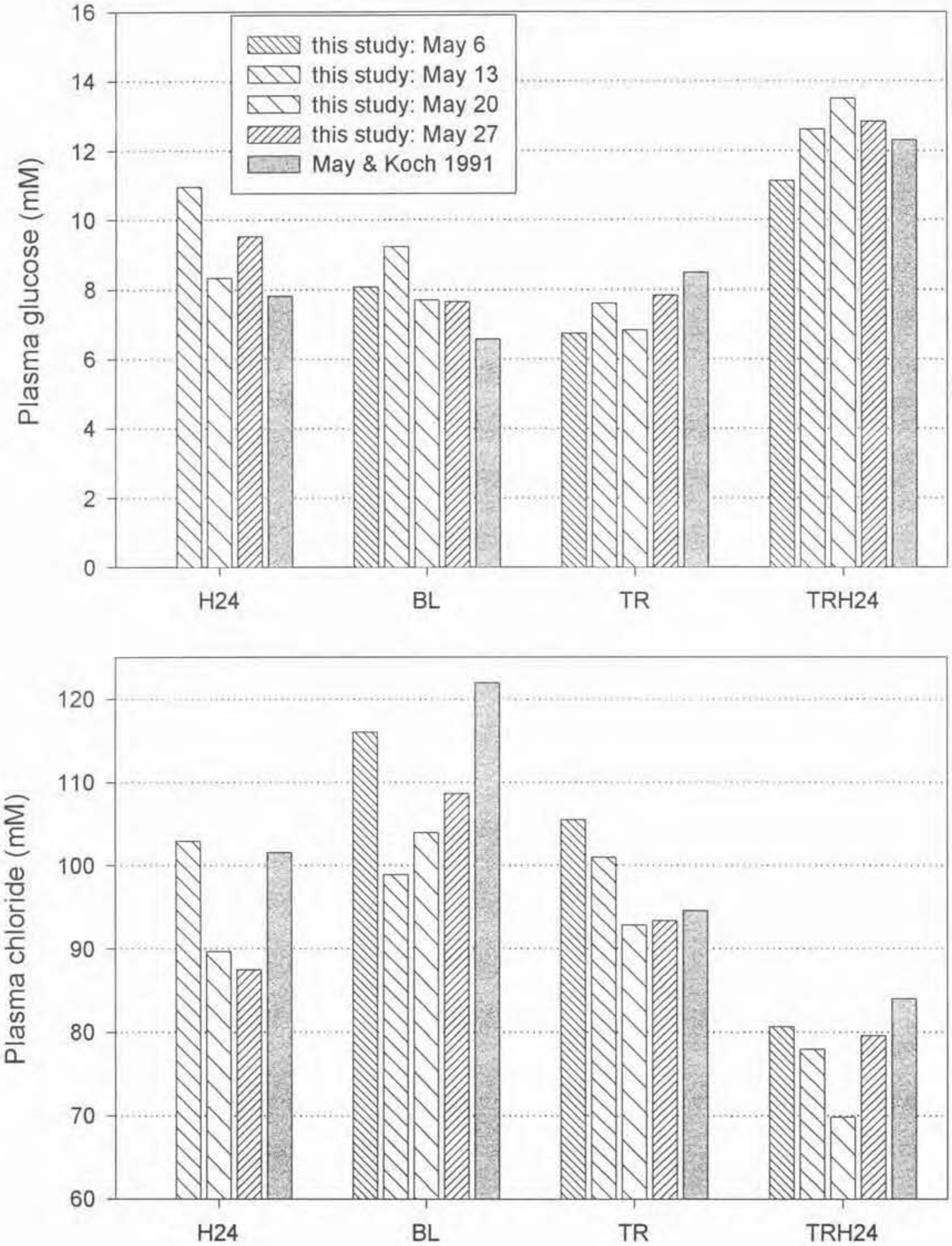

Figure 7. Temporal trends in concentrations of blood chemistry variables in American shad from this study and earlier study by May and Koch (1991). Data for this study are pooled over control and sedated units.

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

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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 2000 were identical to those of 1999 as two pound nets (one in Aberdeen Proving Ground, one in the Susquehanna Flats) were fished (Figure 1). Hook and line sampling in the Conowingo tailrace, however, remained unchanged from 1999. Tagging procedures in 2000 were also unchanged from 1999 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 for 2000 began on 30 March and continued until 11 May, while hook and line effort commenced on 1 May and ended 22 May. Of the 1,861 adult American shad captured, 1,092 (59%) were tagged and 128 (12.0%) subsequently recaptured (Table 1). Recapture data for the 2000 season is summarized as follows:

128 fish recaptured by the Conowingo Fish Lifts

0 fish recaptured by pound net

4 fish recaptured by anglers from the tailrace

0 post-spawned fish recaptured outside the system

6 1999 marked fish recaptured

The 128 recapture total used to calculate the two population indices does not reflect the six fish marked in 1999 and subsequently recaptured or the four tagged fish angled by sport fishermen from the Conowingo tailrace.

The 2000 adult American shad Petersen population index for the upper Chesapeake Bay was 1,357,400 (Table 2, Figure 2), and has been increasing exponentially since 1980 (r^2=0.99, P=<0.01). The Conowingo tailrace population index for 2000 was 957,249 (Table 3, Figure 3), and has also been increasing exponentially since 1984 (r^2=0.91, P=<0.01). A 3% adjustment for tag loss was included in both calculations.

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, reduce the accuracy of the population indices.

Effort, catch, and catch-per-unit-effort (CPUE) by gear type in the upper Bay during 2000 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 (1980-2000) $r^2 = 0.39$, $P = <0.01$; hook and line (1984-2000) $r^2 = 0.83$, $P = <0.02$; fish lifts (1980-2000) $r^2 = 0.65$, $P = <0.001$ (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=0.72 P=<0.001, r^2=0.86 P=<0.0001, r^2=0.85, P=<0.0001, respectively; Table 5);

* hook and line and fish lift CPUE's were correlated with log e transformed tailrace indices (r^2=0.87 P=<0.0001, r^2=0.83 P=<0.0001, 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 2000 indicating that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay continued in 2000.

A total of 368 adult American shad (194 pound net, 174 hook and line) were examined for physical characteristics by DNR biologists in 2000 (Table 6). The 1996 and 1995 year-classes (ages 4 and 5, sexes combined) were the most abundant age groups sampled in the upper Bay (gears combined), accounting for 51% and 27%, respectively of the total catch (Table 6). Age frequency modes occurred at age 4 for both pound net and hook and line males. Age frequency modes for females occurred at ages 4 and 5 for pound net and age 4 for hook and line catches. Males (gears combined) were present in age groups 3-7 while females were found in age groups 4-8 and 10. The overall incidence of repeat spawning in male American shad decreased from 11.4% in 1999 to 4.7% in 2000 while female American shad repeat spawning decreased from 26.8% in 1999 to 13.7% in 2000.

Otoliths from 78 expired adult American shad collected from the two upper Bay pound nets during the spring 2000 sampling were extracted by DNR personnel for analysis. Of the 61 readable pairs, 50 fish (82%) were determined to be of wild origin and 11 (18%) from hatchery production.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 2000.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	1,041	329
	Gateway	90	55
	TOTALS	1,131	384
Hook and Line	Conowingo Tailrace	730	708
Fish Lifts	Conowingo Tailrace	163,331	
	TOTALS	165,192	1,092

Table 2. Upper Chesapeake Bay relative population index of adult American shad in 2000 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 2000 survey -

C = 165,192
R = 128
M = 1,059*

Therefore -

$$N = \frac{(165{,}192 + 1)\ (1{,}059 + 1)}{(128 + 1)}$$

= **1,357,400**

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)

$$\text{Upper } N^* = \frac{(165{,}192 + 1)\ (1{,}059 + 1)}{107.66 + 1} = 1{,}611{,}491$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(165{,}192 + 1)\ (1{,}059 + 1)}{152.18 = 1} = 1{,}143{,}129$$ @ .95 confidence limits

M* adjusted for 3% tag loss

Table 3. Conowingo Dam tailrace relative population index of adult American shad in 2000 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 2000 survey -

C = 162,787
R = 116
M = 687*

Therefore -

$$N = \frac{(162,787 + 1)\ (687 + 1)}{(116 + 1)}$$

= **957,249**

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)

$$\text{Upper } N^* = \frac{(162,787 + 1)\ (687 + 1)}{96.72 + 1} = 1,146,113$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(162,787 + 1)\ (687 + 1)}{139.12 + 1} = 799,303$$ @ .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 1980-2000 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*

* 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

* 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*

* 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 (1980-2000), annual Conowingo tailrace Petersen population indices, and geometric mean CPUE's for two gear types (1984-2000) where N = number of years.

GEAR TYPE	PETERSEN POPULATION INDICES UPPER BAY	TAILRACE
Pound Net		
r_p	0.72	NA
N	20	
P	0.001	
Hook & Line		
r_p	0.86	0.87
N	17	17
P	<0.0001	<0.0001
Fish Lifts		
r_p	0.85	0.83
N	20	17
P	<0.0001	<0.0001

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 2000.

	Males				Females			
Age Group	N	Number of Repeats	Mean Length	Length Range	N	Number of Repeats	Mean Length	Length Range
				POUND NET				
III	7	0	337	325-350	0	--	---	---
IV	50	0	378	340-410	35	0	412	390-445
V	25	1	414	315-465	35	1	446	410-480
VI	6	2	443	435-450	26	13	476	415-510
VII	1	1	450	--	7	6	496	475-510
VIII	0	--	--	--	1	1	490	--
X	0	--	--	--	1	1	540	--
				HOOK AND LINE				
III	7	0	351	330-373	0	--	--	--
IV	66	0	383	345-430	37	0	418	380-498
V	6	2	419	390-445	34	0	446	420-478
VI	3	2	453	448-460	16	2	482	462-500
VII	0	--	--	--	4	2	499	485-509
VIII	0	--	--	--	1	1	505	--
				GEARS COMBINED				
III	14	0	344	325-373	0	--	--	--
IV	116	0	381	340-430	72	0	446	410-480
V	31	3	417	315-465	69	1	478	415-510
VI	9	4	449	435-460	40	15	478	475-510
VII	1	1	450	--	11	8	497	475-510
VIII	0	--	--	--	2	2	498	490-505
X	0	--	--	--	1	1	540	--

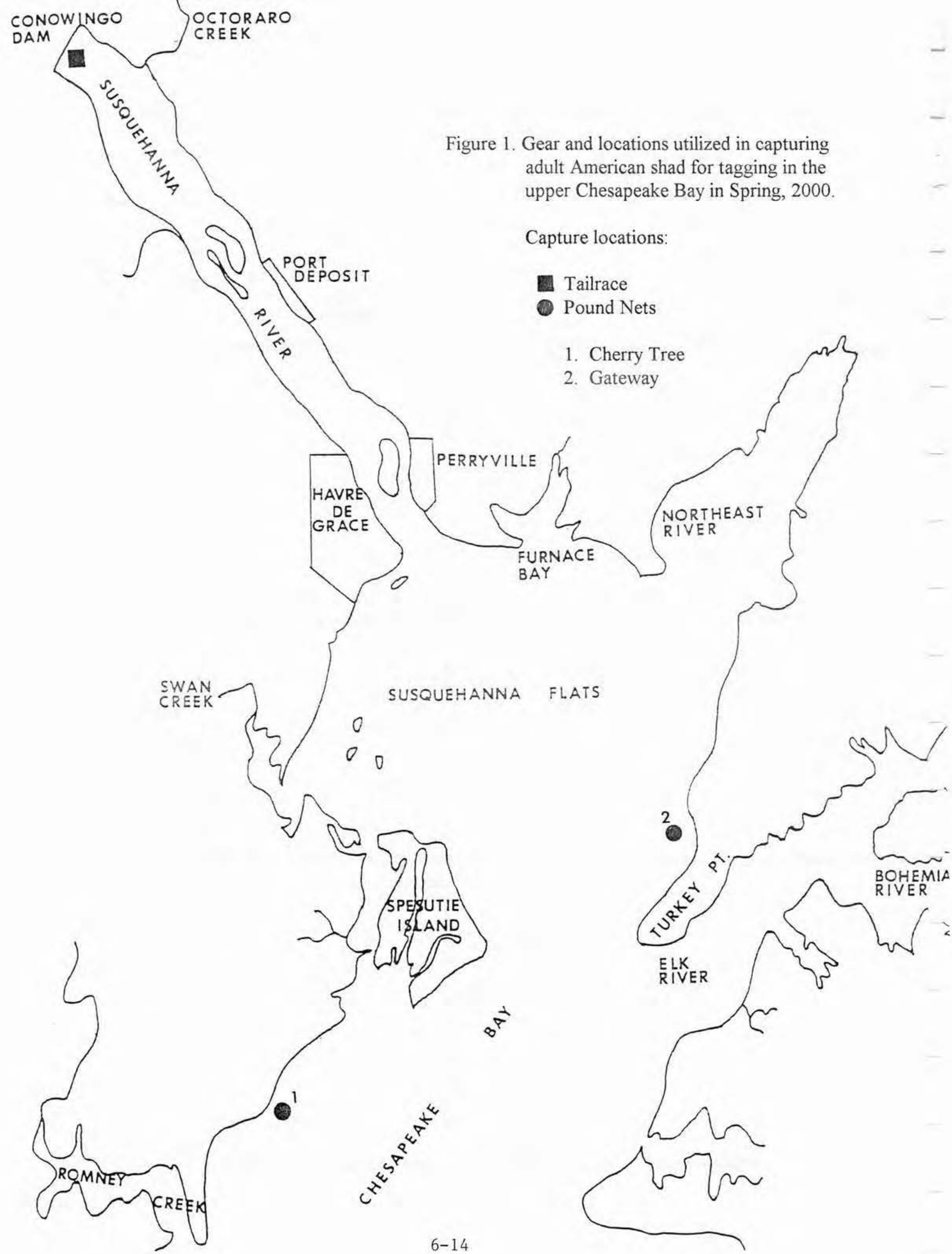


Figure 1. Gear and locations utilized in capturing adult American shad for tagging in the upper Chesapeake Bay in Spring, 2000.

Capture locations:

■ Tailrace
● Pound Nets

1. Cherry Tree
2. Gateway

Figure 2. Upper Chesapeake Bay population indices of American shad, 1980-2000. Bars indicate 95% confidence intervals and numbers above indicate the yearly population index.

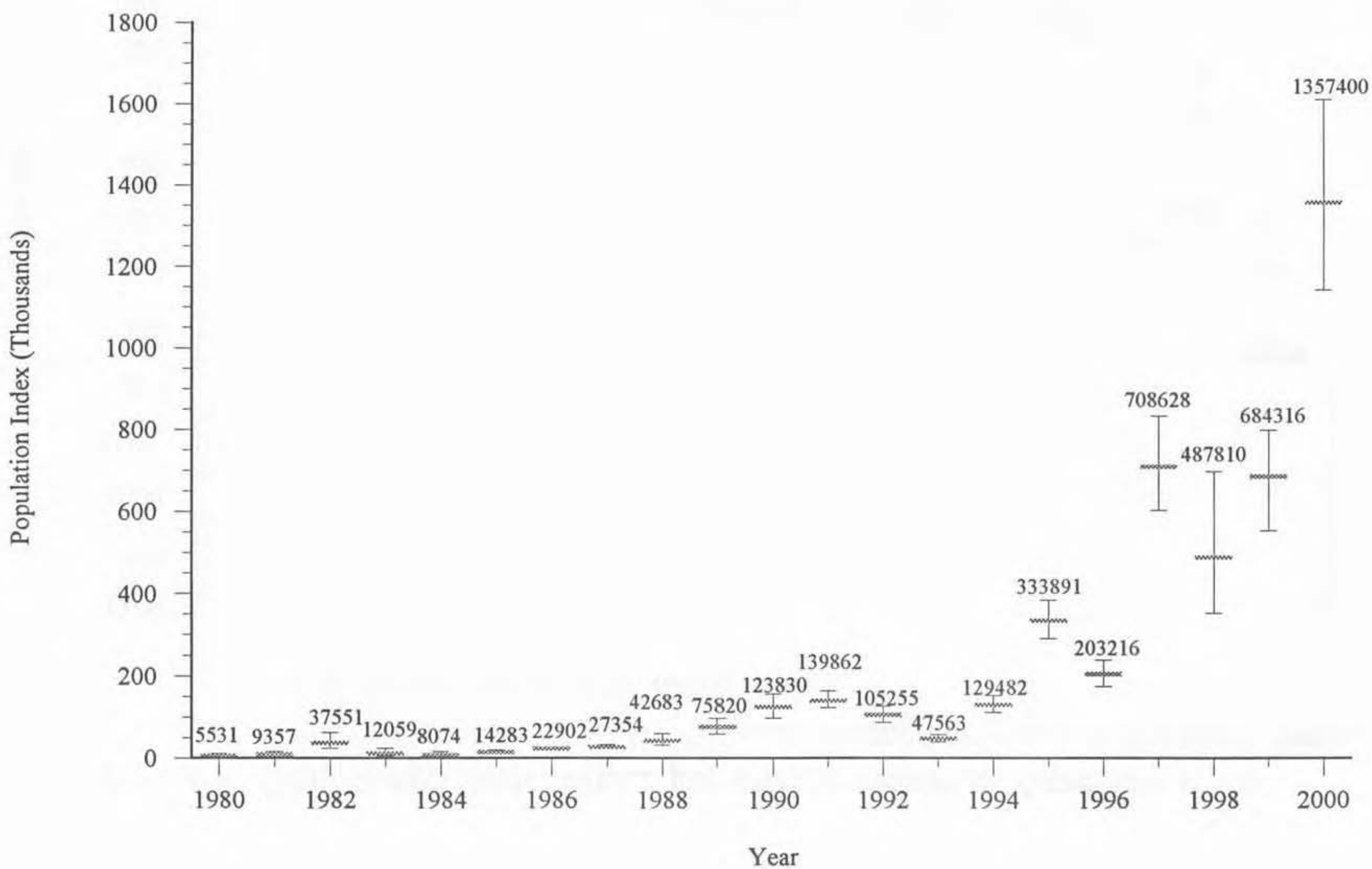


Figure 3. Conowingo Dam tailrace population indices of American shad, 1984-2000. Bars indicate 95% confidence ranges and numbers above indicate the yearly population index.

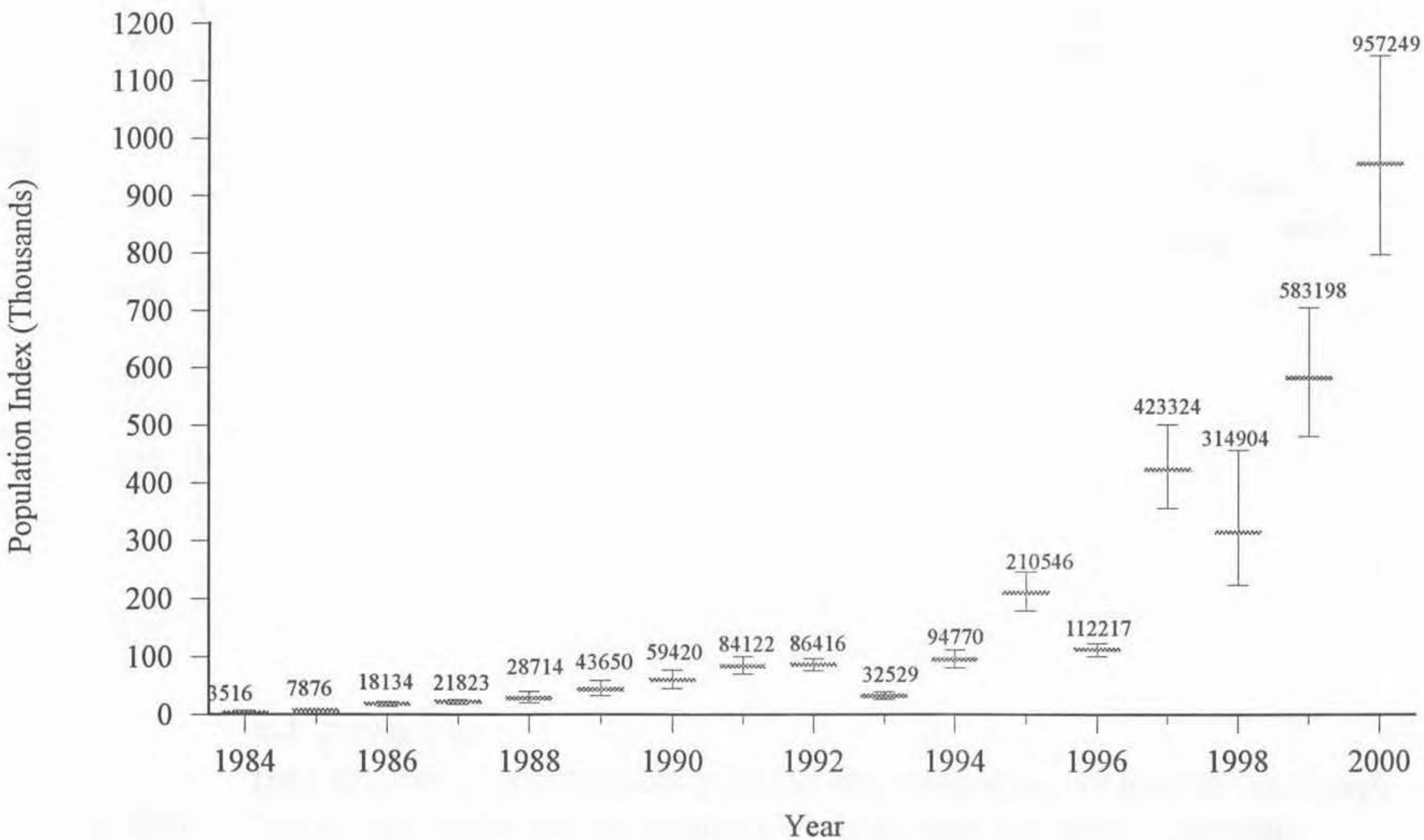
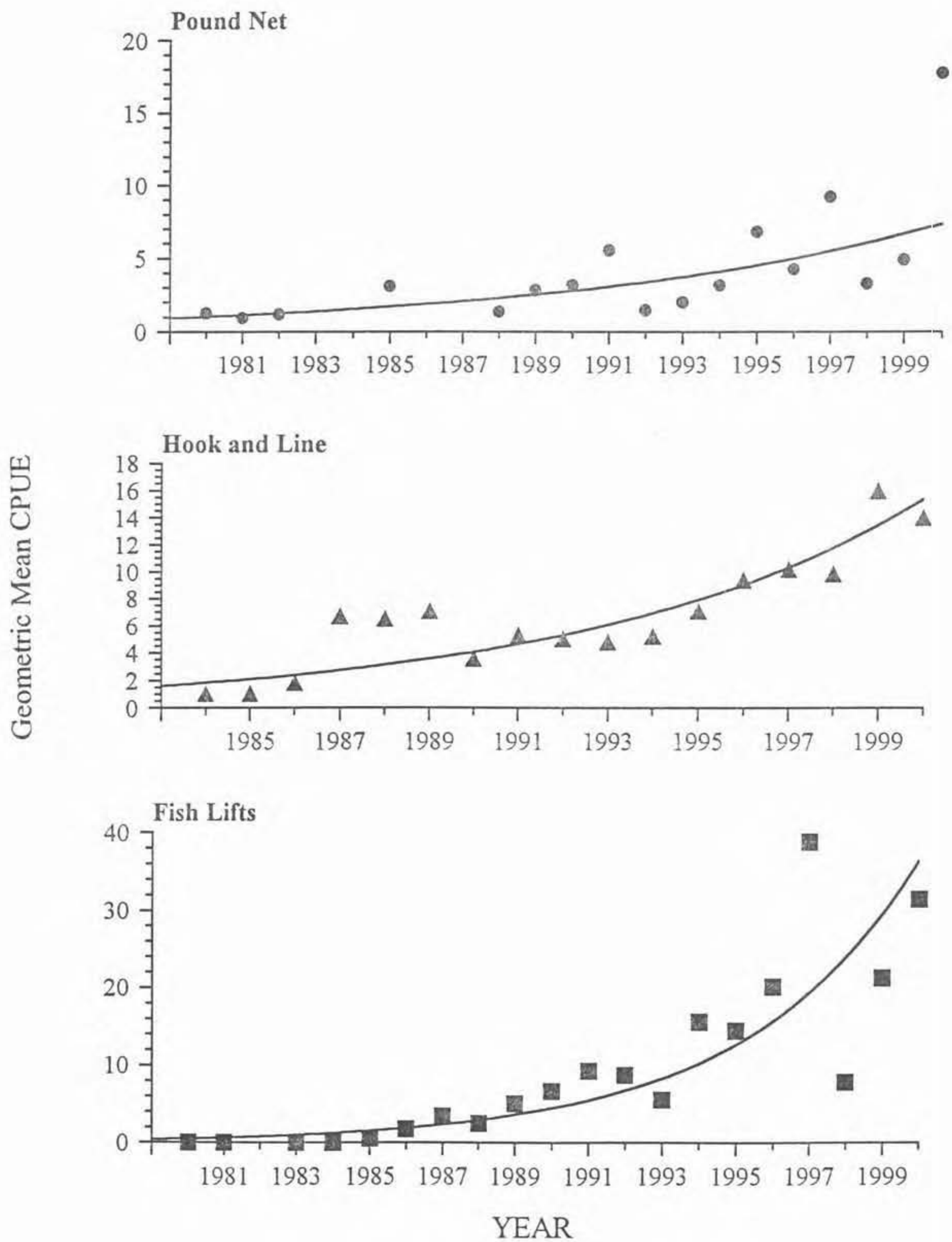


Figure 4. Regression analysis of geometric mean catch-per-unit-efforts (CPUEs) of American shad sampled by pound net, hook and line and Conowingo fish lifts in the upper Chesapeake Bay, 1980-2000.



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