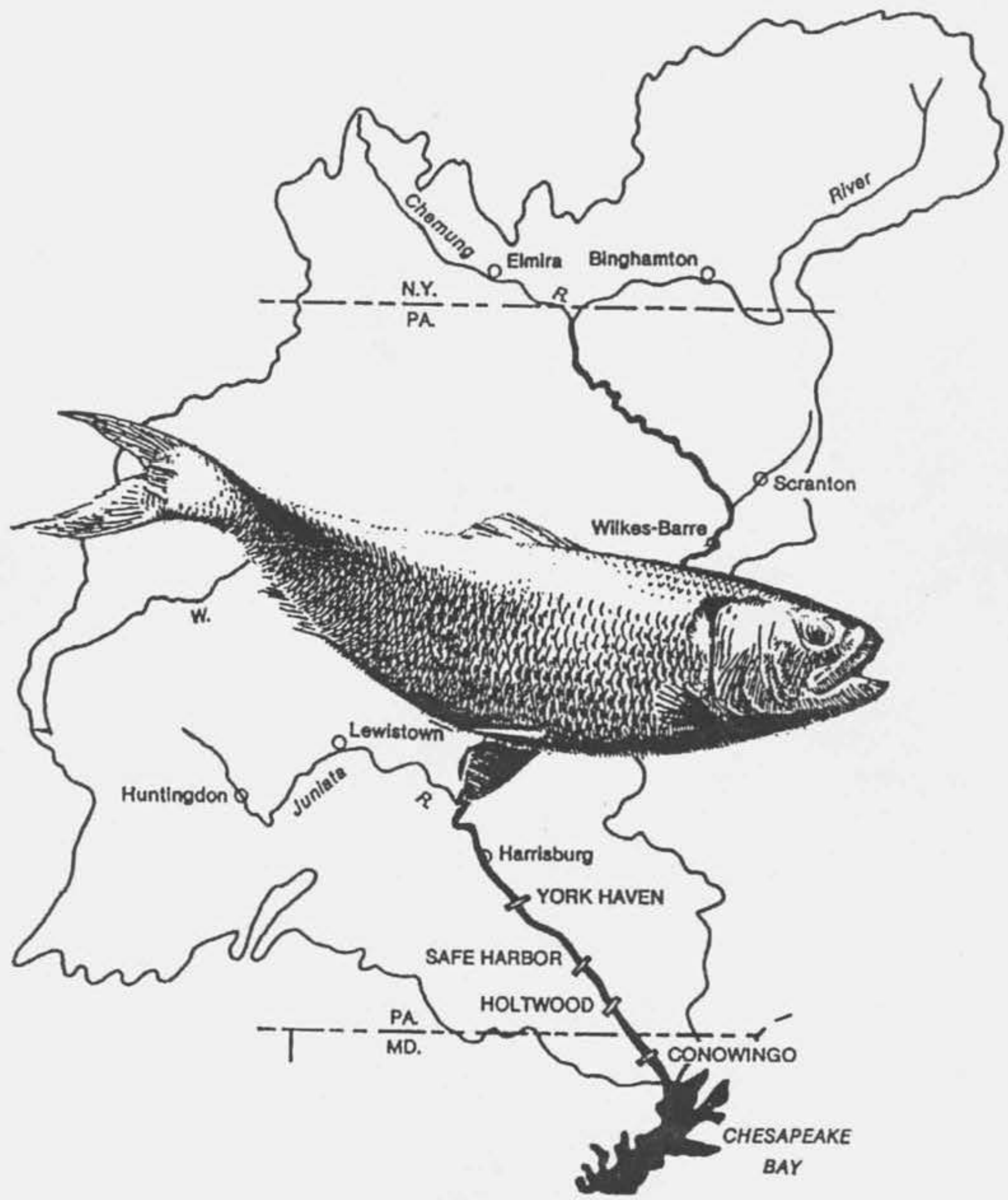
Restoration of American Shad to the Susquehanna River

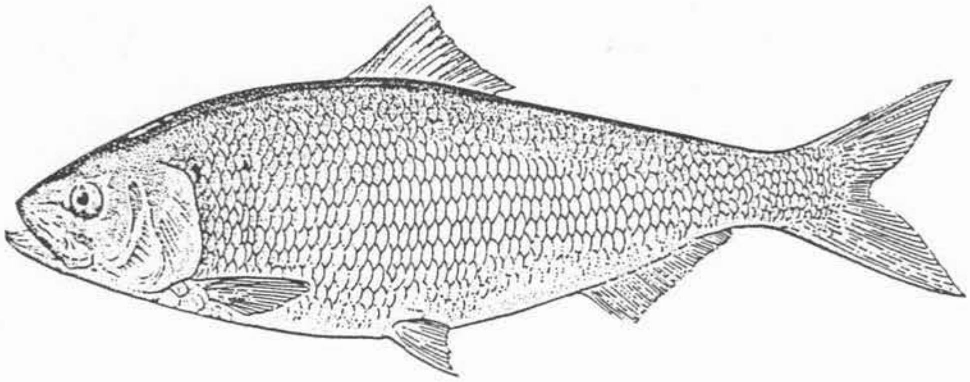
Annual Progress Report
1999



Susquehanna River
Anadromous Fish Restoration Committee

February 2000

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1999

SUSQUEHANNA RIVER
ANADROMOUS FISH RESTORATION COOPERATIVE

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

FEBRUARY 2000

EXECUTIVE SUMMARY

This 1999 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, largely 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 and Safe Harbor 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.

The Conowingo West lift operated on 43 days between April 23 through June 4, fishing for 315 fishing hours and making 709 separate lifts. Total catch amounted to 722,945 fish representing 34 taxa including 9,658 American shad, 8,546 blueback herring, 32 hickory shad, 1,795 alewives, 1,001 striped bass, and 652,770 gizzard shad. Sex ratio in the American shad run was 1.1 to 1 favoring males. Every 50th shad collected throughout the season was killed for otolith analysis and a scale sample.

A total of 5,508 shad were stocked in the mainstem Susquehanna at Tri-County Boat Club and 2,105 bluebacks were stocked in the Conestoga River and Little Conestoga Creek with very low mortality. Other transfers from the West lift included 1,471 shad provided to Maryland DNR and 1,082 delivered to Lamar (USFWS) for tank spawning, and 390 shad delivered to PFBC's Benner Spring Research Station for a special study.

The Conowingo East fish passage facility operated for 467 hours on 52 days and made 610 lifts from April 1 through June 3. Fish were identified and counted as they passed the viewing window and observations were supplemented with video recordings. The season passage included 69,712 American shad, 130,625 blueback herring, 14 alewives, 1,231 striped bass, and 950,500 gizzard shad. Peak shad passage occurred during 26 April through 16 May, and peak herring passage occurred on 7 May. American shad and blueback herring passage in 1999 was the second highest since this facility

began operations in 1991. On May 8, the exit trough clogged with debris and dead fish interrupting flow. This caused additional mortalities including about 2,000 American shad, 500 bluebacks and 500 gizzard shad. The two Conowingo lifts produced a total of 109 Maryland DNR tag recoveries or observations.

The tailrace lift at Holtwood operated on 40 days during late April through early June, fishing for 343 hours and making 519 lifts. A total of 33,042 American shad were passed. Because of low flows, the spillway lift only operated on 21 days making 152 lifts in 155 hours. This device passed an estimated 1,660 American shad. Other fish in combined Holtwood collections included 73 bluebacks, 1 alewife and 430,006 gizzard shad. Peak passage day for American shad was May 10 (2,745 fish). It appeared that migrating shad took an average of 8 days to pass from Conowingo East lift to Holtwood. Shad passage at Holtwood in 1999 was the highest since operations began in 1997 and constituted about 50% of the East lift count.

The Safe Harbor fish lift operated for 235 hours during 29 days between May 1 and June 7 and made 553 lifts. Total fish passage was 427,223 fish including 34,150 American shad, 31 river herring, 1 striper and 361,093 gizzard shad. Peak day of American shad passage was May 11 (2,915). Even though Safe Harbor lost several days to broken equipment, they still passed 98% of the shad passing Holtwood with an average transit time between projects of only one day.

Maryland DNR collected shad from pound nets at Cherry Tree Point and Gateway off Aberdeen during March 24 through May 14 and by angling in the Conowingo tailrace during April 23 through May 20. Total catch from both gears was 1,224 shad of which 963 were tagged and released. Catch per effort from pound nets was down compared to the past few years but the catch per boat hour in the tailrace was the second highest recorded at 15.83.

Total recaptures of 1999 tags at the Conowingo lifts was 109 fish. Using Peterson techniques, shad population indices were calculated for the upper Bay (685,058 fish) and Conowingo tailrace (583,198). Scale analysis from combined pound net and angling samples showed that most males were ages 3-5 with 11.4% repeat spawners and females were 4-6 with 26.8% repeats.

Based on analysis of 188 readable otoliths from adult shad taken at Conowingo West lift in 1999, 100 (53%) were of hatchery origin and 88 (47%) were wild. This was a decline in wild fish compared to 1998 (71%). The majority of hatchery fish (51%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River. Most others (34%) were triple marked on days 3, 13, and 17 or days 5, 9, and 13. Otoliths from 97 shad taken from the Safe Harbor fish lift showed 38% hatchery and 62% wild origin. Based on the annual analysis of hatchery versus wild shad at Conowingo, age of fish, and known stocking numbers, PA Fish and Boat Commission calculated that, on average, it takes 337 larvae, 140 fingerlings, or 0.78 transplanted adults to produce each adult return to Conowingo Dam.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River in 1999. During May 3-27 two fishing crews gill netted spawners, stripped and fertilized eggs, and shipped these to Van Dyke hatchery. A total of 21.1 million eggs were taken at the Coxsackie site with overall viability of 69.2%. PFBC and Ecology III used anchored gill nets to collect ripe shad and take eggs from the Delaware River near Smithfield Beach on May 5-25. A total of 5.5 million were delivered to Van Dyke in 14 shipments. Overall egg viability was unusually low at about 27%. USFWS-Lamar attempted hormone-induced tank spawning of Conowingo shad but failed to take any eggs, presumably due to cumulative stress on broodfish from trapping, handling, and hauling.

For the season a total of 26.6 million shad eggs were delivered to Van Dyke with 59.2% viability. These produced 14.4 million fry of which 10.2 million were stocked at several sites in the Juniata River; 1.2 million in the North Branch; 1.0 million in the West Branch; and 1.1 million into four lower river tributaries. Additionally, 501,000 shad fry were stocked in the Lehigh River and 410,000 were stocked in the Schuylkill River, both Delaware River tributaries. Fry were released at 5 to 23 days of age and received one to five unique tetracycline mark combinations.

Low river levels, high temperatures and drought conditions contributed to relatively poor summer-fall juvenile shad net collections at most locations. Under contract to PFBC, Normandeau Associates conducted weekly haul seine collections at Columbia, PA during mid-July through October and caught 322 juvenile shad. Push netting in Conowingo Pond produced four shad and electrofishing in the Juniata produced 126 shad. No adult shad were collected with electrofishing at Warrior Ridge, Raystown or Sunbury. Normandeau Associates also conducted lift netting at Holtwood Dam's inner forebay and caught 490 juvenile American shad from mid-September through mid-October (CPUE 1.63 shad/lift).

Intake screens at Peach Bottom Atomic Power Station were examined three times weekly from October 18 through December 10 (23 sample dates). Over 5,000 fish were impinged including 285 American shad, 112 juvenile and 2 adult blueback herring. Peak shad collection at PBAPS was on December 6, compared with the last successful collection date at Holtwood of October 25. Conowingo strainers were examined twice a week during October to mid-December and produced 120 shad and 89 bluebacks. Maryland DNR collected 42 juvenile shad in the upper Bay using seines (21 fish) and electrofishing (21 fish).

Otoliths from a total of 791 juvenile shad were examined for hatchery marks from combined collections made at and above Conowingo Dam. Of these, 753 (95% of total) were hatchery marked (the same percentage as in 1998) of which the majority (89%) carried the single day mark indicating that they were stocked at various locations in the Juniata River. All other stocking sites except the West Branch were represented by small numbers amounting to 1.6% - 2.8% of total hatchery fish. No shad stocked in the West Branch were recovered. Of 35 fish examined in Maryland DNR's upper Bay samples only one fish was hatchery origin and carried a double mark.

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

American shad egg collections, hatchery culture and marking, and otolith mark analysis were funded by GPU-Genco and York Haven Power Company according to terms of the 1993 settlement agreement with upstream utilities. The PA Fish and Boat Commission used money provided through

the Atlantic Coastal Fisheries Cooperative Management Act to fund juvenile shad net and electrofishing collections above Conowingo Dam. Maryland DNR funded the adult shad population assessment and juvenile shad seining in the upper Chesapeake Bay. Costs associated with Conowingo West fish lift operations, including collection, sorting, and trucking of shad and herring, 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, 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 1999

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INTRODUCTION

Susquehanna Electric Company (SECO), a subsidiary of PECO Energy, 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, PECO Energy 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 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 and Safe Harbor dams, the East lift has been operated to pass fish directly into Conowingo Pond since spring 1997. Objectives of 1999 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 (Figure 1). 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 recently replaced with more efficient mixed-flow Kaplan type turbines, manufactured by Voith, Inc.

Minimum flow releases from the station during the spring spawning and fishway operating season follow the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500, and 5,000 cfs were maintained from 1 to 30 April, 1 to 31 May, and 1 to 3 June, respectively.

Fishway Operation

East lift operation began on 1 April on an every other day basis through 19 April. Daily lift operation began on 20 April, but was discontinued on 22 April due to the small number of shad collected. The lift was restarted on 23 April, continuing thereafter through 3 June, excepting 8, 9 and 31 May, when mechanical problems with the lift suspended operation. Half-day lift operation (1100 to 1900 h) occurred from 1 April through 30 April. Based on the number of American shad passed, full day operation began on 1 May and continued (except for 8 and 9 May) through 28 May. Generally, full day operation began at 0800 h continuing to approximately 1900 h. Fishway operation was conducted by a staff of three people: a lift operator, supervising biologist, and a biological technician who counted fish.

Work stoppages due to mechanical, electrical, and/or pneumatic failures or maintenance accounted for 32.5 hours of lost fishing time versus 467 hours of operation. The trough valve grating clogged with dead fish (8 May), resulting in a fish kill (approximately 2,000 American shad, 500 blueback herring, and 500 gizzard shad) and accounted for 20 hours of lost fishing time. A hopper sheave wheel problem cancelled operations on 31 May resulting in 12.5 hours of lost operation. A frayed hopper cable and very low numbers of American shad passed on 1 and 2 June resulted in termination of the season's lift operation on 3 June.

The mechanical aspects of East lift operation in 1999 were similar to those described in RMC (1992 and 1998). Fishing time and/or lift frequency was determined by fish abundance, but the hopper was cycled at least hourly throughout the day. Mechanical delays at the East lift were reduced by controlling access of fish over the hopper by operation of the crowder screen. This mode of operation "fast fish" involved leaving the crowder in the normal fishing position and raising the hopper frequently to remove fish that accumulate 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. The entrance used during the entire 1999 season to attract fishes was C. Due to a wicket gate problem, which prevented turbine #10 from completely shutting down, this turbine was used to provide minimum flow releases during the entire fish lift operating season.

Fish Counts

Fish that were lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. The counting area is adjacent to the trough. As fish swim through the trough they approach the counting area and are directed by a series of fixed screens to swim up and through a 3 ft wide channel located on the west side of the trough past a 4 ft by 10 ft window, where fish are enumerated prior to passage from the fishway. Passage from the fishway was controlled by gates located downstream of the window. Generally, fish passage was controlled by a technician who opened/closed a set of gates downstream of the viewing window. During periods of peak passage, two people were used to identify and count fish.

Fish passage data were handled by two systems, a data capture system and a data processing system. The data (species and numbers passed) were recorded by the technician as the fish passed the viewing window on a digital note pad, a ScriptWriter XL, which had been programmed to allow count data to be entered on a real time basis into a digital format. A time stamp feature programmed into the ScriptWriter provided a time reference for each tick mark added to the passage count. Data were entered by writing on a paper template placed on the pad, which provided a hardcopy of the daily passage record. Data processing and reporting were PC based and accomplished by program scripts, or macros, created within Microsoft Excel software.

The fish tally and time stamps were stored in the memory of the ScriptWriter as an ASCII file until the end of operation each day. The file(s) was then uploaded to a PC and read into Microsoft Excel, from which a daily data listing was produced. Listings were reviewed by the biologist and corrected as necessary. After corrections were made, a daily summary of fish passage was produced and distributed to plant personnel. Each day's data were backed up to a diskette and stored off-site.

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 biologist/technician 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 1,184,101 fish of 31 taxa was passed upstream into Conowingo Pond. Gizzard shad (950,500) was the dominant species passed and comprised 80% of the catch. Other common fishes included blueback herring (130,625), American shad (69,712), white perch (27,133), carp (2,430), and striped bass (1,231). Alosids (American shad, bluebacks and alewife) comprised nearly 17% of the total catch. Peak passage occurred on 7 May when 163,240 fish, or nearly 14% of the season total, were passed; blueback herring passage was 125,860 and comprised 77% of that day's catch.

American Shad Passage

The East lift captured and passed 69,712 American shad (Table 1). The first shad was passed on 13 April. Collection and passage of shad varied daily with nearly 87% (60,570) of the shad captured and passed between 26 April and 16 May. The lift captured and passed over 5,000 American shad on 4 separate days and more than 4,000 shad on 3 separate days. Daily passage exceeded 3,000 shad on two days. Peak passage occurred on 3 May when 5,663 American shad were passed.

American shad were collected at water temperatures of 53.6°F to 79.7°F and at natural river flows of 10,300 to 87,100 cfs (Table 2 and Figure 2). Over 53% of the shad were collected at water temperatures >65°F. Generally, water temperature was less than 65°F until 4 May. The hourly passage of American shad in the East lift is given in Table 3. Most shad passed (57,965) through the fishway from 1000 to 1859 h. Peak hourly passage of shad (7,746) occurred between 1800 to 1859 h. Generally shad passage increased hourly until it peaked. Following the peak, passage usually declined steadily until operation ended each night.

Other Alosids

Only 14 alewife were captured and passed (Table 1). Eleven of the alewife were passed between 29 April and 1 May. No hickory shad were collected. A total of 130,625 blueback herring was captured and passed (Table 1). Most blueback herring (96%) were passed on 7 May at a water temperature of 65.3°F and river flow of 22,100 cfs.

Video Record

A limited review of the video records showed that fish passage was adequately captured on the tape record in 1999. 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 1 to 85 shad or from 0.33 to 6.8%. These video counts were derived via a frame by frame review of the time period.

Low river flows in spring 1999 resulted in better water clarity and helped improve the quality of the video tapes. The visual estimates made by technicians accurately reflected the number of fish that passed through the East lift. To further insure the visual accuracy, two people were utilized during periods of increased fish passage.

SUMMARY

During this year's operation, a fish kill occurred in the East Fish lift trough, resulting in the approximate loss of 2,000 American shad, 500 blueback herring, and 500 gizzard shad. After a thorough investigation, it was concluded that several moribund gizzard shad had become impinged on the trough valve grating diminishing flows through the trough and butterfly valve. Modifications to the valve grating and the hopper exit chute are currently being installed to prevent this situation from occurring in the future.

Low river flow during the 1999 operating season substantially improved the American shad catch as compared to the catch in 1998. The 1999 American shad catch was 69,712 and ranked second highest since 1991 (Table 5). The catch of blueback herring (130,625) was also the second highest catch since 1991.

Fish viewing conditions were much better than those encountered in 1998 due to good water clarity, which resulted from the low river flow. Differences between visual counts and tape derived counts were small (0.33 to 6.8%) with most American shad positively identified on the videotapes. Visual accuracy was insured by utilizing two people during periods of increased fish passage.

RECOMMENDATIONS

1) Operate the East lift at Conowingo Dam per annual guidelines developed and approved by the Susquehanna River Technical Committee. Lift operation should adhere to the guidelines, however, flexibility must remain with operating personnel to maximize fishway operation and performance.

2) Continue the use of two fish counters during periods of increased fish passage to accurately reflect the number of fish that pass through the East lift. Continue the video tape record since it provides backup documentation. Review tape if hourly passage exceeds 600 shad.

3) During the season, perform periodic draw downs in the East trough to check for debris/dead fish accumulating on trough valve grating and evaluate effectiveness of modifications to the trough valve grating and hopper exit chute.

4) Inspect all cables and limit switches to meet design specifications.

5) To simplify data collection and reporting, discontinue the use of the ScriptWriter XL digitizing note pad. Develop a program that utilizes Microsoft Excel spreadsheet software to produce the daily and annual reports. Report tables will be similar to those produced in previous years.

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 1999.

Date	*1 Apr*	*2 Apr*	*3 Apr*	*4 Apr*	*5 Apr*	*6 Apr*	*7 Apr*	*8 Apr*
Hours Of Operation	*6.50*		*6.75*		*6.70*		*7.75*	
Numbers Of Lifts	*6*		*6*		*7*		*7*	
Water Temperature	*50.0*		*56.3*		*54.2*		*57.2*	
American Shad								
Gizzard Shad	1,575		8,646		13,285		21,035	
Blueback Herring								
Alewife							1	
Striped Bass							1	
American Eel								
Rainbow Trout			4		1			
Brown Trout			1				1	
Brook Trout								
Carp								
Quillback								
White Sucker	3		12		22		5	
Shorthead Redhorse	15		4		2		2	
White Catfish								
Brown Bullhead								
Channel Catfish								
White Perch								
Rock Bass								
Redbreast Sunfish								
Green Sunfish	6							
Pumpkinseed								
Bluegill	3				1			
Smallmouth Bass	1		7		12		4	
Largemouth Bass			1					
White Crappie								
Black Crappie	1							
Yellow Perch			4		2			
Walleye	2		4		7		3	
Atlantic Needlefish								
Sea Lamprey								
Hybrid Striped Bass	1		1					
TOTAL	***1,607***		***8,684***		***13,332***		***21,052***	

Table 1

Continued.

Date	9 Apr	10 Apr	11 Apr	12 Apr	13 Apr	14 Apr	15 Apr	16 Apr
Hours Of Operation	*6.50*		*7.00*		*7.30*		*7.50*	
Numbers Of Lifts	*7*		*7*		*7*		*7*	
Water Temperature	*57.2*		*57.2*		*53.6*		*53.6*	
American Shad					1		1	
Gizzard Shad	20,069		23,871		33,777		31,120	
Blueback Herring								
Alewife								
Striped Bass								
American Eel								
Rainbow Trout								
Brown Trout								
Brook Trout								
Carp	1				1			
Quillback					1			
White Sucker	3							
Shorthead Redhorse	1				3			
White Catfish								
Brown Bullhead								
Channel Catfish	1		28		4		3	
White Perch								
Rock Bass								
Redbreast Sunfish								
Green Sunfish								
Pumpkinseed								
Bluegill								
Smallmouth Bass	2		6		2			
Largemouth Bass								
White Crappie								
Black Crappie								
Yellow Perch								
Walleye	2		2		5		3	
Atlantic Needlefish								
Sea Lamprey			1					
Hybrid Striped Bass								
TOTAL	***20,079***		***23,908***		***33,794***		***31,127***	

Table 1

Continued.

Date	17 Apr	18 Apr	19 Apr	20 Apr	21 Apr	22 Apr	23 Apr	24 Apr
Hours Of Operation	*7.60*		*8.00*	*8.25*	*8.00*		*8.80*	*8.25*
Numbers Of Lifts	*7*		*8*	*8*	*8*		*9*	*8*
Water Temperature	*53.6*		*53.6*	*53.6*	*53.6*		*56.3*	*53.6*
American Shad	5		214	128	39		647	31
Gizzard Shad	22,269		21,923	18,132	14,082		24,300	14,789
Blueback Herring								
Alewife								1
Striped Bass								
American Eel								
Rainbow Trout								
Brown Trout								
Brook Trout								
Carp							2	
Quillback								
White Sucker					1			
Shorthead Redhorse			1		1		2	2
White Catfish								
Brown Bullhead								
Channel Catfish	2		1	1	5		23	8
White Perch								
Rock Bass								
Redbreast Sunfish								
Green Sunfish								
Pumpkinseed								
Bluegill								1
Smallmouth Bass	1		3	1	3		9	2
Largemouth Bass				2				2
White Crappie							1	
Black Crappie								
Yellow Perch			1		1			
Walleye	2		1					1
Atlantic Needlefish								
Sea Lamprey			2					
Hybrid Striped Bass			1					
TOTAL	***22,279***		***22,147***	***18,264***	***14,132***		***24,984***	***14,837***

Table 1

Continued.

Date	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*
Hours Of Operation	*8.0*	*8.50*	*7.75*	*8.10*	*8.25*	*8.70*	*11.25*	*11.25*
Numbers Of Lifts	*8*	*8*	*9*	*10*	*9*	*8*	*21*	*14*
Water Temperature	*54.5*	*56.3*	*57.2*	*58.1*	*58.1*	*58.1*	*60.8*	*61.7*
American Shad	168	2,831	5,124	2,463	508	649	5,078	5,120
Gizzard Shad	23,933	14,386	7,729	21,800	35,771	33,025	38,320	20,620
Blueback Herring							1	
Alewife					1	4	6	
Striped Bass								
American Eel								
Rainbow Trout		1						
Brown Trout								1
Brook Trout								
Carp			2	1		1	6	1
Quillback			1			1	2	
White Sucker		6		2				
Shorthead Redhorse	6	29	39	46	10	25	15	3
White Catfish								
Brown Bullhead					1			
Channel Catfish		10	2	6		1	11	3
White Perch						16	1,361	547
Rock Bass				1			1	4
Redbreast Sunfish			1					
Green Sunfish						1		
Pumpkinseed								
Bluegill				1		3	4	6
Smallmouth Bass	1	1	18	36	12	18	26	23
Largemouth Bass				2			5	4
White Crappie								
Black Crappie					4			1
Yellow Perch				2		3	2	5
Walleye	1	7	1	11	6	12	24	13
Atlantic Needlefish								
Sea Lamprey		2				1	7	
Hybrid Striped Bass								
TOTAL	***24,109***	***17,273***	***12,917***	***24,371***	***36,313***	***33,760***	***44,869***	***26,351***

Table 1

Continued.

	3 May	4 May	5 May	6 May	7 May	8 May	9 May	10 May
Hours Of Operation	*11.80*	*11.00*	*11.00*	*10.50*	*11.25*	*1.25*	*0.00*	*11.00*
Numbers Of Lifts	*16*	*14*	*16*	*13*	*19*	*1*	*0*	*19*
Water Temperature	*60.8*	*62.6*	*65.3*	*65.3*	*65.3*	*65.3*	*67.0*	*68.0*
American Shad	5,663	3,969	4,673	4,456	2,073	111		4,573
Gizzard Shad	31,582	44,076	31,574	47,953	32,880	791		60,380
Blueback Herring		1	2		125,860	2,380		331
Alewife	1							
Striped Bass		2	9	7	3			56
American Eel								
Rainbow Trout								
Brown Trout		1	1					
Brook Trout								
Carp	4	10	14	9	15	2		147
Quillback			5		20			17
White Sucker			1					
Shorthead Redhorse	1	1		1	7			11
White Catfish	2							
Brown Bullhead								
Channel Catfish		12	4	14				56
White Perch	3,540	595	565	5,766	2,358			9,353
Rock Bass		4	3	1	5			
Redbreast Sunfish		2	4	8				37
Green Sunfish								1
Pumpkinseed								
Bluegill	4			2	2			2
Smallmouth Bass	17	74	118	62	12			75
Largemouth Bass		3	2	2				1
White Crappie	1							
Black Crappie								
Yellow Perch	1	1	4	9	2			24
Walleye	9	5	9	16	3			52
Atlantic Needlefish								
Sea Lamprey	1	5	4					
Hybrid Striped Bass								
TOTAL	***40,826***	***48,761***	***36,992***	***58,306***	***163,240***	***3,284***		***75,116***

Table 1

Continued.

Date	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*
Hours Of Operation	*11.00*	*11.00*	*10.70*	*10.80*	*11.00*	*11.00*	*11.20*	*11.00*
Numbers Of Lifts	*15*	*21*	*21*	*19*	*15*	*20*	*15*	*17*
Water Temperature	*68.0*	*69.9*	*69.9*	*68.9*	*68.9*	*69.9*	*69.9*	*69.9*
American Shad	3,171	2,900	2,204	965	2,541	1,498	462	1,547
Gizzard Shad	7,800	23,100	41,490	46,380	14,670	28,321	18,770	8,600
Blueback Herring	30	15	1,613	15		161	1	
Alewife								
Striped Bass		17	54	36	100	86	101	12
American Eel								
Rainbow Trout			1	1				2
Brown Trout	2				1	1		
Brook Trout		2						
Carp	45	19	51	193	13	46	178	6
Quillback		20	13			16	9	
White Sucker					1			
Shorthead Redhorse		4	5				9	
White Catfish								
Brown Bullhead								
Channel Catfish	2	4	9				2	6
White Perch	250	155	939	320	474	330	55	7
Rock Bass	1		2	2	3	4		
Redbreast Sunfish			26	1	6			
Green Sunfish	5							
Pumpkinseed								
Bluegill				15	10	10	2	
Smallmouth Bass	15	5	81	17	15	25	3	1
Largemouth Bass			1					
White Crappie								
Black Crappie								
Yellow Perch	3	1	5	3	10	14		6
Walleye	2	12	25	5	21	22	17	5
Atlantic Needlefish								
Sea Lamprey		1	1		1			
Hybrid Striped Bass								
TOTAL	***11,326***	***26,255***	***46,520***	***47,953***	***17,866***	***30,534***	***19,609***	***10,192***

Table 1

Continued.

Date	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*
Hours Of Operation	*11.00*	*10.80*	*11.00*	*10.50*	*11.20*	*10.50*	*10.90*	*10.90*
Numbers Of Lifts	*16*	*15*	*15*	*14*	*17*	*12*	*16*	*15*
Water Temperature	*70.7*	*71.6*	*71.6*	*72.5*	*72.5*	*71.6*	*71.6*	*72.5*
American Shad	400	813	1,124	839	568	125	680	468
Gizzard Shad	7,604	6,175	5,525	3,900	11,205	1,800	7,695	2,040
Blueback Herring	14	12	76	1	6		5	30
Alewife								
Striped Bass	58	61	28	121	99	117	38	18
American Eel					1		1	1
Rainbow Trout					1		1	
Brown Trout								
Brook Trout								
Carp	21	48	44	241	44	788	259	32
Quillback	9			9		10		
White Sucker	1				1			
Shorthead Redhorse								
White Catfish								
Brown Bullhead								
Channel Catfish	13			5	7	3		
White Perch	158	115	11	70	80	10	5	5
Rock Bass								
Redbreast Sunfish	3				2			
Green Sunfish								
Pumpkinseed	1							
Bluegill	8	15	7		4			1
Smallmouth Bass	18	10	2		16		2	4
Largemouth Bass		1			3			1
White Crappie					1			
Black Crappie								
Yellow Perch	1	3						
Walleye	12	5	5	8	19	21	7	6
Atlantic Needlefish								
Sea Lamprey								
Hybrid Striped Bass				1				
TOTAL	***8,321***	***7,258***	***6,822***	***5,195***	***12,057***	***2,874***	***8,693***	***2,606***

Table 1

Continued.

Date	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*TOTAL*
Hours Of Operation	*10.70*	*11.00*	*9.80*	*8.50*		*6.50*	*7.50*	*2.00*	***467.00***
Numbers Of Lifts	*14*	*13*	*9*	*8*		*7*	*9*	*0*	***610***
Water Temperature	*72.5*	*70.7*	*73.4*	*77.0*		*77.0*	*79.7*	*78.8*	
American Shad	281	247	129	166		6	53		***69,712***
Gizzard Shad	220	195	200	390		150	551	26	***950,500***
Blueback Herring	11	25	22	13					***130,625***
Alewife									***14***
Striped Bass	87	13	35	18		21	33		***1,231***
American Eel									***3***
Rainbow Trout									***12***
Brown Trout									***9***
Brook Trout									***2***
Carp	21	21	4	4		62	72	2	***2,430***
Quillback			3				8		***144***
White Sucker									***58***
Shorthead Redhorse									***245***
White Catfish									***2***
Brown Bullhead	1								***2***
Channel Catfish	8		4	8					***266***
White Perch	31	2	7	2		1	5		***27,133***
Rock Bass									***31***
Redbreast Sunfish							8	10	***108***
Green Sunfish									***13***
Pumpkinseed									***1***
Bluegill	7	2		3		16	29	1	***159***
Smallmouth Bass	3	2	4	7		5	16		***797***
Largemouth Bass									***30***
White Crappie									***3***
Black Crappie									***6***
Yellow Perch							1		***108***
Walleye	20		1			1	6		***421***
Atlantic Needlefish							4		***4***
Sea Lamprey							1		***27***
Hybrid Striped Bass			1						***5***
TOTAL	***690***	***507***	***410***	***611***		***262***	***787***	***39***	***1,184,101***

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 1999.

Date	American Shad catch	MD DNR Recaptures	River Flow (CFS)	Water Temp (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Crest Gates
1 Apr	0	0	62,400	50.0	20+	11	C	310	22.0-22.5	106.6-105.3	0
2 Apr	-		65,500								
3 Apr	0	0	67,600	56.3	24+	11	C	310	22.5	106.8-106.5	0
4 Apr	-		70,200								
5 Apr	0	0	68,400	54.2	20+	11	C	310	22.0-23.0	107.6-108.2	0
6 Apr	-		65,200								
7 Apr	0	0	65,800	57.2	20+	11	C	310	22.0-22.5	106.2-106.8	0
8 Apr	-		60,900								
9 Apr	0	0	55,300	57.2	20	11	C	310	22.0-22.5	107.3-107.6	0
10 Apr	-		56,400								
11 Apr	0	0	72,700	57.2	20+	11	C	310	22.0	103.5-103.7	0
12 Apr	-		85,900								
13 Apr	1	0	87,100	53.6	16	11	C	310	22.0-22.5	106.7-107.3	0
14 Apr	-		80,100								
15 Apr	1	0	72,700	53.6	16	11	C	310	22.0-22.5	106.1-106.2	0
16 Apr	-		64,000								
17 Apr	5	0	57,000	53.6	20	11	C	310	22.0-22.5	106.8-107-2	0
18 Apr	-		52,000								
19 Apr	214	0	46,800	53.6	20+	11	C	310	22.0-23.0	107.0-108.1	0
20 Apr	128	0	47,400	53.6	20	11	C	310	21.5-22.5	108.1-107.4	0
21 Apr	39	0	45,700	53.6	16	11	C	310	22.0-23.0	108.0-106.4	0
22 Apr	-		44,600								
23 Apr	647	0	44,900	56.3	20	11	C	310	22.5-21.0	107.2-106.8	0
24 Apr	31	0	46,500	53.6	20	9	C	310	22.0-22.5	108-1-107.1	0
25 Apr	168	0	47,400	54.5	16+	9	C	310	23.0-21.5	106.7-106.4	0
26 Apr	2,831	0	51,400	56.3	16+	9	C	310	22.0-22.5	107.8-106.4	0
27 Apr	5,124	0	55,700	57.2	16+	11	C	310	22.5-23.0	108.0-107.3	0
28 Apr	2,463	0	50,500	58.1	12+	9	C	310	22.5	107.0-106.9	0
29 Apr	508	0	46,100	58.1	16	9	C	310	22.5-19.0	107.1-106.3	0
30 Apr	649	0	40,200	58.1	12+	9	C	310	22.5-21.0	106.9-107.5	0
1 May	5,078	0	34,700	60.8	16+	9	C	310	20.0-22.5	108.7-107.4	0
2 May	5,120	0	32,600	61.7	16+	7	C	310	20.0-22.0	108.6-107.7	0

Table 2

Continued.

Date	American Shad catch	MD DNR Recaptures	River Flow (CFS)	Water Temp (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Crest Gates
3 May	5,663	1G	30,100	60.8	12+	9	C	310	22.5-20.0	107.8-106.9	0
4 May	3,969	0	27,300	62.6	12+	9	C	310	22.0-18.0	106.4-107.7	0
5 May	4,673	4G	24,100	65.3	12+	9	C	310	22.5-19.0	107.3-106.5	0
6 May	4,456	0	24,200	65.3	16+	8	C	310	21.0-18.0	108.1-107.7	0
7 May	2,073	0	22,100	65.3	16+	6	C	310	17.5-19.0	108.0-108.3	0
8 May	111	0	22,500	65.3	16+	5	C	310	18.0-17.0	107.2-108.5	0
9 May	-		26,400	67.0							
10 May	4,573	6G	29,400	68.0	20+	7	C	310	22.5-20.0	108.5-107.8	0
11 May	3,171	2G	26,400	68.0	20+	9	C	310	20.5-22.5	108.4-108.0	0
12 May	2,900	8G	24,800	69.9	20+	7	C	310	20.0-22.0	107.3-108.2	0
13 May	2,204	1DB,3LB	23,600	69.9	20+	8	C	310	18.0-22.0	106.5-108.5	0
14 May	965	0	20,900	68.9	24	5	C	310	19.0-17.0	107.6-107.9	0
15 May	2,541	10G,2LB	19,400	68.9	24	3	C	310	17.0-17.5	106.6-108.7	0
16 May	1,498	7G	17,300	69.9	24	4	C	310	18.0-18.5	106.7-108.2	0
17 May	462	1B	18,300	69.9	24	6	C	310	18.5-21.0	108.5-108.1	0
18 May	1,547	6G	16,400	69.9	24	6	C	310	18.0-21.0	106.6-108.6	0
19 May	400	1B,1G	15,800	70.7	24	3	C	310	18.0-20.5	106.4-108.0	0
20 May	813	0	14,600	71.6	24	3	C	310	18.0-20.0	106.8-107.5	0
21 May	1,124	4G	13,500	71.6	24	3	C	310	18.0-20.5	106.9-108.5	0
22 May	839	2G	13,200	72.5	24	3	C	310	18.0-20.5	106.5-108.1	0
23 May	568	3G	13,500	72.5	24	1	C	310	18.0-19.0	106.6-108.2	0
24 May	125	0	13,900	71.6	24	3	C	310	18.0-20.0	106.8-108.4	0
25 May	680	1G	14,000	71.6	24	3	C	310	19.0-19.5	106.2-107.6	0
26 May	468	0	14,700	72.5	20+	3	C	310	17.0-19.5	106.7-107.9	0
27 May	281	0	14,200	72.5	24	7	C	310	19.0-18.0	106.6-108.0	0
28 May	247	0	13,200	70.7	16+	6	C	310	18.0-20.0	106.8-108.2	0
29 May	129	0	13,000	73.4	20+	4	C	310	18.0-19.0	106.3-107.6	0
30 May	166	0	12,600	77.0	20+	4	C	310	18.0	106.5-107.7	0
31 May	-		11,400								
1 Jun	6	0	10,400	77.0	20+	4	C	310	18.0-20.0	106.8-107.7	0
2 Jun	53	0	10,300	79.7	24	3	C	310	18.0-19.5	106.1-106.8	0
3 Jun	0	0	11,600	78.8	24	1	C	310	18.0	106.4-106.8	0

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 1999.

Date	*1 Apr*	*2 Apr*	*3 Apr*	*4 Apr*	*5 Apr*	*6 Apr*	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*
Observation Time - Start	*12:00*		*11:45*		*11:35*		*12:15*		*11:10*		*10:51*		*11:40*
Observation Time - End	*17:30*		*17:45*		*18:15*		*18:45*		*18:10*		*18:00*		*18:20*
Military Time (hrs)													
0700 to 0759													
0800 to 0859													
0900 to 0959													
1000 to 1059											-		
1100 to 1159			-		-				-		-		1
1200 to 1259	-		-		-		-		-		-		-
1300 to 1359	-		-		-		-		-		-		-
1400 to 1459	-		-		-		-		-		-		-
1500 to 1559	-		-		-		-		-		-		-
1600 to 1659	-		-		-		-		-		-		-
1700 to 1759	-		-		-		-		-		-		-
1800 to 1859					-		-		-				-
1900 to 1959													
Total	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***1***

Table 3

Continued.

Date	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*
Observation Time - Start		*11:20*		*11:25*		*10:45*	*11:20*	*11:45*		*10:10*	*11:15*	*10:52*	*11:15*
Observation Time - End		*18:30*		*18:40*		*19:15*	*19:15*	*19:00*		*19:00*	*19:15*	*19:05*	*19:30*
Military Time (hrs)													
0700 to 0759													
0800 to 0859													
0900 to 0959													
1000 to 1059						-				16		4	
1100 to 1159		-		-		-	28	2		14	3	3	19
1200 to 1259		-		-		-	44	5		5	4	2	68
1300 to 1359		-		-		-	13	1		17	1	5	245
1400 to 1459		-		-		1	18	2		113	-	51	341
1500 to 1559		-		-		14	13	5		123	3	27	505
1600 to 1659		-		-		38	-	4		105	7	16	400
1700 to 1759		1		4		77	3	9		141	5	26	447
1800 to 1859		-		1		76	7	11		113	5	32	427
1900 to 1959						8	2				3	2	379
Total	***0***	***1***	***0***	***5***	***0***	***214***	***128***	***39***	***0***	***647***	***31***	***168***	***2,831***

Table 3

Continued.

Date	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*
Observation Time - Start	*11:45*	*10:40*	*11:15*	*10:40*	*8:00*	*8:10*	*7:30*	*8:00*	*8:00*	*8:30*	*8:00*	*8:26*	
Observation Time - End	*19:15*	*19:16*	*19:15*	*19:20*	*19:15*	*19:10*	*19:20*	*19:15*	*19:02*	*19:00*	*19:15*	*9:22*	
Military Time (hrs)													
0700 to 0759							-						
0800 to 0859					5	179	4	18	70	40	21	89	
0900 to 0959					271	88	733	645	104	146	31	19	
1000 to 1059		150		-	359	14	118	1,248	283	229	310		
1100 to 1159	158	250	200	57	414	24	431	203	210	100	183		
1200 to 1259	925	289	69	36	427	210	490	223	232	216	364	3	
1300 to 1359	694	280	11	12	650	313	280	202	144	350	600		
1400 to 1459	581	300	16	21	327	868	451	179	647	649	70		
1500 to 1559	478	231	7	64	440	593	801	126	758	561	52		
1600 to 1659	473	403	23	30	549	345	1,210	184	472	480	81		
1700 to 1759	835	252	57	111	925	613	549	300	867	752	54		
1800 to 1859	610	204	99	50	638	1,254	491	386	886	933	272		
1900 to 1959	370	104	26	268	73	619	105	255	-	-	35		
Total	***5,124***	***2,463***	***508***	***649***	***5,078***	***5,120***	***5,663***	***3,969***	***4,673***	***4,456***	***2,073***	***111***	***0***

Table 3

Continued.

Date	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*
Observation Time - Start	*8:30*	*8:20*	*8:03*	*8:30*	*8:30*	*8:00*	*8:00*	*8:00*	*9:00*	*8:10*	*8:00*	*8:00*	*8:20*
Observation Time - End	*19:15*	*19:00*	*18:58*	*19:10*	*19:15*	*18:48*	*19:00*	*19:10*	*19:00*	*18:57*	*18:50*	*19:00*	*18:50*
Military Time (hrs)	*												
0700 to 0759													
0800 to 0859		123	89	32	-	153	103			1	40	40	14
0900 to 0959		169	119	53	47	264	84	202	96	26	115	169	163
1000 to 1059		170	201	201	381	209	85	26	209	12	103	223	217
1100 to 1159		350	464	310	172	270	100	23	205	27	96	204	141
1200 to 1259		750	618	500	58	179	128	23	200	32	95	84	48
1300 to 1359		750	337	282	29	197	150	10	257	56	20	38	92
1400 to 1459		104	343	264	13	265	394	47	147	46	65	126	54
1500 to 1559		203	207	418	16	217	170	59	125	73	59	60	36
1600 to 1659		200	117	29	20	458	122	13	104	50	75	57	32
1700 to 1759		246	223	48	49	218	103	19	67	50	92	58	12
1800 to 1859		106	182	54	150	111	59	24	127	27	53	65	30
1900 to 1959				13	30			16	10				
Total	***4,573***	***3,171***	***2,900***	***2,204***	***965***	***2,541***	***1,498***	***462***	***1,547***	***400***	***813***	***1,124***	***839***

* Due to an equipment malfunction, time data was lost for this day.

Table 3

Continued.

Date	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	
Observation Time - Start	*8:25*	*8:00*	*8:25*	*8:00*	*18:15*	*8:00*	*9:15*	*7:45*		*12:15*	*9:11*	*9:37*	
Observation Time - End	*19:10*	*19:15*	*18:55*	*18:55*	*18:40*	*18:54*	*17:50*	*16:30*		*18:40*	*17:15*	*11:18*	***TOTAL***
Military Time (hrs)													
0700 to 0759								-					***0***
0800 to 0859	42			3	9	2		-					***1,077***
0900 to 0959	45	11	81	13	23	8	5	16			1	-	***3,747***
1000 to 1059	34	61	135	52	61	32	16	39			8	-	***5,206***
1100 to 1159	83		113	40	44	82	29	41			3	-	***5,097***
1200 to 1259	36	19	66	99	53	24	21	26		-	14		***6,685***
1300 to 1359	22	-	43	73	35	14	27	12		-	6		***6,268***
1400 to 1459	33	-	46	61	36	9	8	29		-	4		***6,729***
1500 to 1559	11	3	74	31	12	33	21	-		-	1		***6,630***
1600 to 1659	38	6	46	33	7	11	2	3		-	12		***6,255***
1700 to 1759	56	2	20	30	-	20	-			4	4		***7,349***
1800 to 1859	147	.12	56	33	1	12				2			***7,746***
1900 to 1959	21	11											***2,350***
Total	***568***	***125***	***680***	***468***	***281***	***247***	***129***	***166***	***0***	***6***	***53***	***0***	***69,712***

Table 4

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 1999 Conowingo Dam East lift fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
11 May	20+	0800 - 0859	123	125	+2 (1.6%)
18 May	24	1000 - 1059	209	208	-1 (0.48%)
4 May	12+	1700 - 1759	300	298	-2 (0.67%)
26 Apr	16+	1600 - 1659	400	399	-1 (0.25%)
13 May	20+	1200 -1259	500	510	+10 (2.0%)
27 Apr	16+	1800 -1859	610	612	+2 (0.33%)
27 Apr	16+	1300 - 1359	694	698	+4 (0.58%)
27 Apr	16+	1700 - 1759	835	819	-16 (1.9%)
27 Apr	16+	1200 - 1259	925	894 (886)[a]	-31 (3.4%)
2 May	16+	1800 -1859	1,254	1,169 (1,163)[a]	-85 (6.8%)

[a] verification of video tape count; *i.e.* , second count

Table 5

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 1999.

Year	Number of Days Operated	Number of Lifts	Operating Time (hrs)	Catch (millions)	Number of Taxa	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**

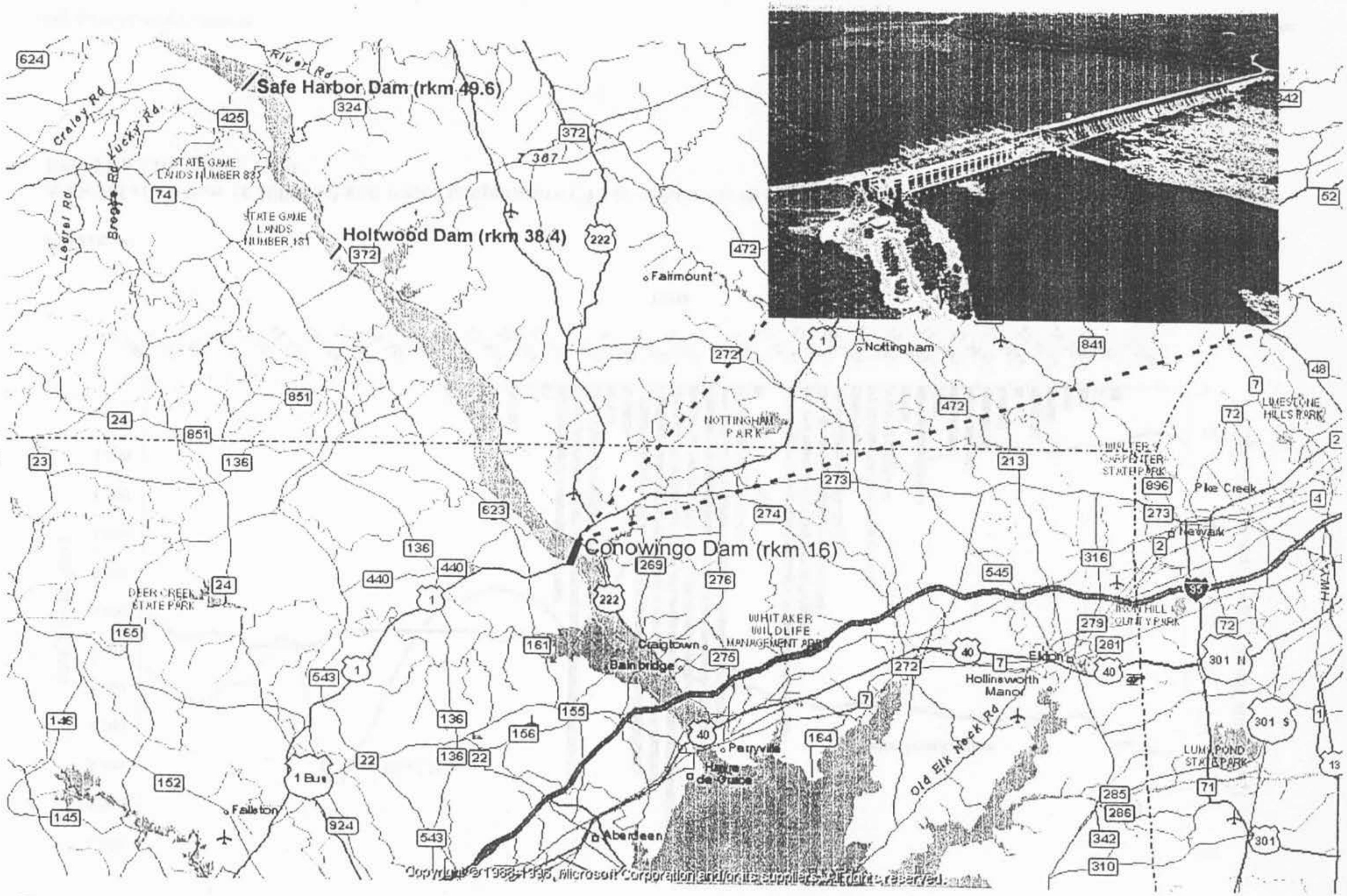

Figure 1

General location of the Conowingo Dam, Susquehanna River.

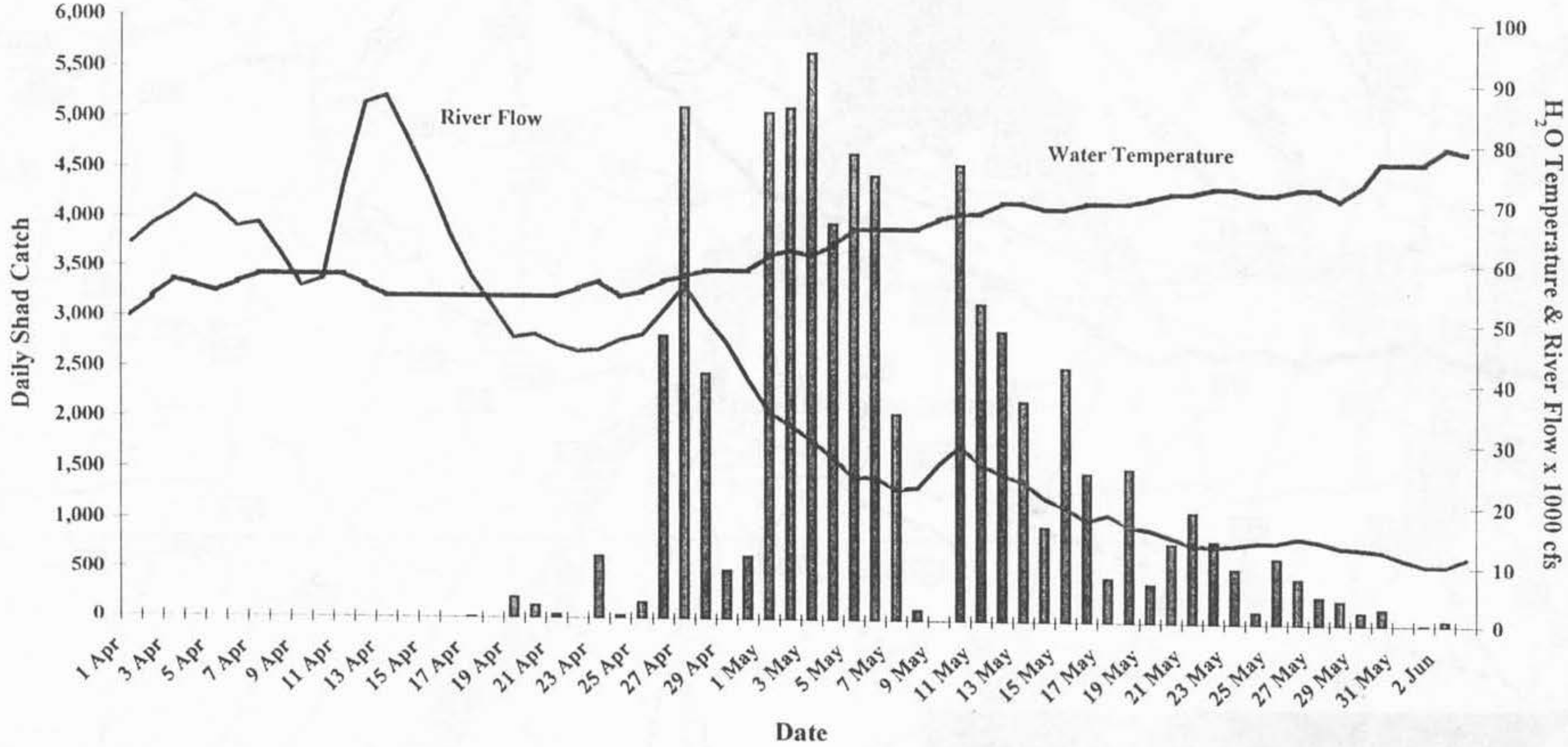

Figure 2

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 1999.

Job I - Part 2
Summary of Conowingo Dam West Fish Lift Operations - 1999

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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 1999 (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 1999 included collection and enumeration of shad, river herring, other migratory and resident fishes; sorting and transportation of up to 10,000 shad to the mainstem above York Haven Dam and 10,000 river herring to select tributaries; delivery of live shad to the USFWS Northeast Fishery Center at Lamar, PA for tank spawning; delivery of live shad to PFBC's Benner Spring Research Station for schooling studies; providing live shad for Maryland DNR's tank spawning operation; recording of DNR tags, sex ratios and archiving of scale samples; and sacrificing shad samples for 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.

In spring 1998, unusually high river flows, exceeding 40,000 cfs on all dates until May 22, limited West lift operations to only 476 lifts in 34 days between April 30 and June 9. Conversely, in 1999, river flows were very low and exceeded 40,000 cfs on only seven days in late April. Daily trapping began at the West lift on April 23 and continued daily through June 4. Total fishing effort over 43 operating days in 1999 included 709 lifts and a fishing time of 313 hours.

Shad and herring collected in the trap were counted and placed into holding tanks. When sufficient numbers were available, typically 125-175 shad and/or 500-1000 herring, these were loaded into truck-mounted 1,000 gallon circular transport tanks and hauled to stocking sites. Most shad were stocked at Tri-County Marina at Middletown, PA and herring were placed stocked into the Conestoga River and Little Conestoga Creek. Fish that died during transport were recovered at the stocking site upon release and delayed transport mortalities were later recovered at Tri-County Marina. Live shad were also delivered to USFWS Northeast Fishery Center and PFBC's Benner Spring Research Station at State College. Maryland DNR picked up shad for tank spawning at their Manning Hatchery. 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 shad catch, river flow and water temperatures for the 1999 lift season. Total catch at the West lift amounted to 722,945 fish of 34 taxa (Table 1). Gizzard shad and white perch comprised 95% of this total. Alosid catch included 9,658 American shad, 8,546 blueback herring, 1,795 alewives, and 32 hickory shad. Most American shad (5,700) were taken during the final two weeks of May and peak daily catches of about 700 fish occurred on May 16 and May 25. Most blueback herring were collected between May 13-18 (Table 2).

Transfers included 5,508 shad stocked at Tri-County Boat Club above York Haven Dam, 1,082 to USFWS-Lamar for tank spawning, and 390 to Benner Spring (Table 3). Total mortalities for transported shad amounted to 232 fish (3.3%). Another 1,471 shad were provided on nine dates to Maryland DNR for tank spawning (Table 4). A total of 1,310 blueback herring were stocked in Little

Conestoga Creek, 795 were placed in the Conestoga River, and 99 went to Lamar (Table 5). Otoliths were taken from 193 shad and provided to PFBC for mark and age analysis. Overall sex ratio of shad in the West lift was 1.1:1.0 favoring males. Average size of male shad was 393 mm (FL) and 662 g, whereas females averaged 449 mm and 1047 g.

Discussion

In 1999, unusually low April and May river flows suggested that a large catch of alosids was likely. However, SECO had a problem with unit 10 (stuck wicket gates) which caused it to operate continuously during most of the season. It is believed that this 8,500 cfs discharge drew fish away from the west shore and toward the East lift. East lift catch in 1999 was the second highest ever recorded there. Nevertheless, highest priority objectives of the West lift were met - providing broodfish to Lamar and Maryland and test fish to Benner Spring.

Of the total American shad collected in 1999, 87.5% were either hauled to upstream spawning waters or provided to hatcheries for tank spawning. West lift catch per effort of about 30.9 shad per fishing hour was the fourth highest capture rate recorded at this facility, exceeded only by the 1996-1998 seasons (Table 6). Average catch per operating day for all fishes (16,800) in 1999 was the highest level recorded since 1992 indicating that this device remains effective in attracting and collecting fish from the tailrace (Table 7). Based on analysis of 188 adult shad otolith samples from Conowingo, hatchery-marked fish comprised 53% of the 1999 run, an increase from 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, 1999.

Number of days	*43*
Number of lifts	*709*
Operating time (hours)	*314.9*
Fishing time (hours)	*312.6*
Number of taxa	*34*
American eel	234
BLUEBACK HERRING	8,546
HICKORY SHAD	32
ALEWIFE	1,795
AMERICAN SHAD	9,658
GIZZARD SHAD	652,770
Brown trout	8
Common carp	5,124
Golden shiner	1
Comely shiner	515
Quillback	823
White sucker	27
Shorthead redhorse	1,485
Yellow bullhead	3
Brown bullhead	8
Channel catfish	2,564
White perch	35,357
STRIPED BASS	1,001
Rock bass	68
Redbreast sunfish	123
Green sunfish	7
Pumkinseed	13
Bluegill	605
Smallmouth bass	1,306
Largemouth bass	78
White crappie	72
Black crappie	10
Yellow perch	134
Walleye	547
Atlantic needlefish	2
Sea lamprey	24
Hybrid striped bass	2
Tadpole Madtom	1
Splake	2
TOTAL	**722,945**

West Final 99.xls/tb1 - 10/12/99

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 1999.

Date	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*
Number of lifts	*17*	*19*	*15*	*13*	*22*	*19*	*22*	*22*	*18*	*18*
Time of first lift	*10:31*	*10:55*	*10:55*	*11:48*	*11:10*	*11:00*	*10:55*	*11:00*	*11:00*	*10:50*
Time of last lift	*18:41*	*19:05*	*18:20*	*18:50*	*18:30*	*18:56*	*18:52*	*18:00*	*17:50*	*17:30*
Operating time (hours)	*8.2*	*8.3*	*7.5*	*7.1*	*7.4*	*8.2*	*8.1*	*7.3*	*7.0*	*6.8*
Fishing time (hours)	*8.2*	*8.3*	*7.5*	*7.1*	*7.4*	*8.2*	*8.1*	*7.3*	*7.0*	*6.8*
Average water temperature (°F)	*55.1*	*54.2*	*56.3*	*58.0*	*58.1*	*58.1*	*59.0*	*58.1*	*60.0*	*60.8*
American Shad	35	84	420	128	1	23	40	66	96	195
Alewife	10	90	49	255	56	525	405	73	44	19
Blueback Herring	0	0	0	0	0	0	0	0	0	0
Gizzard Shad	20,700	19,200	16050	7,600	56,900	17,000	27,125	48,700	36,900	34,300
Hickory Shad	0	23	2	2	0	0	0	0	0	0
Striped Bass	0	0	0	0	0	0	0	0	0	0
Carp	1	0	0	2	251	6	0	0	0	1
Other species	1,353	267	147	464	203	381	358	548	1,000	3,420
TOTAL	**22,099**	**19,664**	**16,668**	**8,451**	**57,411**	**17,935**	**27,928**	**49,387**	**38,040**	**37,935**

Date	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*
Number of lifts	*18*	*19*	*19*	*24*	*20*	*16*	*6*	*4*	*20*	*22*
Time of first lift	*11:45*	*11:00*	*11:30*	*11:00*	*11:15*	*11:00*	*14:55*	*13:15*	*11:00*	*10:55*
Time of last lift	*17:25*	*17:45*	*17:30*	*18:40*	*18:35*	*18:30*	*18:30*	*18:00*	*18:15*	*17:45*
Operating time (hours)	*5.9*	*7.0*	*6.8*	*7.8*	*7.8*	*7.8*	*4.5*	*3.4*	*7.5*	*7.0*
Fishing time (hours)	*5.9*	*7.0*	*6.8*	*7.8*	*7.8*	*7.8*	*4.5*	*3.4*	*7.5*	*7.0*
Average water temperature (°F)	*60.8*	*63.5*	*64.3*	*63.0*	*65.0*	*66.4*	*66.2*	*68.9*	*70.0*	*68.0*
American Shad	248	404	39	18	338	625	388	67	63	43
Alewife	2	256	10	1	0	0	0	0	0	0
Blueback Herring	0	0	6	1	62	1,935	14	0	0	0
Gizzard Shad	19,900	34,200	48,400	22,025	30,200	14,025	1,265	13,450	29,025	28,350
Hickory Shad	3	0	0	0	0	1	0	0	0	1
Striped Bass	0	0	1	1	2	23	0	26	17	10
Carp	0	0	0	247	242	7	178	189	96	45
Other species	1,112	4,487	2,637	667	2,075	423	400	5,988	1,869	994
TOTAL	**21,265**	**39,347**	**51,093**	**22,960**	**32,919**	**17,039**	**2,245**	**19,720**	**31,070**	**29,443**

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Table 2

Continued.

Date	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*
Number of lifts	*19*	*23*	*14*	*17*	*20*	*15*	*14*	*18*	*16*	*15*
Time of first lift	*11:15*	*11:00*	*11:15*	*11:00*	*11:00*	*11:00*	*11:00*	*11:00*	*10:50*	*11:00*
Time of last lift	*18:25*	*18:30*	*17:55*	*18:30*	*18:15*	*17:45*	*18:30*	*18:45*	*18:55*	*18:50*
Operating time (hours)	*7.7*	*7.8*	*7.4*	*7.8*	*7.5*	*7.0*	*7.8*	*8.0*	*8.2*	*8.0*
Fishing time (hours)	*7.7*	*5.5*	*7.4*	*7.8*	*7.5*	*7.0*	*7.8*	*8.0*	*8.2*	*8.0*
Average water temperature (°F)	*67.3*	*69.5*	*68.6*	*69.3*	*70.4*	*70.2*	*70.7*	*71.8*	*72.0*	*73.3*
American Shad	89	113	317	696	66	388	480	265	285	161
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback Herring	4,084	3	663	269	6	1,062	1	1	4	343
Gizzard Shad	7,725	17,650	10,235	10,375	13,350	7,120	13,180	5,240	2,343	4,290
Hickory Shad	0	0	0	0	0	0	0	0	0	0
Striped Bass	180	36	19	24	27	42	31	104	36	85
Carp	89	205	14	1	318	9	27	134	62	78
Other species	956	1,106	389	1,257	574	686	5,514	649	883	640
TOTAL	**13,123**	**19,113**	**11,637**	**12,622**	**14,341**	**9,307**	**19,233**	**6,393**	**3,613**	**5,597**

Date	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*
Number of lifts	*16*	*17*	*10*	*16*	*18*	*15*	*14*	*14*	*12*	*16*
Time of first lift	*11:00*	*10:55*	*11:00*	*10:55*	*11:05*	*11:00*	*11:00*	*10:50*	*10:53*	*11:05*
Time of last lift	*18:55*	*19:05*	*17:15*	*18:55*	*18:30*	*18:30*	*18:30*	*18:30*	*17:45*	*18:45*
Operating time (hours)	*8.2*	*8.3*	*6.3*	*8.2*	*7.5*	*7.8*	*7.8*	*7.8*	*7.1*	*8.0*
Fishing time (hours)	*8.2*	*8.3*	*6.3*	*8.2*	*7.5*	*7.8*	*7.8*	*7.8*	*7.1*	*8.0*
Average water temperature (°F)	*71.1*	*71.8*	*73.6*	*73.1*	*71.8*	*72.0*	*71.8*	*73.3*	*73.3*	*73.1*
American Shad	659	243	700	111	347	89	149	183	548	36
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback Herring	65	11	2	8	1	2	3	0	0	0
Gizzard Shad	11150	4540	2440	3243	2060	3317	2748	1,302	2,534	680
Hickory Shad	0	0	0	0	0	0	0	0	0	0
Striped Bass	21	32	4	57	8	61	53	42	15	21
Carp	5	267	945	82	127	7	7	75	69	251
Other species	192	210	253	305	33	377	195	200	183	188
TOTAL	**12,092**	**5,303**	**4,344**	**3,806**	**2,576**	**3,853**	**3,155**	**1,802**	**3,349**	**1,176**

West Final 99.xls/tb2 - 10/12/99

Table 2

Continued.

Date	*02 Jun*	*03 Jun*	*04 Jun*	*Total*
Number of lifts	*15*	*14*	*8*	***709***
Time of first lift	*11:45*	*11:20*	*11:05*	**-**
Time of last lift	*18:35*	*18:30*	*16:05*	**-**
Operating time (hours)	*7.0*	*7.3*	*5.2*	***314.9***
Fishing time (hours)	*7.0*	*7.3*	*5.2*	***312.6***
Average water temperature (°F)	*76.0*	*76.5*	*77.6*	**-**
American Shad	35	89	288	***9,658***
Alewife	0	0	0	***1,795***
Blueback Herring	0	0	0	***8,546***
Gizzard Shad	494	829	610	***652,770***
Hickory Shad	0	0	0	***32***
Striped Bass	2	12	9	***1,001***
Carp	377	471	239	***5,124***
Other species	114	175	147	***44,019***
TOTAL	**1,022**	**1,576**	**1,293**	***722,945***

West Final 99.xls/tb2 - 10/12/99

Table 3

Summary of American shad transported from the Conowingo Dam West Fish Lift, 1999.

Date	Number of Shad Transported	Location	Observed Mortality	Percent Survival
25 Apr	163	Tri-County Marina	2	98.8%
27 Apr	145	USFWS - Lamar	2	98.6%
30 Apr	115	Tri-County Marina	0	100.0%
04 May	215	USFWS - Lamar	82	61.9%
	196	Tri-County Marina	1	99.5%
05 May	161	Tri-County Marina	1	99.4%
	111	Tri-County Marina	0	100.0%
07 May	175	Tri-County Marina	0	100.0%
08 May	164	Tri-County Marina	0	100.0%
	175	Tri-County Marina	1	99.4%
	170	Tri-County Marina	4	97.6%
	175	Tri-County Marina	2	98.9%
09 May	168	Tri-County Marina	2	98.8%
14 May	180	Tri-County Marina	0	100.0%
15 May	175	Tri-County Marina	12	93.1%
	170	Tri-County Marina	3	98.2%
16 May	152	Tri-County Marina	1	99.3%
	154	Tri-County Marina	3	98.1%
	152	Tri-County Marina	1	99.3%
18 May	80	USFWS - Lamar	0	100.0%
	175	Tri-County Marina	1	99.4%
19 May	103	Benner Springs	1	99.0%
	156	Tri-County Marina	0	100.0%
	175	Tri-County Marina	7	96.0%
20 May	103	USFWS - Lamar	0	100.0%
	172	Tri-County Marina	10	94.2%
21 May	156	Tri-County Marina	5	96.8%
	84	Tri-County Marina	0	100.0%
22 May	144	Tri-County Marina	3	97.9%
23 May	145	Tri-County Marina	4	97.2%
	160	Tri-County Marina	4	97.5%
	150	Tri-County Marina	1	99.3%
24 May	101	Tri-County Marina	0	100.0%
25 May	117	USFWS - Lamar	4	96.6%
	159	Tri-County Marina	0	100.0%
	160	Tri-County Marina	7	95.6%
26 May	100	Benner Springs	4	96.0%
27 May	76	USFWS - Lamar	2	97.4%
	147	Tri-County Marina	1	99.3%
28 May	125	USFWS - Lamar	11	91.2%
	119	Tri-County Marina	2	98.3%
30 May	102	Benner Springs	12	88.2%
31 May	121	USFWS - Lamar	2	98.3%
	150	Tri-County Marina	0	100.0%
	150	Tri-County Marina	25	83.3%
01 Jun	138	Tri-County Marina	0	100.0%
	54	Tri-County Marina	0	100.0%
04 Jun	85	Benner Springs	2	97.6%
	57	Tri-County Marina	2	96.5%
05 Jun	100	USFWS - Lamar	5	95.0%
TOTAL	***6,980***		***232***	**96.7%**

Table 4

Summary of American Shad transported by Maryland DNR from the Conowingo Dam West Fish Lift, 1999.

Date	Water Temp. (°F)	Number of Female Shad	Number of Male Shad	Total Number of Shad Transported
26 Apr	58.0	78	153	231
28 Apr	58.1	18	26	44
03 May	60.8	79	126	205
10 May	68.9	110	157	267
12 May	68.0	36	69	105
17 May	70.4	62	107	169
21 May	72.0	45	100	145
24 May	71.8	60	90	150
26 May	73.1	65	90	155
TOTAL		***553***	***918***	***1,471***

Table 5

Summary of blueback herring transported from the Conowingo Dam West Fish Lift, 1999.

Date	Number of Blueback Collected	Water Temp. (°F)	Number of Blueback Transported	Stocking Location	Observed Mortality	Percent Survival	D.O. (ppm) Start	D.O. (ppm) Finish	Water Temp. (°F) at Stocking Location
13 May	4,084	69.8	1,000	Little Conestoga Creek	1	99.9%	13.8	14.2	69.8
19 May	962	71.8	795	Conestoga River	0	100.0%	13.6	8.2	67.9
20 May	102	71.8	99	Lamar	1	99.0%	13.6	11.0	72.0
22 May	343	73.8	310	Little Conestoga Creek	0	100.0%	10.0	11.9	73.8
TOTAL	*5,491*		*2,204*		*2*				

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Table 6. Catch and effort for American shad taken at the Conowingo Dam West fish lift during primary collection periods[1] in 1985-1999.

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**

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, 1985-1999

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**

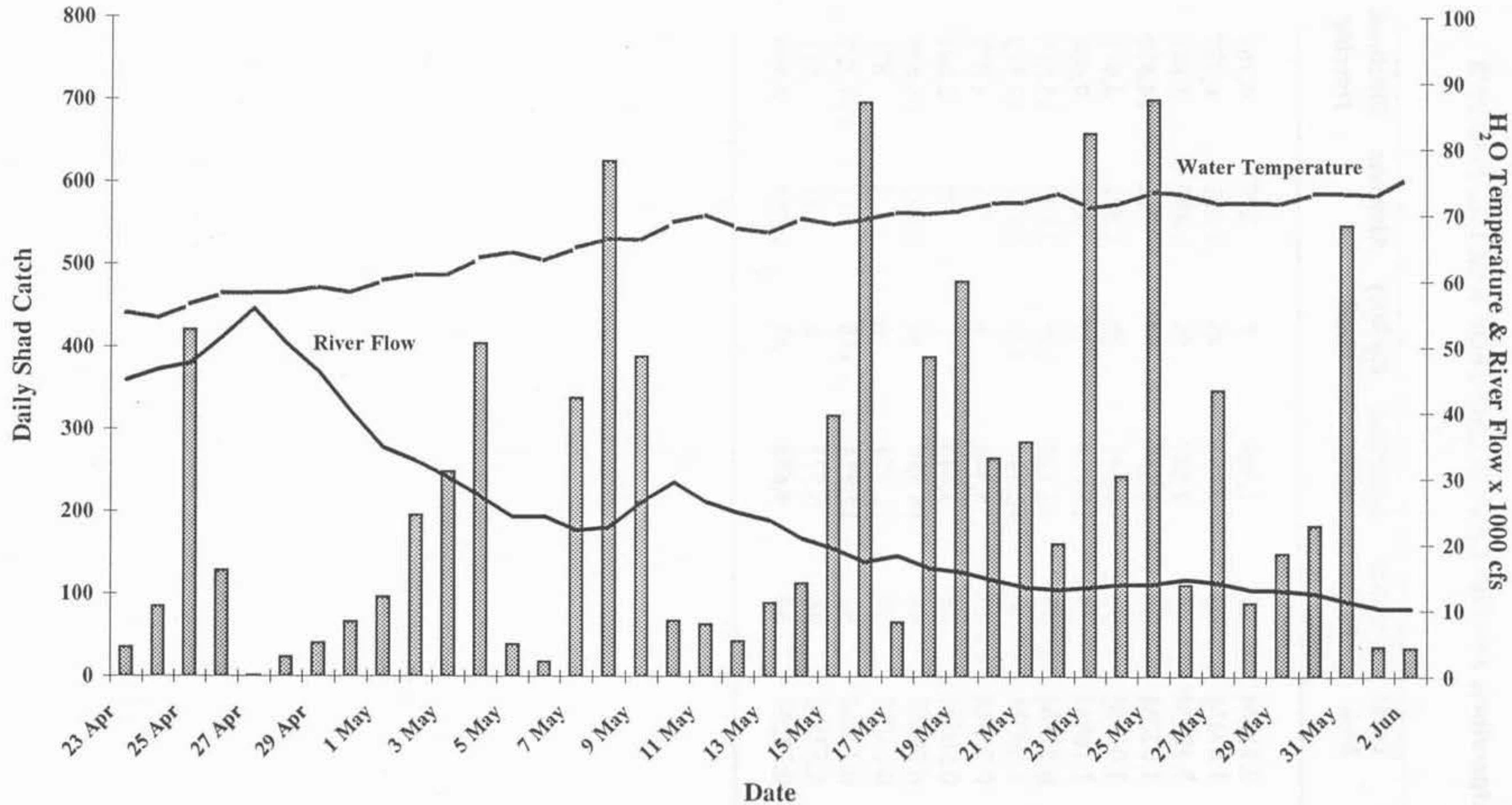

Figure 3

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 1999.

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JOB I - Part 3
SUMMARY OF THE OPERATIONS OF THE HOLTWOOD FISH PASSAGE FACILITY IN SPRING 1999

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EXECUTIVE SUMMARY

Fishway operation at Holtwood Dam began on 25 April 1999. The tailrace lift operated daily until 3 June when operation was terminated for the season. Due to low river flows and minimal spill episodes in the early part of the season, the spillway lift was operated only 21 days. Both lifts were functional 100% of the time during the 1999 season. The fishway passed an estimated 474,660 fish of 28 taxa. Gizzard shad was the dominant species and comprised nearly 91% of the total catch. *Alosa* species captured included a record 34,702 American shad and 73 blueback herring.

The majority of American shad (33,042) were passed in the tailrace lift. Collection and passage of shad varied daily with most shad (28,753) passed between 4 May and 21 May. Peak shad catch occurred between 9 and 18 May when 18,499 shad were moved upstream. On a daily basis, most shad moved through the fishway in the afternoon between 1300 hrs and 1800 hrs. Two peaks of hourly shad passage (4,531 and 4,975) occurred between 1300-1359 hrs and 1600-1659 hrs, respectively. American shad were collected and passed at water temperatures ranging from 54.1°F to 74.5°F, and river flows between 10,300 and 55,700 cfs.

In 1999, the Holtwood fishway operated without interruption for 40 days during the spring spawning season. Passage and survival of all fish that utilized the fishway was excellent. Observations indicated that anadromous fish that reached the project area were effectively captured and passed into Lake Aldred. American shad passage this year was the highest recorded since the fishway's start-up in 1997. Future operation of the fishway will build on the 1999 experience.

INTRODUCTION

On 1 June 1993 representatives of PPL, Inc. (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 and 1998. This year marked the third fish passage effort.

On 26 March 1999, a meeting of the Holtwood Fish Passage Technical Advisory Committee (HFPTAC) comprised of PPL, United States Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held at Holtwood. The meeting included discussions of, and a consensus on operation of the fishway during the 1999 spring migration season. Objectives of 1999 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 (Figure 1). 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 low river flows during spring 1999, flows that exceeded station capacity occurred only during the first seven days of fishway operation (25 April to 1 May). The summer flash boards and slick bar were installed on 5 and 6 May. The two rubber dams were always inflated during fishway operation reducing the discharge of water into the east channel of the spillway.

Fishway Design and Operation

Fishway Design

The Holtwood fishway is sized to pass a design population of 2.7 million American shad and 10 million river herring. The design incorporates numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998). The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (Figure 2). 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 is 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. Based on observation from the 1997 and 1998 fish lift operations, both the 40-ft. long, 10-ft. high rubber crest dam and the 300-ft. long, 4.75-ft. high rubber crest dam were kept inflated throughout the 1999 fish passage season since river flows were generally below station hydraulic capacity which precluded spills.

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 1999.

Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch, and managed in a flexible manner. Constant oversight by PPL and Normandeau staff ensured that when maintenance activities, and mechanical or electrical problems developed these were dealt with in a timely fashion to minimize fish lift operational interruptions. Both the tailrace and spillway lifts were functional 100% of the time throughout the 1999 season. A maintenance program that included periodic cleaning of the exit channel (10 and 20 May), nightly inspections and cleaning of picket screens and weekly lubrication of the hopper doors 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 25 April. Generally, both lifts operated daily through 14 May. The spillway lift was not operated during the installation of the summer flash boards (5 and 6 May). Flash board installation allowed the tailrace lift to operate at low forebay water level. After 14 May, the spillway lift was only operated on 3 occasions due to the lack of water flow in the spillway. Generally, the fishway was operated from 1100 hrs to 1830 hrs from 25 April to 10 May. Based on an increase in the American shad catch lift operations were extended from 0830 hrs to 1830 hrs from 10 May to 31 May. Lift operations terminated for the year on 3 June.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring 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 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 (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 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 is controlled by the technician who opens/closes a set of gates downstream of the viewing window from a controller located in the counting room. At night fish are denied passage from the fishway by closing the gate. When necessary, flow is maintained through the exit channel to insure adequate water quality conditions exist for fish held overnight.

Fish passage data is handled by two systems, a data capture system and a data processing system. The data (species and numbers passed) is recorded by the biologist/biologist technician as fish pass the viewing window on a digital notepad, a ScriptWriter XL. This device has been programmed to allow count data to be entered on a real time basis into a digital format. A time stamp feature programmed into the ScriptWriter provides a time reference for each tick mark added to the passage count. Data is entered by writing on a paper template placed on the pad, which provides a hardcopy of the daily passage record. Data processing and reporting is PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheet software.

The fish tally and time stamps are stored in the memory of the ScriptWriter as an ASCII file until the end of each day. The files are then uploaded to a PC and read into Microsoft Excel, from which a daily data listing is produced. Listings are reviewed by the biologist and corrected as necessary. After corrections are made, 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. Weekly summaries of fish passage 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 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 1999 operational period is presented in Table 1. A total of 474,660 fish of 28 taxa passed upstream into Lake Aldred. Gizzard shad (430,006) dominated the catch comprising nearly 91% of the fishes passed. American shad numbered 34,702 (7.3% of the total), the largest catch observed in the first three years of fish lift operations. Other predominant fishes passed included shorthead redhorse (2,827), walleye (1,568), smallmouth bass (1,348), carp (1,248), and quillback (1,241). Peak passage occurred on 28 May when 81,754 fish (99% gizzard shad) were passed. Other migratory species passed by the fishway included 73 blueback herring and 22 striped bass (Table 1). The majority of these fish were passed after 10 May.

American Shad Passage

The lifts passed 2,291 American shad during the first nine days of operation. Starting on 4 May passage of shad increased with nearly 83% (28,753) encountered between 4 May and 21 May.

During this peak period, the fishway collected and passed more than 1,000 shad on 8 days and passed more than 2,000 shad on 6 days. Peak catch occurred on 10 May when 2,745 shad were captured and passed in 8.5 hrs of operation.

American shad were passed at water temperatures between 54.1°F and 74.5°F and river flows ranging from 10,300 cfs to 55,700 cfs (Table 2 and Figure 3). Water temperature and river flows from 4 May to 21 May during the period when the majority of shad were passed averaged 66.6°F (63.0°F to 70.2°F) and 20,400 cfs (13,500 cfs to 27,300 cfs), respectively.

The capture of shad at the fishway occurred over a wide range of station operation and discharge conditions (Table 2). Shad were attracted into the tailrace lift at tailwater elevations that ranged from 106.3-ft. to 119.4-ft. Generally, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. Prior to 15 May, most tailrace fishway operation coincided with the operation of 10 turbines. Due to unusually low spring river flows, operation of the tailrace lift occurred with less than 10 units operating on several occasions after 15 May. Except for the first 7 days of operation, the spillway lift operated at spillway elevation 116-ft.

Passage of shad into Lake Aldred occurred at forebay elevations ranging from 164.1 ft to 171.5 ft (Table 2). Visual observations indicated that shad readily passed through the fishway into Lake Aldred at this range of forebay elevations. On 5 and 6 May, during installation of the summer flash boards and the slick bar, large numbers of shad passed by the counting window in 8-in. of water and through the fishway in just over 4-ft. of water. The hourly passage of American shad in the Holtwood fishway is provided in Table 3. Most shad (22,207) passed through the fishway during the afternoon between 1300 hrs and 1800 hrs. Generally, shad passage increased throughout the day, peaked by 1800 hrs, then declined until operation was ended each evening.

A qualitative assessment of the relative number of shad using the tailrace and spillway lifts was undertaken by viewing each hopper of fish and estimating the number of shad in each lift as they were sluiced into the trough. This information was summed by lift and applied to the daily shad passage count in an effort to determine the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 33,042 and 1,660 shad (95.2% and 4.8%), were captured in the tailrace and spillway lifts, 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 entrances to the lifts.

Operation and catch of shad in the spillway lift was dependent on flow conditions in the spillway, particularly the east channel. Most shad (1,642; 99%) were captured in the spillway lift prior to 14 May (Table 4). The catch of shad (823) prior to flash board installation (5 and 6 May) was similar to the number of shad collected (819) within the seven-day period following flash board installation. Due to low spring river flows, spill events did not occur after 1 May and flash board installation occurred earlier than in 1998. With virtually no water flowing into the spillway area, (except minimal leakage), very few shad were attracted into the spillway lift after 12 May. Hence, the spillway lift was only operated on four occasions after 13 May. On these four occasions, the lift was operated to verify the absence or low abundance of alosids in the spillway and only 18 American shad were collected.

Passage Evaluation

In 1999, fishway monitoring efforts focused on visual observations of migrating fish movements below and in the tailrace and spillway lifts to optimize future utilization of the fishways. The number of fishes observed in the tailrace was higher than those in the spillway. Fish survival in the fishways was excellent - no mortalities were observed. Debugging of the fishway occurred on an as needed basis throughout the season, and operation was modified based on visual observations of fish movement.

Equipment settings were changed in an effort to improve flows from and within the fishway to enhance its operation. As favorable conditions were identified, they were maintained. The "slick bar" successfully prevented large amounts of debris from accumulating on the fishway exit trash racks. The utilization of gate 8 reduced the vortex in the fish trough. The combination of these practices enabled operation to be conducted with the maximum volume of flow.

Daily surveys were conducted in the east channel of the spillway from the shore of Piney Island during and after spill events. No fish were observed during these surveys. In addition, a survey of the west spillway channel was conducted by two people before operation on 6 May during installation of the summer flash boards. No evidence of shad stranding was observed indicating shad can move freely in and about this area when spills into the area stop.

Video Record

In accordance with the 1999 Holtwood Fish Lift Operational Plan, a review of the 1999 video record was not conducted since the hourly rate of passage never exceeded 1,000 shad during all hours of operation. The highest hourly rate of shad passage (642) occurred on 17 May from 1300 to 1359 hrs. Fish passage was recorded on a daily basis and the video tapes archived and stored off site.

SUMMARY

In 1999, the Holtwood fish lifts operated without interruption for 40 days during the spring migratory fish passage season. Both tailrace and spillway lifts were functional 100% of the time. Fishway systems and equipment functioned as designed and only minor difficulties were encountered. Minor problems resulted from safeguards designed into the electrical and/or mechanical aspects of equipment operation.

A record 34,702 American shad were passed into Lake Aldred. Seventy-three 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 early in the season at Conowingo Dam delayed the start of operation until 25 April. The majority of American shad (33,042) were captured in the tailrace lift. Collection and passage of shad varied daily with most shad (28,753) captured and passed between 4 and 21 May. Peak shad passage occurred between 9 and 18 May when 18,499 shad were captured and passed. Most shad passed through the fishway during the afternoon between 1300 and 1800 hrs. Two peaks of hourly shad passage (4,531 and 4,975) occurred at 1300-1359 hrs and 1600-1659 hrs. American shad were collected and passed at water temperatures between 54.1°F to 74.5°F, and river flows ranging from 10,300 cfs to 55,700 cfs.

Passage and survival of fish that utilized the fishway was excellent. Observations indicated that migratory fishes that reached the project were effectively captured and passed into Lake Aldred by the Holtwood lifts. American shad passage this year was the highest recorded since the fishway's start-up in 1997. Future operation of the fishway will build on the 1999 experience.

RECOMMENDATIONS

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

2. Continue as a routine part of fishway operation, a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel, nightly inspections of picket screen; and weekly lubrication of hopper doors. Routine maintenance activities minimize disruption of fishway operation.

3. As river flow conditions permit install the "Slick Bar" in front of the fishway exit channel to deflect debris from entering and accumulating at the exit/entrance of the trough. After the "slick bar" is installed implement protocols/guidelines that utilize the hydro control room operator to spill trash by

lowering the 10-ft. rubber dam. This should be done on an as needed basis prior to the scheduled start of fishway operation.

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

5. To simplify data collection and reporting, discontinue the use of the ScriptWriter XL digitizing notepad. Develop a program that utilizes Microsoft Excel spreadsheet software to produce the daily and annual reports. Report tables will be similar to those produced in previous years.

LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Holtwood Fish Passage Facility in 1997. Report prepared for PPL, Inc., Allentown, PA.

Normandeau Associates, Inc. 1999. Summary of the operation at the Holtwood Fish Passage Facility in 1998. Report prepared for PPL, Inc., Allentown, PA.

Table 1

Summary of the daily number of fish passed by the Holtwood fish passage facility in 1999.

Date:	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*
Hours of Operation - Tailrace:	*6.3*	*6.25*	*5.75*	*7.5*	*6.75*	*7*	*8*	*7*	*7.5*	*8*	*7*
Hours of Operation - Spillway:	*6.3*	*6.25*	*5*	*7.5*	*6.75*	*7*	*5*	*7*	*7.5*	*8*	*0*
Number of Lifts - Tailrace:	*7*	*7*	*8*	*11*	*7*	*10*	*12*	*11*	*10*	*13*	*13*
Number of Lifts - Spillway:	*5*	*6*	*7*	*7*	*7*	*7*	*5*	*7*	*7*	*8*	*8*
Water Temperature (°F):	*54.1*	*54.2*	*57.4*	*58*	*58.5*	*59.2*	*60.4*	*61.3*	*62.1*	*63*	*63.7*
American Shad	1	8	72	274	103	175	82	751	825	1,166	2,008
Gizzard Shad	8,686	3,910	4,575	8,000	6,263	5,979	9,120	18,600	13,074	14,128	15,905
Alewife									1		
Blueback Herring											
Striped Bass						1					
Rainbow Trout					1			1	3		3
Brown Trout		6		2		5	1		5	3	1
Brook Trout											
Muskellunge				1							
Carp	1		8		1				5	4	4
Comely Shiner											
Quillback	6	177	173	170	102	14	18	10	18	11	3
White Sucker	12	4	1	3	82	100	49	1		11	
Northern Hogsucker							2				
Shorthead Redhorse	87	246	393	209	82	35	156	62	106	71	87
Channel Catfish				1			4	15	15		2
White Perch											
Rock Bass	4	2		1	8	11	6	3	1	4	4
Redbreast Sunfish											
Green Sunfish											
Pumpkinseed											
Bluegill					1	3			3	2	3
Smallmouth Bass	14	16	21	60	44	61	66	68	66	150	15
Largemouth Bass		1			1	2				6	1
White Crappie						1					
Yellow Perch	6	3	4			1	1	1	2		2
Walleye	82	44	26	58	53	27	29	28	91	80	10
Sea Lamprey							1			1	
Total	***8,899***	***4,417***	***5,273***	***8,779***	***6,741***	***6,415***	***9,535***	***19,540***	***14,215***	***15,637***	***18,048***

Table 1

Continued.

Date:	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Hours of Operation - Tailrace:	*5.5*	*8*	*8*	*7*	*8.5*	*9*	*9*	*10*	*9.25*	*10*	*10*
Hours of Operation - Spillway:	*0*	*8*	*8*	*7*	*8.5*	*9*	*10.5*	*10*	*9.25*	*0*	*0*
Number of Lifts - Tailrace:	*8*	*13*	*13*	*13*	*16*	*14*	*14*	*12*	*16*	*16*	*21*
Number of Lifts - Spillway:	*0*	*9*	*8*	*7*	*8*	*7*	*7*	*6*	*9*	*0*	*0*
Water Temperature (°F):	*64.2*	*64.7*	*65.7*	*66.5*	*66.2*	*66.4*	*68.1*	*68.6*	*68.7*	*69*	*68.6*
American Shad	1,185	908	760	1,434	2,745	2,358	1,265	550	2,575	1,043	2,054
Gizzard Shad	17,300	7,195	11,460	11,761	15,958	22,642	15,876	9,800	24,500	11,154	8,435
Alewife											
Blueback Herring			4	7		16	1	1	3	12	6
Striped Bass									1		
Rainbow Trout	1								4	12	17
Brown Trout	2	14	21	7	6	7	7	10	23		
Brook Trout		2						6			
Muskellunge											
Carp	5	6	26	92	48	39	13	41	33	156	151
Comely Shiner											
Quillback	14	8	63	75	6	5	1	9	4	8	12
White Sucker		2	10	6	7	1					
Northern Hogsucker											
Shorthead Redhorse	51	61	66	147	20	12		6	6	20	9
Channel Catfish	7	14	4	27	166	10	15	7	2	13	13
White Perch		2		4		3	11	2	2	2	6
Rock Bass	3		5	5	10	11	5	2	2	10	4
Redbreast Sunfish			1			4		1	1	25	5
Green Sunfish											
Pumpkinseed									1		
Bluegill		3	2	5	4	4	6		1		6
Smallmouth Bass	36	85	63	76	49	41	23	7	31	33	16
Largemouth Bass	1							2		4	6
White Crappie		9	2			2	1	2			
Yellow Perch					8		1			6	3
Walleye	23	68	70	136	101	58	39	30	34	28	24
Sea Lamprey		1					1			1	
Total	***18,628***	***8,378***	***12,557***	***13,782***	***19,128***	***25,213***	***17,265***	***10,476***	***27,223***	***12,527***	***10,767***

Table 1

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours of Operation - Tailrace:	*10.5*	*10.5*	*10.5*	*8*	*10.25*	*10*	*10.25*	*10.5*	*10.5*	*10.25*	*10*
Hours of Operation - Spillway:	*0*	*0*	*0*	*0*	*0*	*6*	*0*	*0*	*0*	*5.5*	*0*
Number of Lifts - Tailrace:	*24*	*15*	*16*	*14*	*19*	*17*	*16*	*17*	*16*	*16*	*12*
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	*0*	*6*	*0*	*0*	*0*	*5*	*0*
Water Temperature (°F):	*68*	*68.9*	*67.8*	*68*	*70.2*	*71.2*	*71.4*	*71.5*	*70.9*	*71.3*	*70.3*
American Shad	2,652	1,823	867	1,561	1,799	485	311	829	361	492	160
Gizzard Shad	17,344	8,413	4,610	4,215	3,531	6,196	4,026	6,585	2,128	6,162	5,020
Alewife											
Blueback Herring		6		5	8						
Striped Bass			1		1	6	4	3			1
Rainbow Trout			16			7	11	8			3
Brown Trout	7	2	2	4	16				2	10	
Brook Trout											
Muskellunge											
Carp	120	28	15	10	39	156	91	31	27	14	9
Comely Shiner								1			
Quillback	4	1		1	1	138	151	20	5		3
White Sucker						4		14	1	4	2
Northern Hogsucker											
Shorthead Redhorse	9	6	1		13	59	94	33	257	32	24
Channel Catfish	64	5	3	6	5	11	24	8	33	1	7
White Perch	1	6		1	7	1	2	5	2	6	
Rock Bass	21	8		4	6	6	6	2	5	1	
Redbreast Sunfish	2	1				8	9	4	8	2	
Green Sunfish		1									
Pumpkinseed											
Bluegill	27	5		3	11				5	2	
Smallmouth Bass	53	27	3	12	40	41	45	10	21	12	
Largemouth Bass									1		
White Crappie	1			1							
Yellow Perch						1	5			1	
Walleye	44	26	26	9	24	40	50	55	32	16	28
Sea Lamprey				1	1			1			
Total	***20,349***	***10,358***	***5,544***	***5,833***	***5,502***	***7,159***	***4,829***	***7,609***	***2,888***	***6,755***	***5,257***

Table 1

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	
Hours of Operation - Tailrace:	*8.75*	*9.5*	*9*	*8.3*	*8*	*8.2*	*8.2*	**342.5**
Hours of Operation - Spillway:	*0*	*7*	*0*	*0*	*0*	*0*	*0*	**155.1**
Number of Lifts - Tailrace:	*12*	*11*	*11*	*12*	*9*	*9*	*8*	**519**
Number of Lifts - Spillway:	*0*	*6*	*0*	*0*	*0*	*0*	*0*	**152**
Water Temperature (°F):	*70.1*	*70.7*	*70.9*	*72*	*72.8*	*73.3*	*74.5*	***Total***
American Shad	67	75	326	125	296	102	29	**34,702**
Gizzard Shad	81,660	3,100	1,301	2,850	1,184	6,310	1,050	**430,006**
Alewife								**1**
Blueback Herring		3	1					**73**
Striped Bass		2	2					**22**
Rainbow Trout	2	3	4				1	**97**
Brown Trout				1				**164**
Brook Trout								**8**
Muskellunge								**1**
Carp		20	3	21	13	8	10	**1,248**
Comely Shiner								**1**
Quillback			4	3	2		1	**1,241**
White Sucker	1							**315**
Northern Hogsucker								**2**
Shorthead Redhorse	3	56	99	61	132	6	10	**2,827**
Channel Catfish	1	18	14	4	12	2	1	**534**
White Perch	2							**65**
Rock Bass	2							**162**
Redbreast Sunfish	2				3			**76**
Green Sunfish					1			**2**
Pumpkinseed								**1**
Bluegill					2			**98**
Smallmouth Bass	5	7		6	20	5		**1,348**
Largemouth Bass								**25**
White Crappie								**19**
Yellow Perch						1		**46**
Walleye	9	24	9	18	7	5	7	**1,568**
Sea Lamprey								**8**
Total	***81,754***	***3,308***	***1,763***	***3,089***	***1,672***	***6,439***	***1,109***	**474,660**

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 1999.

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)
25 Apr	47,400	53.2	20	10	150	150	220	119.3 - 119.3		171.3 - 171.5
26 Apr	51,400	55.6	22	10	150	150/0	220	119.0 - 119.2	120.0	169.8 - 169.8
27 Apr	55,700	56.9	22	10	150		220	119.2 - 119.4	125.0	170.4 - 171.6
28 Apr	50,500	58.4	18	10	150		220	118.9 - 119.3	124.0 - 128.0	170.2 - 171.5
29 Apr	46,100	58.7	22	10	150		220	118.8 - 119.1	118.0 - 119.0	169.4 - 170.6
30 Apr	40,200	59.5	22	10	150		220	119.0 - 119.1	118.0 - 121.0	169.1 - 170.7
1 May	34,700	60.5	22	10	150	150/0	0/220	118.9 - 119.0	116.0 - 118.0	167.9 - 169.5
2 May	32,600	61.4	20	10	150		220	118.7 - 118.8	116.0	166.3 - 166.7
3 May	30,100	62.2	20	10	150		220	118.6 - 118.8	116.0	165.8 - 167.5
4 May	27,300	62.9	20	10	150		220	118.4 - 118.6	116.0	165.4 - 166.6
5 May	24,100	63.6	22	7 to 10	150			114.4 - 118.4	116.0	163.7 - 165.1
6 May	24,200	64.5	22	10	150			112.3 - 118.4	116.0	164.1 - 164.9
7 May	22,100	64.8	22 to 30	10	150		220	117.2 - 118.2	116.0	165.6 - 168.0
8 May	22,500	65.8	28	10	150	150	220	118.6 - 118.8	116.0	167.6 - 169.2
9 May	26,400	66.4	36	10	150	150	220	117.9 - 118.7	116.0	167.6 - 168.6
10 May	29,400	66.2	24	10	150		220	117.5 - 118.7	116.0	167.7 - 169.3
11 May	26,400	66.8	24	10	150		220	118.3 - 118.7	116.0	165.3 - 169.0
12 May	24,800	67.8	24	10	150		220	118.5 - 118.8	116.0	165.5 - 169.2
13 May	23,600	68.5	20	10	150		220	117.3 - 118.8	116.0	167.0 - 169.5
14 May	20,900	68.7	30	10	150		220	117.1 - 118.4	116.0	165.2 - 168.1
15 May	19,400	69.5	30	8 to10	150	150		115.7 - 118.8	116.0	168.6 - 169.3
16 May	17,300	68.7	30	7 to 10	150	150		114.8 - 118.5	116.0	168.2 - 169.2
17 May	18,300	68.1	24	7	150	150		114.4 - 117.4	116.0	168.8 - 169.2
18 May	16,400	68.0	22	7	150	150		112.2 - 117.4	116.0	168.5 - 169.5
19 May	15,800	68.0	22	5 to 10	150	150		112.6 - 118.6	116.0	168.3 - 169.2
20 May	14,600	68.4	20	5 to 8	150	150		113.4 - 115.5	116.0	168.8 - 169.6
21 May	13,500	70.1	26	7 to10	150	150		113.5 - 118.5	116.0	168.8 - 169.6
22 May	13,200	71.2	20	5 to 10	150	150	220	112.7 - 117.4	116.0	168.8 - 169.4
23 May	13,500	71.5	20	5 to 8	150	150		109.8 - 115.5	116.0	168.6 - 169.1
24 May	13,900	71.6	20	5 to 8	150	150		112.2 - 115.5	116.0	168.2 - 169.1
25 May	14,000	71.3	20	5 to 8	150	150		110.6 - 117.2	116.0	168.0 - 169.0

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)
26 May	14,700	71.3	22	6 to 8	150	0/150	220/0	113.0 - 115.3	116.0	167.7 - 168.3
27 May	14,200	70.5	20	5 to 8	150	150		112.0 - 118.6	116.0	168.3 - 169.7
28 May	13,200	70.1	22	5 to 8	150	150		112.1 - 117.4	116.0	168.9 - 169.4
29 May	13,000	70.3	20	0 to10		150	220	106.4 - 118.7	116.0	168.5 - 169.5
30 May	12,600	71.2	20	0 to10	150	150		106.6 - 117.3	116.0	167.8 - 169.2
31 May	11,400	72.2	17	3 to 9	150	150		109.5 - 116.4	116.0	168.4 - 169.3
1 Jun	10,400	72.9	20	1 to10	150	150		107.5 - 117.7	116.0	167.7 - 169.2
2 Jun	10,300	73.8	18	0 to10	150	150		106.3 - 116.3	116.0	168.9 - 169.5
3 Jun	11,600	74.8	18	3	150	150		106.7 - 115.4	116.0	168.7 - 169.4

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 1999.

Date:	*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):	*13:59*	*12:24*	*12:08*	*11:23*	*12:29*	*12:06*	*11:10*	*12:00*	*10:53*	*10:38*	*12:27*
Observation Time (End):	*18:46*	*18:46*	*18:00*	*19:02*	*18:57*	*18:37*	*18:45*	*19:00*	*19:04*	*19:00*	*19:10*
MILITARY TIME (HRS)											
0800 to 0859											
0900 to 0959											
1000 to 1059									-	11	
1100 to 1159				-			17		32	190	
1200 to 1259		-	1	7	18	8	26	21	72	127	7
1300 to 1359	-	2	9	20	10	12	10	51	58	62	750
1400 to 1459	-	-	26	24	15	9	7	64	35	36	485
1500 to 1559	-	1	17	48	20	93	5	122	63	57	240
1600 to 1659	-	1	17	68	25	41	13	264	140	177	237
1700 to 1759	1	3	2	54	11	11	-	149	230	313	142
1800 to 1859	-	1		53	4	1	4	80	195	193	134
1900 to 1959											13
TOTAL CATCH	**1**	**8**	**72**	**274**	**103**	**175**	**82**	**751**	**825**	**1,166**	**2,008**

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):	*11:43*	*11:15*	*11:13*	*12:03*	*8:35*	*8:32*	*8:52*	*8:33*	*9:50*	*8:45*	*8:49*
Observation Time (End):	*18:49*	*19:02*	*18:58*	*18:55*	*18:55*	*18:50*	*18:55*	*18:47*	*18:56*	*18:54*	*19:00*
MILITARY TIME (HRS)											
0800 to 0859					6	3	-	-		5	-
0900 to 0959					21	4	239	147	-	118	94
1000 to 1059					-	262	104	89	82	44	36
1100 to 1159	3	142	18		-	218	46	115	55	34	79
1200 to 1259	245	69	57	127	77	144	46	61	35	120	73
1300 to 1359	200	38	62	630	320	-	90	20	33	85	226
1400 to 1459	12	72	113	349	248	354	136	17	178	65	360
1500 to 1559	20	117	204	105	334	240	142	18	703	116	277
1600 to 1659	335	168	139	122	625	470	160	25	625	31	191
1700 to 1759	245	170	115	70	472	401	28	36	513	213	328
1800 to 1859	125	132	52	31	642	262	274	22	351	212	384
1900 to 1959											6
TOTAL CATCH	**1,185**	**908**	**760**	**1,434**	**2,745**	**2,358**	**1,265**	**550**	**2,575**	**1,043**	**2,054**

Table 3

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Observation Time (Start):	*8:05*	*8:15*	*9:00*	*9:46*	*8:25*	*8:30*	*8:22*	*8:30*	*8:10*	*8:40*	*9:00*
Observation Time (End):	*18:50*	*18:52*	*18:00*	*18:48*	*18:45*	*18:35*	*18:40*	*18:55*	*18:58*	*18:45*	*18:58*
MILITARY TIME (HRS)											
0800 to 0859	112	12			50	5	32	21	5	-	
0900 to 0959	220	142	31	-	169	50	37	208	20	6	5
1000 to 1059	150	108	113	104	212	134	29	176	47	94	5
1100 to 1159	253	66	122	-	212	79	33	114	37	38	23
1200 to 1259	424	143	108	182	337	33	35	87	57	41	31
1300 to 1359	642	131	79	299	364	22	26	44	53	42	61
1400 to 1459	316	228	76	299	170	29	29	24	-	104	17
1500 to 1559	203	312	202	255	178	30	53	26	68	81	6
1600 to 1659	171	310	57	282	64	21	20	38	53	27	5
1700 to 1759	123	276	47	107	13	57	10	59	11	52	3
1800 to 1859	38	95	32	33	30	25	7	32	10	7	4
1900 to 1959											
TOTAL CATCH	**2,652**	**1,823**	**867**	**1,561**	**1,799**	**485**	**311**	**829**	**361**	**492**	**160**

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	
Observation Time (Start):	*8:30*	*10:00*	*8:19*	*9:35*	*8:10*	*8:30*	*8:20*	
Observation Time (End):	*17:10*	*18:30*	*17:55*	*17:45*	*16:55*	*16:37*	*16:30*	*TOTAL*
MILITARY TIME (HRS)								
0800 to 0859	5		3		4	5	-	**268**
0900 to 0959	7		118	15	33	48	8	**1,740**
1000 to 1059	20	-	73	22	43	2	12	**1,972**
1100 to 1159	14	8	23	17	71	12	-	**2,071**
1200 to 1259	-	15	8	13	87	13	3	**2,958**
1300 to 1359	13	10	18	5	29	5	-	**4,531**
1400 to 1459	2	16	18	8	15	2	3	**3,961**
1500 to 1559	6	14	8	9	9	8	3	**4,413**
1600 to 1659	-	8	27	6	5	7	-	**4,975**
1700 to 1759	-	2	30	30				**4,327**
1800 to 1859		2						**3,467**
1900 to 1959								**19**
TOTAL CATCH	**67**	**75**	**326**	**125**	**296**	**102**	**29**	**34,702**

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 1999.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
25 Apr	1	1	0	100%	0%
26 Apr	8	8	0	100%	0%
27 Apr	72	70	2	97%	3%
28 Apr	274	164	110	60%	40%
29 Apr	103	103	0	100%	0%
30 Apr	175	88	87	50%	50%
1 May	82	20	62	24%	76%
2 May	751	488	263	65%	35%
3 May	825	701	124	85%	15%
4 May	1,166	991	175	85%	15%
5 May	2,008	2,008		100%	
6 May	1,185	1,185		100%	
7 May	908	681	227	75%	25%
8 May	760	570	190	75%	25%
9 May	1,434	1,290	144	90%	10%
10 May	2,745	2,608	137	95%	5%
11 May	2,358	2,313	45	98%	2%
12 May	1,265	1,201	64	95%	5%
13 May	550	538	12	98%	2%
14 May	2,575	2,575	0	100%	0%
15 May	1,043	1,043		100%	
16 May	2,054	2,054		100%	
17 May	2,652	2,652		100%	
18 May	1,823	1,823		100%	
19 May	867	867		100%	
20 May	1,561	1,561		100%	
21 May	1,799	1,799		100%	
22 May	485	473	12	98%	2%
23 May	311	311		100%	
24 May	829	829		100%	
25 May	361	361		100%	
26 May	492	487	5	99%	1%
27 May	160	160		100%	
28 May	67	67		100%	
29 May	75	74	1	99%	1%
30 May	326	326		100%	
31 May	125	125		100%	
1 Jun	296	296		100%	
2 Jun	102	102		100%	
3 Jun	29	29		100%	
Total	***34,702***	***33,042***	***1,660***	***95.2%***	***4.8%***

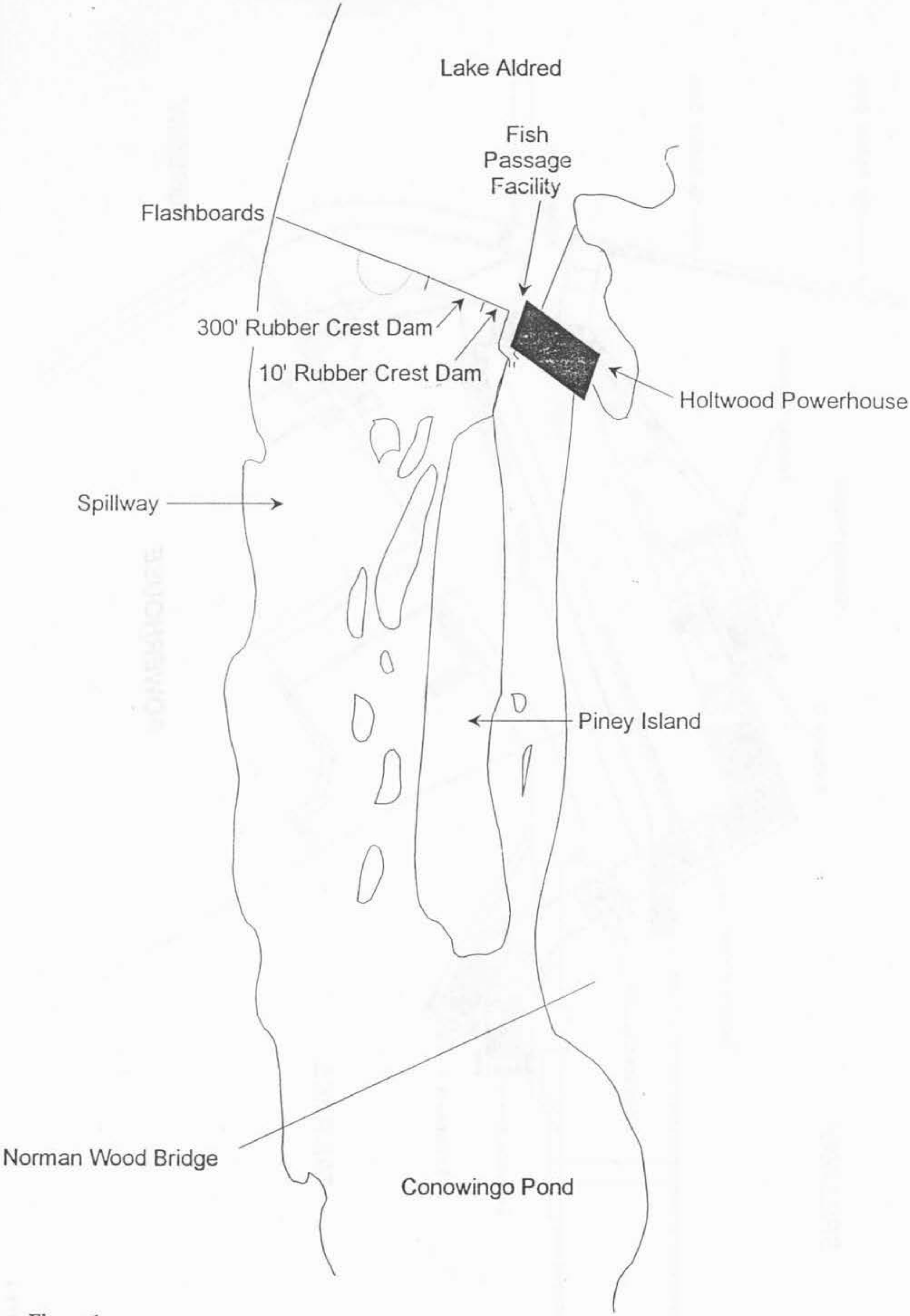

Figure 1

General layout of the Holtwood Hydroelectric Project showing the fish passage facility and associated inflatable rubber crest dams.

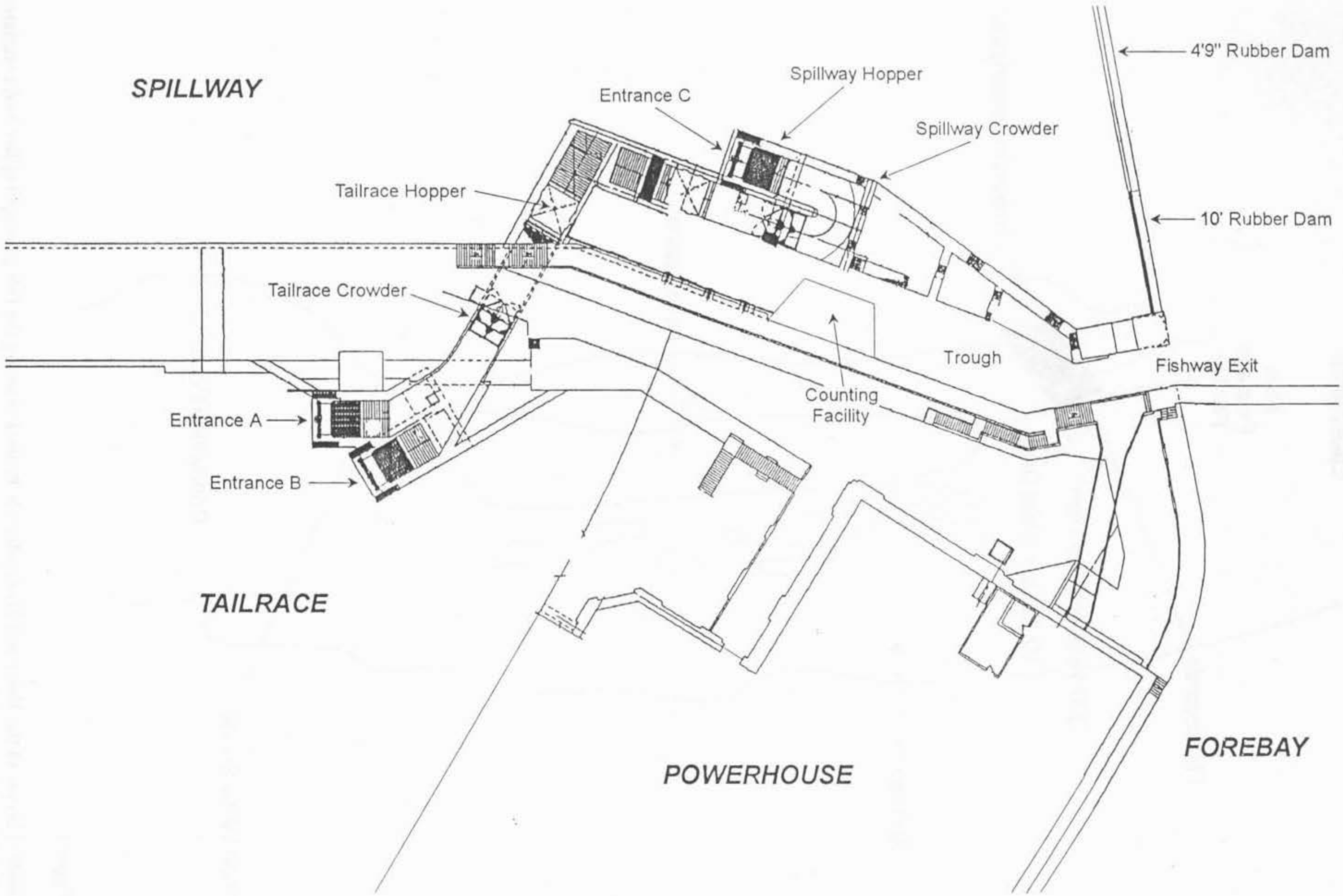

Figure 2

General layout of the Holtwood fish passage facility.

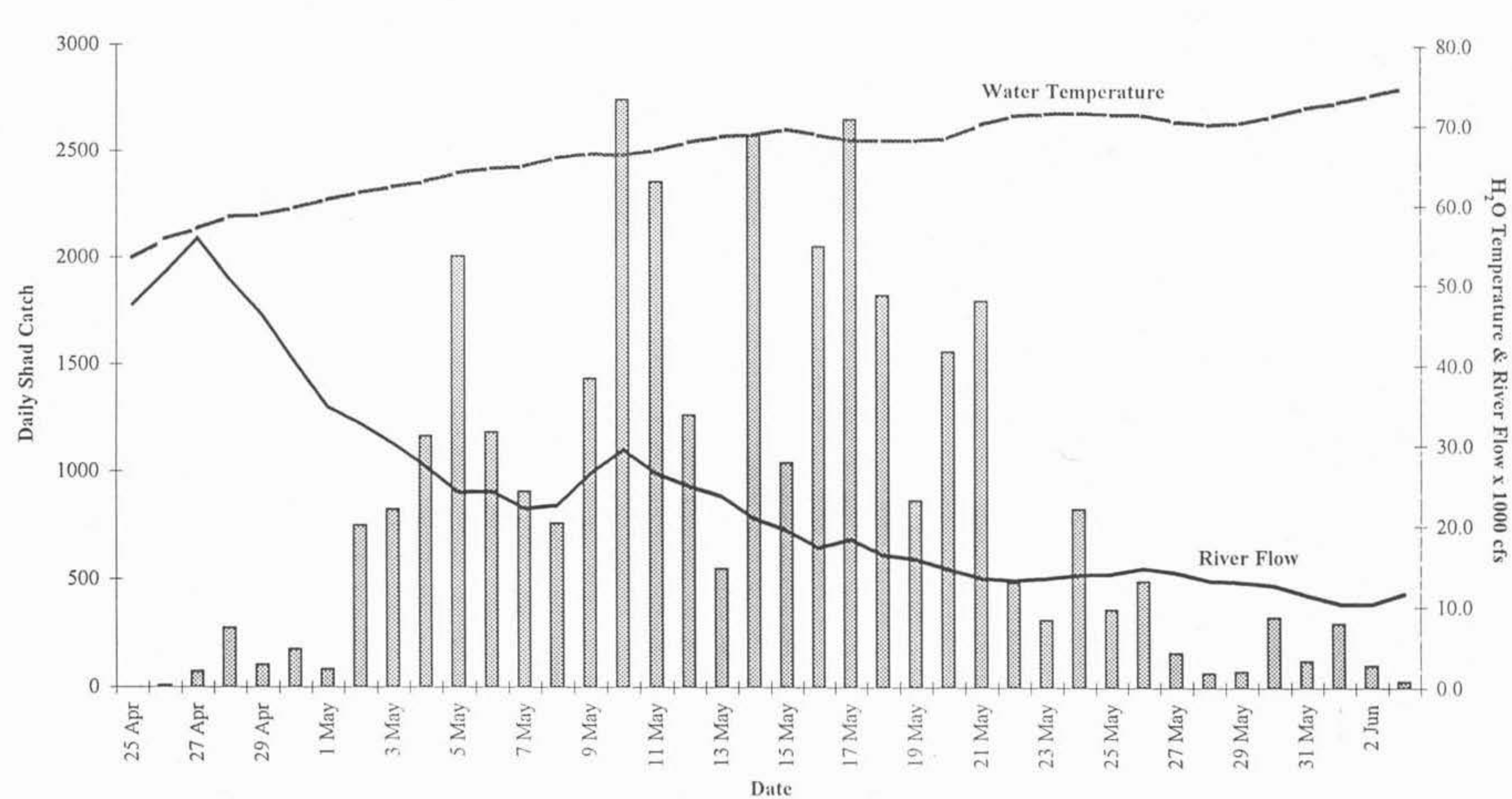

Figure 3

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 1999.

JOB I - Part 4
SUMMARY OF OPERATION AT THE SAFE HARBOR FISH PASSAGE FACILITY IN 1999

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INTRODUCTION

On June 1, 1993 representatives of Safe Harbor Water Power Corporation (SHWPC), 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 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 26 February 1999, 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. The meeting included an update of capital improvements and associated construction activities, and discussions and consensus on operation of the fishway during the 1999 spring migration season. Objectives of 1999 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATIONS

Project Operation

The Safe Harbor Hydroelectric Station is situated on the Susquehanna River (river mile 31) in Lancaster and York counties, Pennsylvania (Figure 1). 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 consisted of seven generating units. Five units were added and were 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 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.

This year, installation of a new forebay skimmer wall (replacing the original skimmer wall, destroyed by flooding in 1996) took place. This required a modification of the fishway's upper trough that would allow fish to leave the fishway upstream of the wall, and not behind it. An extension was added, moving the fishway exit into the forebay 40 feet further to the west, and past the new 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 half of the 1999 season (May 1 to May 14) utilized a combination of entrance A and C. Operation during the second half of the season utilized a combination of entrances B and C, with exception of the last day (June 7) when entrance B alone was used.

Fishway Operation

Fishway operation was scheduled to commence when 500 American shad were passed via the Holtwood Fishway, which occurred on 30 April. Operation began on 1 May and continued until 22 May, when it was temporarily discontinued after some separated cable strands in the west hopper cable were observed. The hopper cable was replaced and operations resumed on 26 May. Operations continued through 1 June, when a gearing failure of the 78-inch valve, MOV 1, ended operations. The fish lift ran again for one day, 7 June, for the purpose of testing operational parameters without the use of MOV 1. Fish lift operations were then ended for the year.

Daily operation of the Safe Harbor fishway was based 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. Though the fishway was not operational 100% of the time in 1999, it was operational for the bulk of the American shad run. Further, the effectiveness of the fishway was not impacted by the time lost, as 98% of the shad passed at the Holtwood fishway also passed at Safe Harbor.

Operations of the Safe Harbor fishway followed methods established during the 1997 and 1998 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 1997, 1998).

Fish Counts

Fish lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3-ft. wide channel on the east side of the trough. The channel is adjacent to a 4-ft. by 10-ft. window located in the counting room where fish are enumerated prior to passage from the fishway. Passage from the fishway was controlled by one gate located downstream of the window. Generally, fish passage was controlled by the technician, who opened/closed a set of gates downstream of the viewing window from a controller located in the counting room. Once shad passage increased, fish were denied passage from the fishway by closing the gates downstream of the window each night.

A 1,500 watt halogen lamp mounted above the viewing window and three adjustable 500 watt underwater lights (two at mid-depth on either side of the window and one on the bottom) gave the biologist and/or technician a degree of control over lighting conditions at the window. Overhead and underwater light intensity was adjusted daily, based on the constantly changing ambient light conditions in an effort 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.

Fish passage data were handled by two systems, a data capture system and a data processing system. The data (species and numbers passed) were recorded by the technician as the fish passed the viewing window on a digital note pad, a ScriptWriter XL, which had been programmed to allow count data to be entered on a real time basis into a digital format. A time stamp feature programmed into the ScriptWriter provided a time reference for each tick mark added to the passage count. Data were entered by writing on a paper template placed on the pad, which provided a hardcopy of the daily passage record. Data processing and reporting were PC based and accomplished by program scripts, or macros, created within Microsoft Excel software.

The fish tally and time stamps were stored in the memory of the ScriptWriter as an ASCII file until the end of operation each day. The file(s) was then uploaded to a PC and read into Microsoft Excel, from which a daily data listing was produced. Listings were reviewed by the technician and corrected as necessary. After corrections were made, a daily summary of fish passage was produced and distributed to plant personnel. Each day's data were backed up to a diskette and stored off site. 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 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 motion and frame by frame. When shad passage exceeded 1,000 in an hour, a technician reviewed that segment of tape, and the number of shad passing the window during that time period was counted.

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed by the Safe Harbor fishway is presented in Table 1. A total of 427,223 fish of 32 taxa passed upstream into Lake Clarke. Gizzard shad (361,093) was the dominant species passed and comprised almost 85% of the catch. Some 34,150 American shad were passed upstream through the fishway. Other predominant fishes passed included walleye (11,632), quillback (9,824), smallmouth bass (3,714), and shorthead redhorse (3,172). Peak passage occurred on the first day of fish lift operation, May 1, when 36,969 fish were passed.

Passage of American Shad and Other Alosids

The Safe Harbor fishway passed 34,150 American shad in 1999 during 29 days of operation (Table 1), the highest number passed in three seasons of operation. Though collection and passage of shad varied daily, numbers remained relatively steady through most of May with over 70% (24,022) of the catch passing in the two week period prior to 22 May. Peak shad passage occurred on 11 May when 2,915 shad were captured and passed in approximately 12 hours of operation.

American shad were passed at water temperatures of 59.8°F to 76.0°F and river flows of 34,700 to 7,500 cfs (Table 2 and Figure 2). Water temperature and river flow from 8 May to 21 May, a period that includes the most significant peak in shad passage averaged 67.2°F (65.0°F to 70.0°F) and 20,664 cfs (29,400 cfs to 13,500 cfs), respectively.

The hourly passage of American shad in the Safe Harbor fishway is given in Table 3. Shad passage varied daily with nearly 90% of shad (30,638) passing between 0800 and 1659 hrs. Peak hourly passage (4,532) occurred between 1100 and 1159 hrs. Although no obvious trend was evident the catch declined after 1700 hrs.

Passage of other alosids was limited to 30 blueback herring and 1 alewife (Table 1). No hickory shad were observed. Although numbers passed were small, the Safe Harbor fishway passed over 41% of the other alosids (74) that passed into Lake Aldred via the Holtwood fishway.

Video Record

All shad passage was captured on video in 1999. As recommended in 1998, a count review of these records was done when hourly shad passage exceeded 1,000 fish. This occurred once during the season, from 0800 to 0859 hrs on 11 May. The original visual count for that hour was 1,129. A review of the video record yielded a count of 1,099, a 2.7% difference. Similar reviews of fish passage conducted in 1997 and 1998 showed negligible differences, with counts either identical or differing by 1.0% to 2.0%. These results verify that at this level of passage, visual counts conducted during daily operation accurately reflected shad passage.

SUMMARY

The 1999 Safe Harbor fishway operating season was very successful, passing more American Shad than the previous two seasons combined. Although mechanical problems interrupted fishway operations late in the season, this did not significantly impact the overall effectiveness of the lift. In 29 days 34,150 American shad were passed into Lake Clarke, or over 98% 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. Few other alosids (30 blueback herring, 1 alewife) were passed by the Safe Harbor fishway.

Debugging of the fishway occurred daily throughout the season, and operation was modified based on equipment availability and visual observations of fish movement. Throughout the season operating personnel made modifications to lift operation based on visual observations of fish movement into and through the fishway to enhance capture and passage. Generally, fish survival in the fishway was excellent with little mortality observed.

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 as it provides a backup record. However, discontinue tape review unless hourly passage exceeds 1,000 shad.

To simplify data collection and reporting, discontinue the use of the ScriptWriter XL digitizing note pad. Develop a program that utilizes Microsoft Excel spreadsheet software to produce the daily and weekly reports. Report tables will be similar to those produced in previous years.

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 by Normandeau Associates, Inc., Muddy Run Ecological Laboratory, Drumore, Pennsylvania.

Normandeau Associates, Inc. 1999. Summary of operation at the Safe Harbor Fish Passage Facility in 1998. Prepared for Safe Harbor Water Power Corporation by Normandeau Associates, Inc., Muddy Run Ecological Laboratory, Drumore, Pennsylvania.

Table 1

Number and disposition of fish passed by the Safe Harbor fishway in 1999.

Date:	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*
Hours Of Operation:	*8.3*	*5.7*	*6.3*	*6.8*	*6.0*	*6.9*	*6.8*	*8.0*
Start Time:	*10:30*	*10:49*	*10:00*	*10:30*	*10:30*	*11:20*	*10:30*	*10:30*
End Time:	*18:50*	*16:30*	*16:15*	*17:20*	*17:20*	*18:15*	*18:17*	*18:30*
Numbers Of Lifts:	*25*	*13*	*14*	*17*	*21*	*17*	*19*	*17*
Water Temperature (F):	*59.8*	*60.6*	*62.0*	*62.0*	*63.0*	*65.0*	*57.0*	*65.0*
American Shad	464	129	417	889	936	1743	1221	933
Gizzard Shad	34415	5880	18000	27700	16935	8750	12280	7565
Alewife				1				
Blueback Herring								
Striped Bass								
Rainbow Trout					1			
Brown Trout	2	3	2	1		3	1	1
Brook Trout						1		
Palomino (Rainbow) Trout								
Muskellunge								
Carp	18	8	13	4	107	362	76	23
Quillback	581	508	195	72	251	473	1350	798
White Sucker		2			5			2
Northern Hogsucker				1				
Shorthead Redhorse	382	415	295	120	144	397	610	276
Yellow Bullhead								
Brown Bullhead	1							
Channel Catfish	2	1	14	12	3	1	37	67
White Perch								
Rock Bass	14	8	13	10	1	16	32	22
Redbreast Sunfish	2		1	1	1	1	3	7
Green Sunfish		1			1			
Pumpkinseed	1							1
Bluegill	1		5	1	2	4	5	1
Smallmouth Bass	743	201	445	355	169	152	285	283
Largemouth Bass	2	1	1	1	1	2	2	
White Crappie								1
Black Crappie	1				1		1	
Yellow Perch	1	1		1		4	3	1
Walleye	338	157	435	355	84	517	1645	332
Sea Lamprey						1	1	1
Tiger Muskie	1					1		
Splake (Brook x Lake Trout)								
Total	**36,969**	**7,315**	**19,836**	**29,524**	**18,642**	**12,428**	**17,552**	**10,314**

Table 1

Continued.

Date:	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Hours Of Operation:	*7.0*	*11.3*	*12.0*	*11.8*	*10.8*	*8.4*	*10.6*	*10.9*
Start Time:	*10:30*	*8:03*	*7:27*	*7:23*	*8:00*	*10:55*	*8:00*	*8:18*
End Time:	*17:30*	*19:20*	*19:29*	*19:10*	*18:50*	*19:20*	*18:34*	*19:10*
Numbers Of Lifts:	*17*	*27*	*29*	*26*	*27*	*21*	*30*	*24*
Water Temperature (F):	*65.0*	*64.8*	*65.8*	*67.1*	*68.0*	*69.0*	*69.0*	*68.0*
American Shad	903	1212	2915	2327	1269	1004	2013	1553
Gizzard Shad	12950	18540	22132	17400	23920	23800	18500	9345
Alewife								
Blueback Herring						1		5
Striped Bass						1		
Rainbow Trout								
Brown Trout	3	4	6	4	7	6	3	
Brook Trout								
Palomino (Rainbow) Trout								
Muskellunge		1						
Carp	7	11	12	75	23	21	25	9
Quillback	377	128	89	730	329	1100	765	13
White Sucker							3	2
Northern Hogsucker								
Shorthead Redhorse	67	32	36	101	56	42	36	1
Yellow Bullhead								
Brown Bullhead								
Channel Catfish	19	12	28	9	45	366	42	8
White Perch							2	
Rock Bass	45	48	59	78	89	93	25	7
Redbreast Sunfish		2	5		12	3		1
Green Sunfish		1	2					1
Pumpkinseed								
Bluegill	10	1		22	19	11		
Smallmouth Bass	117	46	79	101	121	99	223	14
Largemouth Bass		6	1	6	2	1	4	2
White Crappie		1	1		253		2	
Black Crappie		4	1	4	2	2		
Yellow Perch	1	6	1	1	1	3		
Walleye	224	397	940	899	948	1110	837	164
Sea Lamprey			1	2	1	1		1
Tiger Muskie						1		
Splake (Brook x Lake Trout)								
Total	**14,723**	**20,452**	**26,308**	**21,759**	**27,097**	**27,665**	**22,480**	**11,126**

Table 1

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*
Hours Of Operation:	*10.1*	*10.8*	*9.9*	*8.8*	*7.6*	*	*	*
Start Time:	*8:40*	*8:00*	*8:20*	*9:20*	*8:00*			
End Time:	*18:45*	*18:45*	*18:15*	*18:05*	*15:35*			
Numbers Of Lifts:	*22*	*27*	*29*	*22*	*19*			
Water Temperature (F):	*66.0*	*66.0*	*68.0*	*70.0*	*69.0*			
American Shad	2532	2891	1941	848	1681			
Gizzard Shad	8310	10130	13750	5600	7350			
Alewife								
Blueback Herring		1	2					
Striped Bass								
Rainbow Trout	1							
Brown Trout	4	12	5	8				
Brook Trout								
Palomino (Rainbow) Trout			1					
Muskellunge								
Carp		4	90	33	4			
Quillback	18	35	1345	87	153			
White Sucker								
Northern Hogsucker								
Shorthead Redhorse	2	3	8	6	4			
Yellow Bullhead								
Brown Bullhead								
Channel Catfish	18	21	128	211	60			
White Perch					1			
Rock Bass	2	38	30	10	4			
Redbreast Sunfish	3	7		1	2			
Green Sunfish								
Pumpkinseed								
Bluegill	3	9	6	11	10			
Smallmouth Bass	19	45	35	49	41			
Largemouth Bass								
White Crappie		2	3	2	5			
Black Crappie	1	1						
Yellow Perch		2	1					
Walleye	183	209	428	344	133			
Sea Lamprey								
Tiger Muskie								
Splake (Brook x Lake Trout)		1						
Total	**11,096**	**13,411**	**17,773**	**7,210**	**9,448**	**0**	**0**	**0**

* Lift operations suspended due to mechanical failure

Table 1

Continued.

Date:	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*
Hours Of Operation:	*	*4.7*	*9.8*	*8.4*	*5.0*	*5.9*	*5.0*	*7.4*
Start Time:		*14:30*	*7:55*	*10:30*	*8:00*	*7:15*	*8:00*	*9:15*
End Time:		*19:11*	*17:45*	*19:05*	*13:00*	*13:10*	*13:00*	*16:37*
Numbers Of Lifts:		*14*	*22*	*13*	*8*	*8*	*7*	*12*
Water Temperature (F):		*71.0*	*69.5*	*68.5*	*68.4*	*71.0*	*72.0*	*76.0*
American Shad		2332	1009	368	54	126	159	247
Gizzard Shad		5350	3975	2030	10290	5015	1250	9920
Alewife								
Blueback Herring		14	1	4	1		1	
Striped Bass								
Rainbow Trout			1			2		
Brown Trout				1				
Brook Trout								
Palomino (Rainbow) Trout								
Muskellunge		1						
Carp		6	11	6				3
Quillback		29	260	112	6	2	6	12
White Sucker								
Northern Hogsucker								
Shorthead Redhorse		3	63	54	5		1	13
Yellow Bullhead								
Brown Bullhead								
Channel Catfish		58	31	46	3		4	32
White Perch								
Rock Bass		4	3	5			2	1
Redbreast Sunfish		1		2	2	2	2	1
Green Sunfish					1	1		
Pumpkinseed						3		
Bluegill		4	18	3	1	5	1	4
Smallmouth Bass		15	29	15	4	1	16	10
Largemouth Bass				4				
White Crappie				2		1	2	
Black Crappie		1				1		
Yellow Perch								
Walleye		144	305	130	26	25	186	125
Sea Lamprey		1	1					
Tiger Muskie								
Splake (Brook x Lake Trout)								
Total	**0**	**7,963**	**5,707**	**2,782**	**10,393**	**5,184**	**1,630**	**10,368**

* Lift operations suspended due to mechanical failure

Table 1

Continued.

Date:	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*TOTAL*
Hours Of Operation:	*	**	*	*	*	*3.7*	**234.5**
Start Time:						*8:27*	
End Time:						*12:10*	
Numbers Of Lifts:		*0*				*6*	**553**
Water Temperature (F):						*75.0*	
American Shad		33				1	**34,150**
Gizzard Shad						11	**361,093**
Alewife							**1**
Blueback Herring							**30**
Striped Bass							**1**
Rainbow Trout							**5**
Brown Trout							**1**
Brook Trout							**1**
Palomino (Rainbow) Trout							**1**
Muskellunge							**2**
Carp							**951**
Quillback							**9,824**
White Sucker							**14**
Northern Hogsucker							**1**
Shorthead Redhorse							**3,172**
Yellow Bullhead						1	**1**
Brown Bullhead							**1**
Channel Catfish						3	**1,281**
White Perch							**3**
Rock Bass						1	**660**
Redbreast Sunfish							**62**
Green Sunfish						2	**10**
Pumpkinseed							**5**
Bluegill							**157**
Smallmouth Bass						2	**3,714**
Largemouth Bass							**36**
White Crappie						2	**277**
Black Crappie							**20**
Yellow Perch							**27**
Walleye						12	**11,632**
Sea Lamprey							**11**
Tiger Muskie							**3**
Splake (Brook x Lake Trout)							**1**
Total	**0**	**33**	**0**	**0**	**0**	**35**	**427,223**

* Lift operations suspended due to mechanical failure

** No lift operation, fish counted were held over in trough from previous catch

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 1999.

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)
1 May	34,700	59.8	<18	9	3 to 9,11,12	A & C	500	173.7-171.2	226.4-225.9
2 May	32,600	60.6		7	3 to 7,9,11	A & C	500	172.0-169.7	226.6-226.4
3 May	30,100	62.0		9	2 to 9,12	A & C	500	172.66-168.9	225.99-226.1
4 May	27,300	62.0		8	2 to 7,9,11	A & C	500	172.2-168.8	226.3-225.9
5 May	24,100	63.0		4	5,6,8,9	A & C	500	169.62-170.1	226.8-226.3
6 May	24,200	65.0		4	5,6,8,9	A & C	500	169.8-170.0	226.6-225.9
7 May	22,100	57.0		7	3 to 9	A & C	500	170.4-169.1	226.9-225.4
8 May	22,500	65.0		7	3 to 7,9,12	A & C	500	171.1-169.1	226.5-225.4
9 May	26,400	65.0		5	3 to 7	A & C	500	170.4	227.0
10 May	29,400	64.8		7	1 to 7	A & C	500	170.46-170.3	226.94-226.2
11 May	26,400	65.8		7	1 to 7	A & C	500	169.2-169.3	226.88-225.3
12 May	24,800	67.1		6	1 to 6	A & C	500	169.35-168.9	226.62-224.4
13 May	23,600	68.0		4	1,2,8,9	A & C	500	170.6-168.1	226.8-226.7
14 May	20,900	69.0		7	2 to 7,9	B & C,A & C	500	168.9-170.8	226.9-225.3
15 May	19,400	69.0	<18	5	3 to 7	A & C	500	171.0-169.7	226.5-225.6
16 May	17,300	68.0		4	2,4 to 6	B & C	500	169.4-170.0	226.8-226.6
17 May	18,300	66.0		4	1,2,5,6	B & C	500	169.8-169.6	226.9-226.6
18 May	16,400	66.0	<18	4	1,2,5,6	B & C	500	169.5-169.6	226.9-226.4
19 May	15,800	68.0		5	1,2,4 to 6	B & C	500	169.8-169.7	226.6-226.4
20 May	14,600	70.0	<18	4	1,2,5,6	B & C	500	169.7-169.5	226.7-226.2
21 May	13,500	69.0		4	1,2,5,6	B & C	500	169.7-170.0	226.7-226.8
22 May	13,200	-							
23 May	13,500	-							
24 May	13,900	-							
25 May	14,000	-							
26 May	14,700	71.0		3	2,5,6	B & C	500	168.4-170.9	226.9-226.4
27 May	14,200	69.5	<18	3	2,5,6	B & C	500	169.2-170.1	227.1-226.3
28 May	13,200	68.5	<18	3	2,5,6	B & C	500	169.38-169.9	226.67-225.6
29 May	13,000	68.4		2	2,6	B & C	500	169.0-169.4	226.6-227.0
30 May	12,600	71.0		2	2,6	B & C	500	168.6-170.3	226.6-227.0
31 May	11,400	72.0		2	2,6	B & C	500	169.3-169.5	226.5-226.8
1 Jun	10,400	76.0		2	1,3	B & C	500	169.1	226.9
2 Jun	10,300	-							
3 Jun	11,600	-							
4 Jun	9,800	-							
5 Jun	9,000	-							
6 Jun	9,100	-							
7 Jun	7,500	75.0		3	1,2,9	B	250	169.6-169.3	226.3-226.3

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 1999.

Date:	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*
Observation Time (Start):	*11:00*	*10:40*	*10:39*	*10:40*	*10:50*	*10:50*	*10:25*	*10:45*	*11:00*	*7:48*
Observation Time (End):	*18:50*	*16:30*	*16:15*	*17:20*	*17:20*	*18:15*	*18:17*	*18:30*	*17:30*	*19:20*
MILITARY TIME (HRS)										
0700 To 0759										1
0800 To 0859										115
0900 To 0959										464
1000 To 1059		3	24	-	1	20	10	5		122
1100 To 1159	113	21	100	354	426	68	294	242	167	98
1200 To 1259	100	45	140	100	159	635	366	160	162	66
1300 To 1359	97	30	68	167	116	387	176	273	132	85
1400 To 1459	48	13	36	77	51	223	139	93	180	125
1500 To 1559	53	16	49	51	134	167	68	37	173	64
1600 To 1659	27	1		105	29	136	82	52	59	13
1700 To 1759	16			35	20	98	81	36	30	22
1800 To 1859	10					9	5	35		25
1900 To 1959										12
2000 To 2059										
TOTAL CATCH	**464**	**129**	**417**	**889**	**936**	**1,743**	**1,221**	**933**	**903**	**1,212**

Table 3

Continued.

Date:	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*
Observation Time (Start):	*7:45*	*7:30*	*7:40*	*10:38*	*8:17*	*8:18*	*7:45*	*7:42*	*7:45*	*9:02*
Observation Time (End):	*19:29*	*19:10*	*18:50*	*19:20*	*18:34*	*19:10*	*18:45*	*18:45*	*18:15*	*18:05*
MILITARY TIME (HRS)										
0700 To 0759	142	104	39				-	12	25	
0800 To 0859	1,129	744	262		35	190	56	105	20	
0900 To 0959	371	370	192		740	191	312	640	342	14
1000 To 1059	179	245	178	23	260	305	496	590	729	255
1100 To 1159	135	182	136	206	204	175	421	360	265	201
1200 To 1259	161	97	110	219	253	178	362	200	183	100
1300 To 1359	143	131	28	156	238	88	255	163	137	83
1400 To 1459	164	107	46	118	102	83	22	400	108	82
1500 To 1559	78	82	93	74	69	52	93	110	67	50
1600 To 1659	166	68	63	45	55	96	170	125	12	33
1700 To 1759	122	91	76	62	44	108	164	101	50	26
1800 To 1859	97	90	46	48	13	78	81	85	3	4
1900 To 1959	28	16		53		9	100			
2000 To 2059										
TOTAL CATCH	**2,915**	**2,327**	**1,269**	**1,004**	**2,013**	**1,553**	**2,532**	**2,891**	**1,941**	**848**

Table 3

Continued.

Date:	*21 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*3 Jun*	*7 Jun*	***TOTAL***
Observation Time (Start):	*7:44*	*14:34*	*8:20*	*10:44*	*8:00*	*8:00*	*8:30*	*9:13*	*	*10:00*	
Observation Time (End):	*15:35*	*19:11*	*17:45*	*19:05*	*13:00*	*13:10*	*13:00*	*16:37*		*12:10*	
MILITARY TIME (HRS)											
0700 To 0759	-										**323**
0800 To 0859	475		174		10	39	-				**3,354**
0900 To 0959	501		187		15	38	79	28			**4,484**
1000 To 1059	208		165	5	7	21	29	37		1	**3,918**
1100 To 1159	113		99	47	9	14	21	61		-	**4,532**
1200 To 1259	100		78	97	-	12	30	45		-	**4,158**
1300 To 1359	109		76	47	13	2		37			**3,237**
1400 To 1459	120	-	104	-							**2,441**
1500 To 1559	55	305	67	25				38			**2,070**
1600 To 1659		1,012	29	65				1			**2,444**
1700 To 1759		572	30	62							**1,846**
1800 To 1859		321		20							**970**
1900 To 1959		122									**340**
2000 To 2059											**0**
TOTAL CATCH	**1,681**	**2,332**	**1,009**	**368**	**54**	**126**	**159**	**247**	**33**	**1**	**34,150**

*No time data recorded

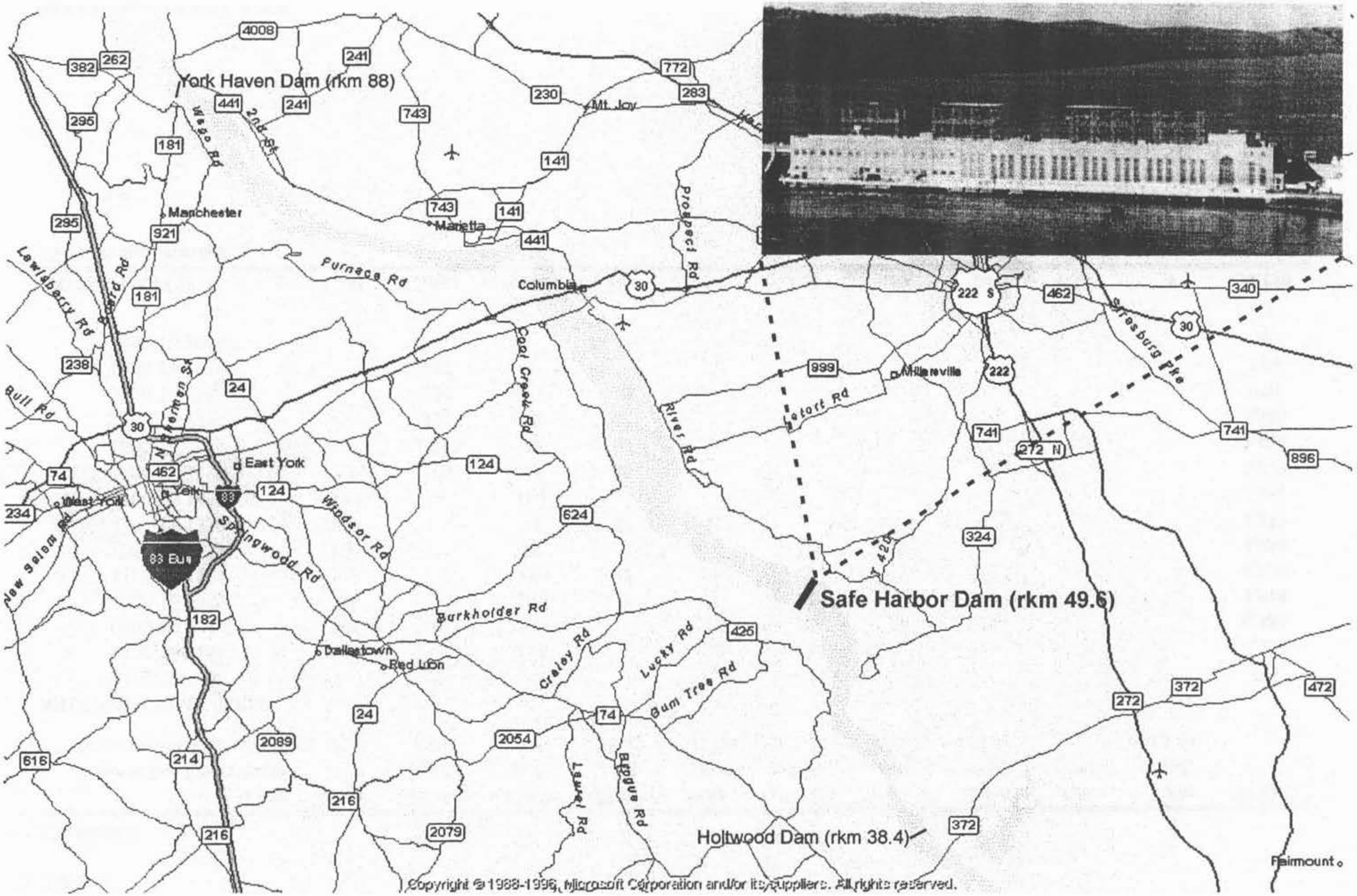

Figure 1

Location of the Safe Harbor Hydroelectric Station on the lower Susquehanna River.

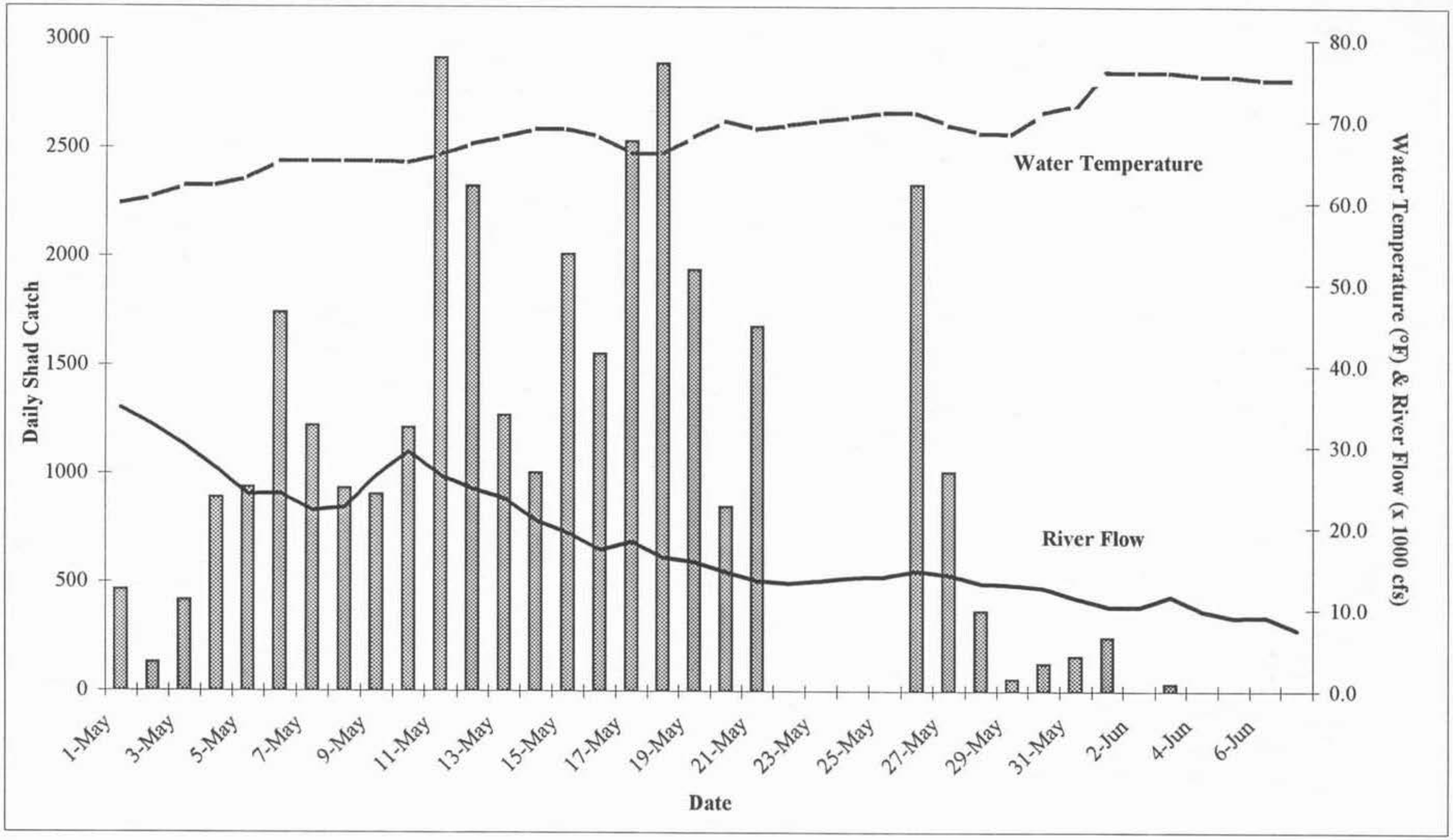

Figure 2

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 1999.

JOB II - Part 1

AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER IN 1999

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INTRODUCTION

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

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. was contracted to capture ripe adult shad on the spawning grounds during spawning activity, artificially fertilize the eggs, and deliver them to the hatchery. The objective in 1999 was to deliver 10 to 20 million fertilized American shad eggs with a viability of 60-70 percent.

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

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. 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.

Messrs. Nack and Lake began gill netting for shad in the second week of April. They were initially contracted 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 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 Messrs. 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 last week of April 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 68°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 to date, 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.

Shad were captured by gill net and haul seine. 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 123). The primary collection site in 1999 was Coxsackie. 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. Ready for shipment the bags were placed into coolers and labeled with river location, date, quantity 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 their estimated arrival time.

RESULTS AND DISCUSSION

The first crew began sampling on May 3. The second crew started gill netting on May 4. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on May 29 when water temperature reached 68°F. Sampling occurred on 23 dates during this period including 39 boat-days of gill netting. Haul seining was not used during the 1999 shad fishing season.

A total of 21.1 million eggs were shipped to the Van Dyke Hatchery (Table 2). Hudson River egg collection in 1999 exceeded that of 1991 when 17.6 million eggs were taken. All of the eggs came from the Coxsackie site. The Cheviot and Castleton sites were unsuccessful in producing eggs. The goal of 60-70% viability was achieved with an average of 69.2% and a range from 59% to 79% in individual shipments.

Eggs were collected over a period of 23 days from May 3 to May 29. Examination of daily results (Table 3) shows that eggs were available on a consistent basis at Coxsackie. Because of this success less effort was made, compared to past years, in finding new sites. Boat 1 began collection efforts on May 3 and ended on May 29. Boat 2 joined the collection efforts on May 4 and ended on May 27. Weather conditions did not hamper egg collection in 1999. Water temperature increased gradually contributing in part to consistent collection of eggs.

Each year since 1991, The Wyatt Group has cooperated with the U. S. Fish and Wildlife Service (USFWS) to provide American shad carcasses taken from the Hudson River for the purpose of examining wild shad for bacteria and viral infections. A representative of the USFWS Fish Health Unit at Lamar, PA met the egg collecting crew on May 5 and examined carcasses of unintentional mortalities from that night's sampling efforts. No pathogens were identified.

SUMMARY

A total of 21.1 million American shad eggs were collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 1999. The number of eggs collected this year exceeded that of 1991 when 17.6 million eggs were taken. 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 69.2%, meeting 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, 1983-1999.

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	15.68	26.02
1999	5.49	21.10	26.59
Totals	130.65	122.20	252.85

TABLE 2. Collection data for American shad eggs, Hudson River, New York, 1999.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability	Gear
3-May	Coxsackie	10.7	333,817	1	56	79.7	Gill
4-May	Coxsackie	44.5	1,450,227	2	58	79.4	Gill
5-May	Coxsackie	53.5	1,919,060	4	58	69.1	Gill
6-May	Coxsackie	65.5	2,766,297	6	59	66.7	Gill
8-May	Coxsackie	70.3	2,469,147	7	60	68.7	Gill
9-May	Coxsackie	63.7	2,308,988	9	60	62.0	Gill
10-May	Coxsackie	62.6	2,643,819	10	60	60.7	Gill
11-May	Coxsackie	58.5	1,969,095	13	61	66.2	Gill
12-May	Coxsackie	10.6	349,202	15	61	69.2	Gill
13-May	Coxsackie	26.2	881,885	16	62	63.2	Gill
15-May	Coxsackie	23.1	846,108	17	63	72.0	Gill
16-May	Coxsackie	18.0	638,916	19	64	59.5	Gill
19-May	Coxsackie	7.8	303,930	22	64	70.1	Gill
20-May	Coxsackie	13.1	489,894	25	65	79.1	Gill
22-May	Coxsackie	12.8	435,477	26	67	73.6	Gill
23-May	Coxsackie	5.0	185,055	28	67	65.3	Gill
24-May	Coxsackie	5.7	208,780	30	67	75.4	Gill
25-May	Coxsackie	5.0	175,615	32	67	55.6	Gill
26-May	Coxsackie	15.0	545,758	33	68	75.8	Gill
27-May	Coxsackie	5.0	181,076	34	66	73.2	Gill
Total		576.6	21,102,146	20	63	69.2	

TABLE 3. Summary of American shad egg collections, Hudson River, New York, 1999.

		Water	Eggs Shipped			Shad Collected		
Site	Date	Temp (F)	Liters	Number	Viability(%)	Roe	Males	Ripe
Cheviot	17-May	63	-	-	-	4	6	2
Coxsackie	3-May	56	10.7	333,817	79.7	27	7	19
Coxsackie	4-May	58	44.5	1,450,227	79.4	112	28	80
Coxsackie	5-May	58	53.5	1,919,060	69.1	135	34	96
Coxsackie	6-May	59	65.5	2,766,297	66.7	165	41	118
Coxsackie	8-May	60	70.3	2,469,147	68.7	177	44	127
Coxsackie	9-May	60	63.7	2,308,988	62.0	161	40	115
Coxsackie	10-May	60	62.6	2,643,819	60.7	158	39	113
Coxsackie	11-May	61	58.5	1,969,095	66.2	147	37	105
Coxsackie	12-May	61	10.6	349,202	69.2	27	7	19
Coxsackie	13-May	62	26.2	881,885	63.2	66	17	47
Coxsackie	15-May	63	23.1	846,108	72.0	58	15	42
Coxsackie	16-May	64	18.0	638,916	59.5	45	11	32
Coxsackie	18-May	64	-	-	-	21	3	8
Coxsackie	19-May	64	7.8	303,930	70.1	20	5	14
Coxsackie	20-May	65	13.1	489,894	79.1	33	8	24
Coxsackie	22-May	67	12.8	435,477	73.6	32	8	23
Coxsackie	23-May	67	5.0	185,055	65.3	13	3	9
Coxsackie	24-May	67	5.7	208,780	75.4	14	4	10
Coxsackie	25-May	67	5.0	175,615	55.6	13	3	9
Coxsackie	26-May	68	15.0	545,758	75.8	38	9	27
Coxsackie	27-May	66	5.0	181,076	73.2	13	3	9
Coxsackie	29-May	68	0.0	0	0.0			
Castleton	17-May	63	-	-	-	26	3	19
Totals		72	576.6	21,102,146	76.3	1,474	362	1,046

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS
FROM THE DELAWARE RIVER, 1999

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PA Fish & Boat Commission
Area 5 Fisheries Manager
Bushkill, PA 18324

Introduction

The goal of this activity in 1999, as in past years, was to collect and ship up to 15 million eggs taken from American shad captured in gill nets set in Delaware River spawning waters at Smithfield Beach within the Delaware Water Gap National Recreation Area near Bushkill, PA. Immediately after netting ripe shad, eggs were stripped and fertilized and allowed to harden in river water. Water-hardened eggs were then sealed in plastic bags containing river water and pure oxygen, and driven 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

Methods

Ecology III provided a boat, equipment and labor support to assist the PFBC Area Fisheries Manager and his staff stationed at Bushkill, PA. Each evening during the fishing season, two crews gathered at the emergency boat ramp at Smithfield Beach. Eighteen 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 delivered nightly to the hatchery.

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 1999. Gill netting for spawners began on 5-6 May during the first week. Although many of the 102 shad caught on those dates were green females, a total of 20.1 liters of eggs was sent in two shipments. The river level was relatively low for this early in the season and daily river temperature decreased slightly from 16.9 to 16.6°C.

During the second week, netting resumed on 9 May and continued through 13 May. Each day was warm and the river temperature rose 3.3 C throughout the week. The nights, however, were unseasonably cool. Shad catch averaged 53 fish nightly, and between 10 to 20 liters of eggs were shipped on each of the first four nights. There was no shipment on the last night due to insufficient numbers of eggs collected. Percent viability of eggs during week 2 varied from 42.3% to 45.3% for the first three nights and then it dropped to 8.6% on the fourth night. This sharp drop in viability was probably the result of a flow blockage at the hatchery rather than conditions at the river.

The third week of gill netting occurred from 16 May through 20 May. Catch of shad ranged from 22 to 75 fish with an average of 50 shad nightly. This was only about half the number of shad that were captured with one to three fewer nets during the same fishing week in 1998 (Ecology III, Inc. 1999). Compared to prior years noticeably fewer shad were observed swimming freely in the river at night when gill nets were checked. Not surprisingly, nightly shipments averaged only 11 liters of eggs compared to an average of 18 liters nightly in 1998.

On the fourth week, netting resumed on Monday, 23 May. Fishing continued for three nights before closing down for the season on 25 May. Average catch during week 4 was only 31 shad each night compared to an average of 159 shad for a similar three night period in 1998 (Ecology III, Inc. 1999). River temperature remained cool decreasing from 19°C to 17°C during the last three nights. Egg viability ranged for 0.0% on 23 May when all but one of the 55 fish captured were females, to a season high of 54.8% on the next night when 22 shad produced a shipment of 5 liters of eggs.

Summary

Shad eggs were collected and shipped on 14 of the 15 nights that were fished from 5 May through 25 May 1999. During this time, 714 adult shad were captured and 164 liters of eggs were shipped for a hatchery count of 5.5 million eggs. This was 58% fewer shad captured and 53% fewer liters of eggs shipped than in 1998 with comparable effort. Overall, the percent viability of eggs was 27%, about 15% lower than last year. In 1999, there were noticeably fewer shad in the Delaware River at the Smithfield Beach egg-collection-site than in previous years.

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).

TABLE 1

Delaware River Shad Egg Collection Data
5 May - 25 May 1999

Date	Water Temp (C)	No. of Nets Set	No. of Shad Captured	Eggs Shipped (liters)		Eggs (million)	Percent Viability
				Field Count	Van Dyke Count		
05 May	16.9	18	33	9	5.6	0.186	49.9
06 May	16.6	18	69	20	14.5	0.618	33.9
09 May	16.1	18	47	10	9.1	0.453	45.3
10 May	16.9	18	60	15	10.8	0.456	42.3
11 May	17.9	18	56	15	10.7	0.443	43.2
12 May	18.9	18	61	20	16.0	0.562	8.6*
13 May	19.4	18	42	NO SHIPMENT			
16 May	19.9	18	56	10	7.2	0.519	9.4
17 May	19.9	18	63	15	12.6	0.610	24.2
18 May	20.2	18	36	10	6.7	0.346	17.5
19 May	19.3	18	75	15	11.5	0.481	29.3
20 May	19.0	18	22	5	3.6	0.132	51.1
23 May	19.0	18	55	10	9.8	0.402	0.0*
24 May	18.7	18	22	5	3.2	0.150	54.8
25 May	17.0	18	17	5	2.2	0.130	0.0
TOTALS		270	714	164	123.5	5.488	27.1***

* High mortality due to flow blockage.

** Total of 55 shad (54 females, 1 male).

***Weighted mean.

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1999

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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. This year's effort was supported by funds from the settlement agreement between upstream hydroelectric project owners and intervenors in the FERC re-licensing proceedings related to shad restoration in the Susquehanna River.

Production goals for 1999 were to stock 10-20 million American shad fry. All Van Dyke hatchery-reared American shad fry 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 26.6 million eggs (700 L) were received in 34 shipments in 1999 (Table 1). This was slightly fewer eggs than 1998 and the second most since 1991 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 59.2%.

Egg collection efforts on the Delaware River were hampered by availability of spawners. Delaware River shipments were received from May 6 to May 26. A total of 14 shipments of eggs were received from the Delaware River (5.5 million eggs) with a viability of 27.1%. The lower viability for the Delaware River shipments, compared to previous years was due to use of a new method to enumerate dead eggs (see Appendix 2). 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 since it accounts for the large number of small dead eggs which do not layer out, cannot be siphoned and are unaccounted for by standard methods.

Hudson River eggs were collected only from the site at Coxsackie, where water depths permit gill netting at all stages of the tide. Twenty shipments (21.1 million eggs) were delivered with an overall viability of 67.6%. This is the most eggs ever received from the Hudson River. Stable weather conditions contributed to the record egg take on the Hudson.

The U. S. Fish and Wildlife Service, Northeast Fishery Center, in Lamar, PA continued tank-spawning operations in 1999. 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. Unfortunately, few eggs were produced and none were shipped to the Van Dyke hatchery.

SURVIVAL

Overall survival of fry was 91.5% compared to a range of 41% to 94% for the period 1984 through 1998. The high survival was due to extreme vigilance in preventing mortality due to fry 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). Sixteen tanks exhibited 17d survival averaging 92%. Thirty-four tanks exhibited 11-day survival averaging 98%. Two tanks exhibited high mortality within the first three days after hatch due to fry laying on top of each other. Nine-day survival for these tanks was 84%. This has been an ongoing problem (Hendricks, 1996, 1997, 1998). All the mortality problems noted in 1995- 1998 were also associated with fry 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 1999 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. This may be a problem which will never be completely solved, and will require constant vigilance to keep mortalities to a minimum.

FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 14.4 million. A total of 10.2 million was released in the Juniata River, 1.2 million in the North Branch Susquehanna River and 1 million in the West Branch Susquehanna River at Montgomery Ferry. American shad fry were also stocked in tributaries: 373 thousand in Conodoguinet Creek, 236 thousand in the Conestoga River, 249 thousand in Swatara Creek, and 219 thousand in West Conewago Creek. In addition, 501 thousand fry were stocked in the Lehigh River and 410 thousand stocked in the Schuylkill River to support restoration efforts there.

TETRACYCLINE MARKING

All American shad fry 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 fry were marked according to stocking site. Fry from out-of-basin egg sources and stocked in the Juniata River were marked at 3 days of age. Fry stocked in the Conodoguinet Creek were given a quadruple mark at 3, 6, 9, and 12 days of age. Fry stocked in the Conestoga River were given a quadruple mark at 3, 9, 12, and 15 days of age. Fry stocked in Swatara Creek were given a quintuple mark at 3, 6, 9, 15, and 18 days of age. Fry stocked in West Conewago Creek were given a quintuple mark at 3, 6, 9, 12, and 18 days of age. Fry stocked in the North Branch Susquehanna River were given a quintuple mark at 3, 6, 12, 15, and 18 days of age. Fry stocked in the West Branch Susquehanna River were given a quadruple mark at 3, 6, 9, and 15 days of age. Fry stocked in the Lehigh River were given a triple mark at 9, 12 and 15 days of age. Fry stocked in the Schuylkill River were given a triple mark at 3, 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, however, the possibility of confusion in assigning marks was noted on some. For example, of the 17 specimens marked on days 3,6,9,12,18; we noted four which could potentially be confused with marks on days 3,6,9,12,15 and one which we thought we definitely would call 3,6,9,12,15. Similarly, two of the 17 specimens marked on days 3,6,9,15 could potentially have been confused with marks on days 3,6,9,12. This confusion results from slowing of growth and consequent crowding of daily increments as the larvae get older. Specimens from the wild, which exhibit these marks, will have to be analyzed by counting increments. Analysis of relative survival of each uniquely marked group is discussed in Appendix A.

SUMMARY

A total of 34 shipments (26.6 million eggs) was received at Van Dyke in 1999. Total egg viability was 59% and survival to stocking was 92%, resulting in production of 14.4 million fry. The majority of the fry were stocked in the Juniata River (10.2 million. Fry were also released in Conodoguinet Cr. (373 thousand), Conestoga River (236 thousand), Swatara Creek (249 thousand), West Conewago Creek (219 thousand), the North Branch Susquehanna River (1.2 million), the West Branch Susquehanna River (984 thousand), the Lehigh River (501 thousand), and the Schuylkill River (410 thousand).

Overall survival of fry was 92%. The high survival was largely due to preventing smothering of fry when they lay on the bottom in the first few days after hatch.

All American shad fry 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, however, some potential for confusion exists between certain multiple 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 fry 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, before sunning and transferring to the tanks.
6. Continue to siphon egg shells from the rearing tank within hours of egg hatch.

7. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
8. Construct new foam bottom screens for Van Dyke jars each year.
9. Do not disinfect foam bottom screens prior to use.
10. Continue to hold Delaware River eggs until 8:00AM before processing.
11. Construct and evaluate an experimental 2mm mesh screen to remove small eggs from Delaware River egg shipments. Develop a method to enumerate these eggs and account for them in reporting egg viability.

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Figure 1. Survival of American shad fry, Van Dyke, 1999.

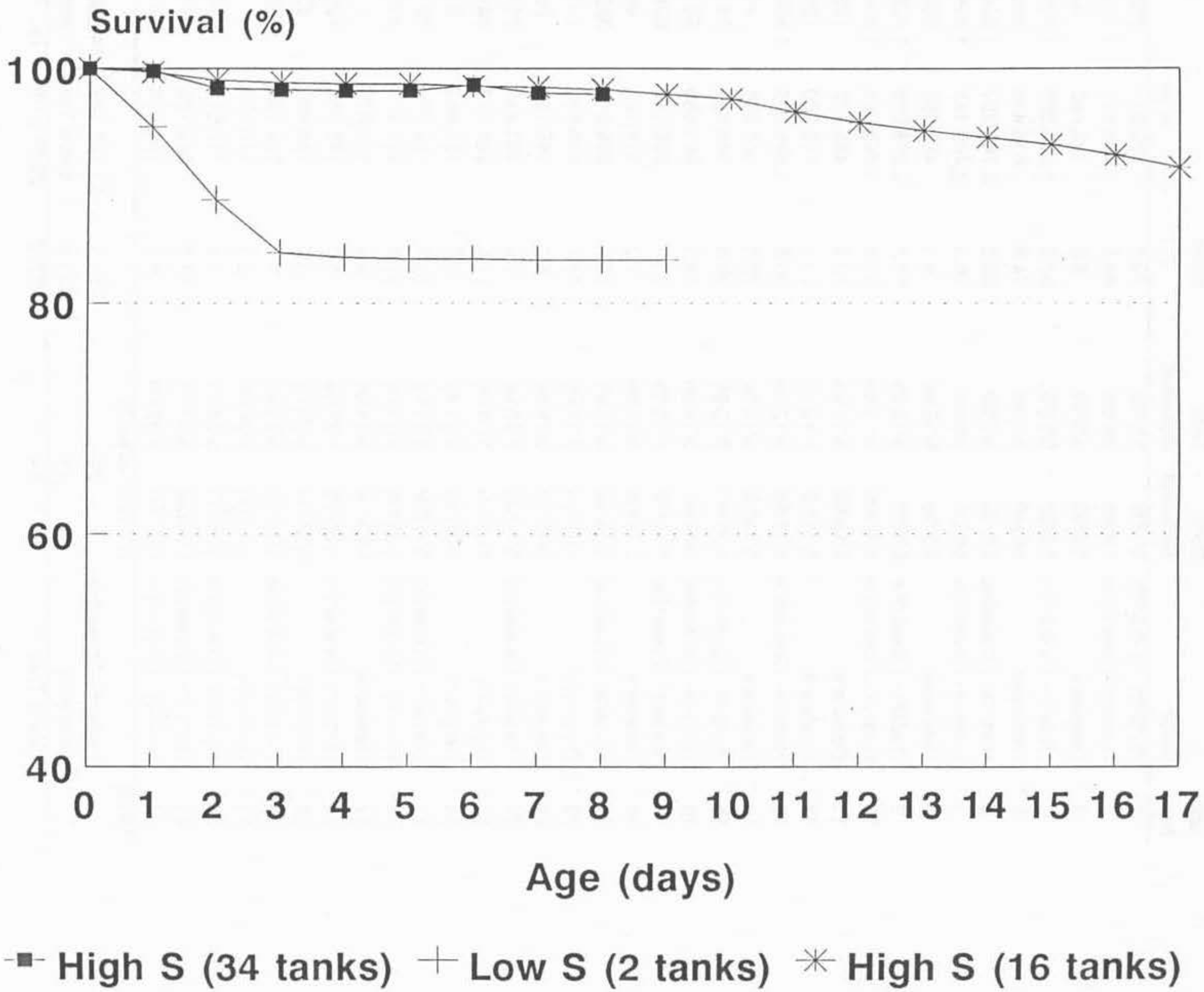

Table 1. American shad egg shipments received at Van Dyke, 1999.

hip-ent No.	River	Date Spawned	Date Received	Vol. Rec-ieved (L)	Eggs	Viable Eggs	Percent Viable
1	Hudson- Coxsackie	5/3/99	5/4/99	10.7	333,817	266,004	79.7%
2	Hudson- Coxsackie	5/4/99	5/5/99	44.5	1,450,227	1,151,943	79.4%
3	Delaware	5/5/99	5/6/99	5.6	186,482	93,145	49.9%
4	Hudson- Coxsackie	5/5/99	5/6/99	53.5	1,919,060	1,326,783	69.1%
5 *	Delaware	5/6/99	5/7/99	14.5	618,490	209,461	33.9%
6	Hudson- Coxsackie	5/6/99	5/7/99	65.5	2,766,297	1,844,981	66.7%
7	Hudson- Coxsackie	5/8/99	5/9/99	70.3	2,469,147	1,695,830	68.7%
8	Delaware	5/9/99	5/10/99	9.1	452,950	205,361	45.3%
9	Hudson- Coxsackie	5/9/99	5/10/99	63.7	2,308,988	1,432,069	62.0%
10	Hudson- Coxsackie	5/10/99	5/11/99	62.6	2,643,819	1,604,165	60.7%
11 *	Delaware	5/10/99	5/11/99	10.8	456,122	192,917	42.3%
12 *	Delaware	5/11/99	5/12/99	10.7	442,980	191,219	43.2%
13	Hudson- Coxsackie	5/11/99	5/12/99	58.5	1,969,095	1,303,223	66.2%
14 **	Delaware	5/12/99	5/13/99	16.0	561,968	48,285	8.6%
15	Hudson- Coxsackie	5/12/99	5/13/99	10.6	349,202	241,751	69.2%
16	Hudson- Coxsackie	5/13/99	5/14/99	26.2	881,885	557,212	63.2%
17	Hudson- Coxsackie	5/15/99	5/16/99	23.1	846,108	608,979	72.0%
18 *	Delaware	5/16/99	5/17/99	7.2	519,387	49,028	9.4%
19	Hudson- Coxsackie	5/16/99	5/17/99	18.0	638,916	380,428	59.5%
20 *	Delaware	5/17/99	5/18/99	12.6	609,633	147,464	24.2%
21 *	Delaware	5/18/99	5/19/99	6.7	346,194	60,518	17.5%
22	Hudson- Coxsackie	5/19/99	5/20/99	7.8	303,930	213,105	70.1%
23 *	Delaware	5/19/99	5/20/99	11.5	480,877	141,010	29.3%
24 *	Delaware	5/20/99	5/21/99	3.6	131,861	67,400	51.1%
25	Hudson- Coxsackie	5/20/99	5/21/99	13.1	489,894	387,321	79.1%
26	Hudson- Coxsackie	5/22/99	5/23/99	12.8	435,477	320,516	73.6%
27	Delaware	5/23/99	5/24/99	9.8	401,676	0	0.0%
28	Hudson- Coxsackie	5/23/99	5/24/99	5.0	185,055	120,822	65.3%
29 *	Delaware	5/24/99	5/25/99	3.2	150,460	82,411	54.8%
30	Hudson- Coxsackie	5/24/99	5/25/99	5.7	208,780	157,317	75.4%
31 *	Delaware	5/25/99	5/26/99	2.2	130,259	0	0.0%
32	Hudson- Coxsackie	5/25/99	5/26/99	5.0	175,615	97,624	55.6%
33	Hudson- Coxsackie	5/26/99	5/27/99	14.9	545,758	413,854	75.8%
34	Hudson- Coxsackie	5/27/99	5/28/99	4.6	181,076	132,494	73.2%
Totals		No. of Shipments					
	Hudson- Coxsackie	20		576.1	21,102,147	14,256,421	67.6%
	Delaware	14		123.5	5,489,339	1,488,218	27.1%
	Grand Total	34		699.6	26,591,485	15,744,638	59.2%

* Viability estimated by counting live eggs in sample

** High mortality of eggs occurred due to flow blockage overnight

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976-1999.

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	1003	0.16	0.34
1978	381	14.5	44.0	6.4	2124	6	2130	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	3526	5	3531	0.28	0.43
1981	286	11.6	44.9	5.2	2030	24	2053	0.18	0.39
1982	624	25.9	35.7	9.2	5019	41	5060	0.20	0.55
1983	938	34.5	55.6	19.2	4048	98	4146	0.12	0.22
1984	1157	41.1	45.2	18.6	11996	30	12026	-	0.73
1985	814	25.6	40.9	10.1	6960	115	7075	0.28	0.68
1986	1535	52.7	40.7	21.4	15876	61	15928	0.30	0.74
1987	974	33.0	40.7	15.8	10274	81	10355	0.31	0.66
1988	885	31.8	38.7	12.3	10441	74	10515	0.33	0.86
1989	1220	42.7	60.1	25.7	22267	60	22327	0.52	0.87
1990	896	28.6	56.7	16.2	12034	253	12287	0.43	0.76
1991	902	29.8	60.7	18.1	12963	233	13196	0.44	0.73
1992	532	18.5	68.3	12.6	4645	34	4679	0.25	0.37
1993	558	21.5	58.3	12.8	7870	79	7949	0.37	0.62
1994	551	21.2	45.9	9.7	7720 *	140	7860	0.31	0.68
1995	768	22.6	53.9	12.2	10930 *	-	10930	0.43	0.79
1996	460	14.4	62.7	9.0	8466 *	-	8466	0.59	0.94
1997	593	22.8	46.6	10.6	8019	25	8044	0.35	0.76
1998	628	27.7	57.4	15.9	11757	2	11759	0.42	0.74
1999	700	26.6	59.2	15.7	14412	-	14412	0.54	0.92
						Total	197,178		
					Total since 1985 (OTC marked)		165,781		

*Includes fry reared at Manning.

Table 3. American shad stocking and transfer activities, 1999.

Date	Tank	Number	OTC Mark (days)	Location	Origin	Age	Size
5/17/99	A11	265,000	3	Millerstown (Greenwood)	Hudson	6	Fry
5/17/99	A21	295,000	3	Millerstown (Greenwood)	Hudson	5	Fry
5/18/99	A31	267,000	3	Millerstown (Rt. 17 Bridge)	Hudson	6	Fry
5/18/99	A41	266,000	3	Millerstown (Rt. 17 Bridge)	Hudson	6	Fry
5/18/99	B11	263,000	3	Millerstown (Rt. 17 Bridge)	Hudson	6	Fry
5/19/99	B21	292,000	3	Miller's Canoe Rental	Hudson	6	Fry
5/19/99	B31	305,000	3	Miller's Canoe Rental	Hudson	6	Fry
5/20/99	B41	283,000	3	Muskrat Springs	Hudson	7	Fry
5/20/99	C11	296,000	3	Muskrat Springs	Hudson	7	Fry
05/21/99	C21	132,000	3	Mexico	Hudson	8	Fry
05/21/99	C31	278,000	3	Mexico	Delaware	7	Fry
05/21/99	C41	278,000	3	Mexico	Hudson	7	Fry
5/22/99	D11	422,000	3	Mifflin	Hudson	8	Fry
5/22/99	D21	424,000	3	Mifflin	Hudson	8	Fry
5/23/99	D31	422,000	3	Thompsontown	Hudson	9	Fry
5/24/99	D41	322,000	3	Millerstown (Rt. 17 Bridge)	Hudson	8	Fry
5/24/99	F11	309,000	3	Millerstown (Rt. 17 Bridge)	Delaware	7	Fry
5/24/99	F21	273,000	3	Millerstown (Rt. 17 Bridge)	Hudson	7	Fry
5/25/99	F31	242,000	3	Miller's Canoe Rental	Hudson	8	Fry
5/25/99	F41	288,000	3	Miller's Canoe Rental	Hudson	8	Fry
5/25/99	G11	305,000	3	Miller's Canoe Rental	Hudson	8	Fry
5/26/99	G21	392,000	3	Muskrat Springs	Hudson	8	Fry
5/26/99	G31	268,000	3	Muskrat Springs	Hudson	8	Fry
5/27/99	G41	319,000	3	Treaster's Exxon	Hudson	9	Fry
5/27/99	H11	311,000	3	Treaster's Exxon	Hudson	9	Fry
5/27/99	H21	257,000	3	Treaster's Exxon	Hudson	9	Fry
5/28/99	H41	275,000	3	Mexico	Hudson	9	Fry
5/28/99	I11	264,000	3	Mexico	Hudson	9	Fry
5/28/99	I21	200,000	3	Mexico	Hudson	9	Fry
5/29/99	I31	256,000	3	Mifflin	Hudson	10	Fry
5/29/99	I41	272,000	3	Mifflin	Hudson	10	Fry
5/30/99	J31	259,000	3	Millerstown (Rt. 17 Bridge)	Hudson	7	Fry
5/30/99	A12	341,000	3	Millerstown (Rt. 17 Bridge)	Hudson	7	Fry
5/31/99	A32	197,000	3	Muskrat Springs	Hudson	7	Fry
5/31/99	A42	181,000	3	Muskrat Springs	Hudson	7	Fry
6/1/99	B12	210,000	3	Mexico	Hudson	5	Fry
6/4/99	E11	333,000	3,6,12,15,18	N. Branch Susq. R.	Hudson	19	Fry
6/4/99	E21	346,000	3,6,12,15,18	N. Branch Susq. R.	Hudson	19	Fry
6/4/99	E31	302,000	3,6,12,15,18	N. Branch Susq. R.	Hudson	19	Fry
6/4/99	E41	230,000	3,6,12,15,18	N. Branch Susq. R.	Hudson	19	Fry
6/6/99	H31	410,000	3,9,12	Schuylkill R.	Delaware	18	Fry
6/8/99	J41	219,000	3,6,9,12,18	West Conewago Cr.	Hudson	19	Fry
6/10/99	J11	249,000	3,6,9,15,18	Swatara Cr.	Hudson	20	Fry
6/10/99	J21	236,000	3,9,12,15	Conestoga R.	Hudson	20	Fry
6/11/99	B32	373,000	3,6,9,12	Conodoguinet Cr.	Hudson	14	Fry
6/17/99	A22	207,000	9,12,15	Lehigh R.	Delaware	23	Fry
6/17/99	B22	223,000	9,12,15	Lehigh R.	Delaware	21	Fry
6/17/99	C12	71,000	9,12,15	Lehigh R.	Delaware	16	Fry
6/21/99	B42	278,000	3,6,9,15	W. Branch Susq. R.	Hudson	22	Fry
6/21/99	C22	217,000	3,6,9,15	W. Branch Susq. R.	Hudson	20	Fry
6/21/99	C32	377,000	3,6,9,15	W. Branch Susq. R.	Hudson	18	Fry
6/21/99	C42	112,000	3,6,9,15	W. Branch Susq. R.	Hudson	17	Fry

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1999.

	Site	Fry
Releases	Millerstown (Greenwood)	560,000
	Millerstown (Rt. 17 bridge)	2,300,000
	Miller's Canoe Rental	1,432,000
	Thompsontown	422,000
	Muskrat Springs	1,617,000
	Mexico	1,637,000
	Mifflin	1,374,000
	Treaster's Exxon	887,000
	Juniata River Sub-total	**10,229,000**
	Conodoguinet Cr.	373,000
	Conestoga R.	236,000
	Swatara Cr.	249,000
	West Conewago Cr.	219,000
	N. Branch Susq. R.	1,211,000
	W. Branch Susq. R.	984,000
	Susquehanna River Basin Sub-total	**13,501,000**
	Schuylkill River	410,000
	Lehigh River	501,000
	Total	**14,412,000**

Table 5. Tetracycline marking regime for American shad stocked in the Mid-Atlantic region, 1999.

			Mark				Mark		Hatchery			
			Immersion		Taggant		Retention (%)		Fry	Fingerling	Stocking	Egg
Year	Number	Size	(days)	Feed	Immersion	Feed	Immers.	Feed	Culture	Culture	Location	Source
1999- American shad												
	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	Fry	Subtotal									
	526,000	Fry	Egg,1		200ppm OTC				Manning		Patuxent R.	Susq.
	0	Fry	9,12	-	200ppm OTC	-		-	Manning	-	Patuxent R.	Susq.
	442,000	Fry	Egg	-	1000ppm OTC	-		-	Manning	-	Choptank R.	Susq.
	968,000	Fry	Subtotal									
	60,377	Fing.	-	single*	-	500mg/kg live wt.		-	Manning	PEPCO Ponds	Patuxent R.	Susq.
	64,956	Fing.	-	single*	-	500mg/kg live wt.		-	Manning	PEPCO Ponds	Choptank R.	Susq.
	125,333	Fing.	Subtotal									
	1,304,218	Fry	3,9	-	200ppm OTC	-		-	Harrison L.	-	Potomac R.	Potomac R.
	905,891	Fry	9	-	200ppm OTC	-		-	Harrison L.	-	Rivanna R.	York R.
	96,259	Fry	3,4,5,6,9,	-	200ppm OTC	-		-	Harrison L.	-	Rivanna R.	York R.
	1,480,380	Fry	9	-	200ppm OTC	-		-	Harrison L.	-	James R.	York R.
	4,767,439	Fry	9	-	200ppm OTC	-	100	-	King & Queen	-	James R.	York R.
	1,478,652	Fry	3,6,12,15	-	200ppm OTC	-	100	-	King & Queen	-	York R.	York R.
	3,000,000	Fry	15	-	200ppm OTC	-		-	PTG	-	York R.	York R.
	175,000	Fry	3,6,12	-	200ppm OTC	-	-	-	Edenton	-	Roanoke R.	Meherrin R.
	50,000	Fry	3,6,12	-	200ppm OTC	-	-	-	Edenton	-	Roanoke R.	Tar R.
	50,000	Fry	3,6,12	-	300ppm OTC	-	-	-	Watha	-	Roanoke R.	Tar R.
Hickory Shad												
	3,509,000	Fry	Egg,3	-	1000/200ppm OTC	-		-	Manning	-	Tukahoe R.	Susq.
	826,000	Fry	3	-	200ppm OTC	-		-	Manning	-	Patapsco R.	Susq.
	8,106,000	Fry	Egg	-	1000ppm OTC	-		-	Manning	-	Patuxent R.	Susq.
	0	Fry	2	-	200ppm OTC	-		-	Manning	-	Choptank R.	Susq.
	5,210,000	Fry	Egg,3	-	1000/200ppm OTC	-		-	Manning	-	Choptank R.	Susq.
	17,651,000	Fry	Subtotal									
	4,601	Fing.	Egg	single*	1000ppm OTC	500mg/kg live wt.		100	Manning	PEPCO Ponds	Patuxent R.	Susq.

*Also recieved coded wire tags

Appendix 1

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 1999.

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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. 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).

In 1999, we continued to spread larvae out by stocking at various sites, however, no formal experiment was designed to test this. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 1999 and summarizes results from 1995 to 1999.

Materials and Methods

The majority (76%) of production larvae stocked in 1999 was marked at three days of age and stocked at various sites in the Juniata River. Sites were generally stocked in succession, moving upriver. Repeated stockings at one site, within a short time interval, were avoided. Smaller numbers of uniquely marked larvae were stocked at other sites, including the North and West Branches of the Susquehanna River and Conestoga, Conewago, Conodoguinet, and Swatara Creeks. No fingerlings were stocked in 1999.

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 1999 are tabulated in tables 1-1 through 1-5, respectively. In 1999, larvae stocked in the Conestoga River exhibited the best survival (relative survival set to 1.00, Table A1-5). Larvae stocked in Swatara Cr., Conodoguinet Cr. and at various sites in the Juniata River also survived well (relative survival 0.81, 0.77 and 0.75, respectively. Larvae stocked in the North Branch and in Conewago Cr. did relatively less well with a relative survival of 0.22 and 0.15, respectively. No shad from stockings in the West Branch were recovered, despite release of almost 1 million larvae there. No larvae were stocked from the Susquehanna River egg source.

A summary of the results of four years of uniquely marking larvae according to stocking site is provided in Table A1-6. Recovery rates for 1999 varied from 0.0 to 0.59. The overall recovery rate for 1999 (0.38) was second only to 1997 (0.57).

Although the data are not definitive, spreading larvae out appears to promote increased survival. Larvae stocked in this manner for the last three years (Juniata R., various sites) survived well (relative survival 0.89, 0.71 and 0.75). Larvae stocked by multiple stockings at the same site (Juniata R./ Susquehanna R. at Montgomery Ferry) did well in 1997 (relative survival 1.00) but poorly in 1995 and 1996 (0.27 and 0.33).

Larvae stocked in the North Branch did extremely well in previous years, but poorly in 1999. Larvae stocked in the West Branch have not done well, exhibiting relative survival of 0.38 and 0.35 in 1996 and 1997, and 0.00 in 1998 and 1999.

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 were not detected in 1996 and 1998. This may relate to stocking site since the 1995 and 1999 releases were at the Rt. 322 bridge near Ephrata (river mile 38) while the other 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 (0.50), but poor relative survival in other years (0.18 to 0.25; 1995, 1997 and 1998). Water quality in Conodoguinet Creek is suspect and may be marginal for American shad. Larvae were stocked in Conewago and Swatara Creeks in 1998 and 1999. They did well in Swatara Cr. (relative survival 0.93 and 0.81, respectively). In Conewago Cr., they did well in 1998 and poorly in 1999 (relative survival 1.00 and 0.15, respectively), despite release at the same site.

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	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	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	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	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	%	Juveniles Recovered N	%	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	%	Juveniles Recovered N	%	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 A1-6. 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, 1995-1999.

Stocking	Recovery Rate					Relative Survival				
Site	1995	1996	1997	1998	1999	1995	1996	1997	1998	1999
Juniata R./Susq. R. @ Mont. Ferry	0.34	0.08	0.69			0.27	0.33	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	0.18	0.50	0.25	0.18	0.77
mouth of Conodiguinet Cr.	0.39					0.31				
Conestoga R.	1.26	0.00	0.26	0.00	0.59	1.00	0.00	0.37	0.00	1.00
mouth of Conestoga Cr.	0.42					0.33				
Muddy Cr.	0.00					0.00				
Conewago Cr.				0.19	0.09				1.00	0.15
Swatara Cr.				0.17	0.48				0.93	0.81
W. Br. Susq. R.		0.09	0.24	0.00	0.00		0.38	0.35	0.00	0.00
N. Br. Susq. R.		0.23	0.48	0.19	0.13		1.00	0.68	1.00	0.22
Overall	0.35	0.09	0.57	0.13	0.38					

Appendix 2

Evaluation of the accuracy of the standard method for estimating viability of Delaware River eggs, 1999.

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Introduction

Estimation of egg viability for American shad eggs at the Van Dyke Research Station is the first step and a key element in assessing the performance of the hatchery product. Egg viability is the basis for initial tank density, which is, in turn, the basis for final tank density or the number of larvae stocked. The number stocked is the basis for computing relative survival of groups of larvae, number of larvae required to return one adult to Conowingo, and estimates of survival (S) and mortality (Z) to adulthood.

Standard practice is to determine the number of live eggs by estimating the initial number of eggs delivered and subtracting the number of dead eggs taken off during incubation and after hatch. Initial and dead egg estimates are conducted by the methods of von Bayer (1910). Egg viability is calculated by dividing the number of live eggs by the total number of eggs delivered.

The accuracy and precision of seven methods of initial egg enumeration were tested in 1986 (Hendricks et al., 1987). The standard Van Dyke method (von Bayer dry volume method; von Bayer, 1910) was found to underestimate the number of eggs by 5 to 14 percent with a coefficient of variation from 6.5 to 8.9. This method was clearly superior in accuracy and precision to four of the methods tested. The fifth method tested, the wet volume method (300 egg sample), was less accurate than the von Bayer (20 to 26% underestimate), but had high precision (C.V. 2.2 – 3.0), suggesting that a correction factor could be developed to improve accuracy. A sixth method, the displacement/wet volume (300 egg sample), was slightly more accurate than the von Bayer method (0.1 to 10% overestimate) but with higher precision (C.V. 0.7 to 4.0). Unfortunately, this method is a mathematical hybrid and has no logical basis. It was concluded that further testing to validate these methods was needed. Additional testing was never done, and the von Bayer method has remained the standard.

While the accuracy and precision of initial enumeration has been tested, no testing has been done to validate the process as a whole by counting of number of live eggs at hatch. This would be extremely time-consuming and would result in mortality of large numbers of larvae.

Potential problems with the enumeration procedure, particularly with Delaware River eggs, were discussed in Hendricks (1995) and Hendricks (1999). These problems relate to the large number of small eggs which do not layer out, cannot be siphoned off, and result in underestimation of dead eggs and overestimation of egg viability for Delaware River shipments. More specifically, it was noted that Delaware River egg shipments typically contain numbers of small diameter eggs which have not been fertilized or water hardened. These eggs do not layer on top of live eggs as do dead eggs which **have** water hardened. Consequently, they cannot be siphoned off. This creates several problems. First, increased numbers of dead eggs can create fungus problems during incubation. Second, these eggs can only be enumerated as dead after the live eggs have hatched and only the dead remain. The procedure for enumeration of dead eggs after hatch is the same as the procedure for eggs which have been siphoned off during incubation. Unfortunately, these eggs have been dead longer and they often do not get treated with formalin on the day of hatch. As a result, they have more fungus, and are softer, less turgid, and more prone to disintegrate upon handling. At this stage, the eggs cannot be placed on a twelve inch rule to determine diameter. Egg counts (egg diameter) used to enumerate these eggs is taken from the previous dead egg enumeration, which consisted of dead eggs siphoned off several days earlier. This sample typically consists of large dead eggs which have layered on top and contains very few small eggs. As a result, the counts are low, egg diameter is high, and the total number of dead eggs after hatch is seriously underestimated. This, of course, results in an overestimate of number of live eggs and egg viability for those Delaware River egg shipments which contain large numbers of small dead eggs (Hendricks 1995, 1999).

This study examined the accuracy of the standard method for estimating viability of Delaware River eggs. While the total number of live eggs in the jar could not be counted, a sub-sample was counted and viability estimated using a combination of von Bayer counts and sub-sampling.

Materials and Methods

Standard method- Siphon and subtract

Standard practice is to enumerate eggs immediately upon delivery to Van Dyke by the von Bayer (dry volume) method. Dead eggs which layer on top of the live eggs are siphoned off the day after delivery (day I) and again three days after delivery (day III). Dead eggs which were not siphoned off remain in the jar after hatch. All three groups of dead eggs are enumerated and subtracted from the initial number delivered, to estimate the number of live eggs at hatch. The number of live eggs at hatch is taken to be the initial number of larvae in the tank (initial tank density). Larval mortalities are estimated each day and subtracted from the initial density to obtain a final tank density (number stocked).

von Bayer enumerations are conducted by taking a sample of eggs with a turkey baster and lining them up egg-to-egg on a twelve-inch rule. The number of eggs in twelve inches (a measure of egg diameter) is counted and the number of eggs per liter is determined from tables provided by von Bayer (1910). The entire egg batch is poured into screened bottom graduates and the total volume in liters is multiplied by the number per liter to estimate the number of eggs in the shipment. For dead eggs taken on day IV and after hatch, measurement in a screen bottom graduate results in egg breakage. These eggs are put into regular graduates with a water cushion. Water is added to cover the eggs and the wet volume is recorded and converted to dry volume by multiplying by a correction factor of 0.73. Number of eggs per liter is determined as before, except that dead eggs after hatch cannot be put on a twelve inch rule without breakage. Number of eggs per liter for dead eggs after hatch is assumed to be the same as for dead eggs taken on day IV.

Validation- Sampling method

The Sampling method differed from the standard method in that it eliminated von Bayer enumeration of dead eggs after hatch. Number of live eggs on day V was determined by subtracting dead eggs siphoned off on days I and IV from initial egg counts, using von Bayer methods. On day V, or on day IV after dead eggs were taken off, eggs remaining in the jar were stirred and three random samples of at least 100 eggs were collected. These eggs were viewed under a dissecting microscope and counts of live and dead were recorded. I assumed that any egg which was alive on day IV or V would live to hatch. Number of live eggs was calculated by multiplying the number of eggs remaining in the jar by the proportion of live in the three samples. Egg viability was calculated by dividing the number of live eggs by the initial number of eggs in the jar as determined by the von Bayer method.

Results and Discussion

The results of this study support the observations of Hendricks (1995, 1999). Table 2.1 clearly shows that egg viability, as estimated by the standard siphon and subtract method, is inflated as compared to the sampling method. Twelve of thirteen egg jars exhibit higher viabilities as measured by the standard method. Mean difference between the standard and sampling methods was +12%. Figure 2-1 suggests that the difference in egg viability between the two methods is a function of number of eggs per liter. The presence of large numbers of small eggs increases the number of eggs per liter and results in a larger difference between the two methods. Linear regression of percent difference vs. number of eggs per liter results in a slope of 1.04 and an x intercept of 33,151 eggs per liter. Therefore, at 33,000 eggs per liter there is no difference in egg viability between the two methods. Interestingly, high viability Hudson River egg shipments with few small eggs run 30,000 to 35,000 eggs per liter. This supports the hypothesis that small eggs are the cause of over-estimates of egg viability with the siphon and subtract method.

The sampling method relied on the assumption that any egg which was alive on day IV or V, when the sample was taken, would live to hatch. At this stage, American shad larvae are well developed in the tail-free stage. Over the last 15 years, we have seen very few dead eggs which were developed to the tail-free stage. Most of the dead eggs observed had no apparent development at all. The only cases where developed larvae were observed to die were cases where the flow was cut off to the egg jar. Stoppage of flow to the egg jar is detected by the absence of overflow from the jar, usually results in overnight total mortality to an otherwise normal egg shipment and cannot be confused with any other phenomena. These observations suggest that the assumption that eggs which are alive on day IVor V will hatch, is a valid one.

This study demonstrates that viability of Delaware River egg shipments is overestimated as a result of the presence of small eggs which do not layer out and cannot be removed by siphoning. Egg viabilities reported for 1999 (Job III, Table 1) were derived from the sampling method, not the standard siphon and subtract method. For 2000, I recommend evaluating a 2mm screen to separate the small eggs from the remainder of the shipment (Sam Chapman, pers. comm.). In the event the screen is not effective, the sampling method should be used in lieu of the siphon and subtract method.

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von bayer, H. 1910. A method of measuring fish eggs. Bull. U.S. Fisheries 18 (1908) (2): 1011-1014.

Figure 2-1. Percent difference in egg viability estimates between siphon and subtract method and sampling method

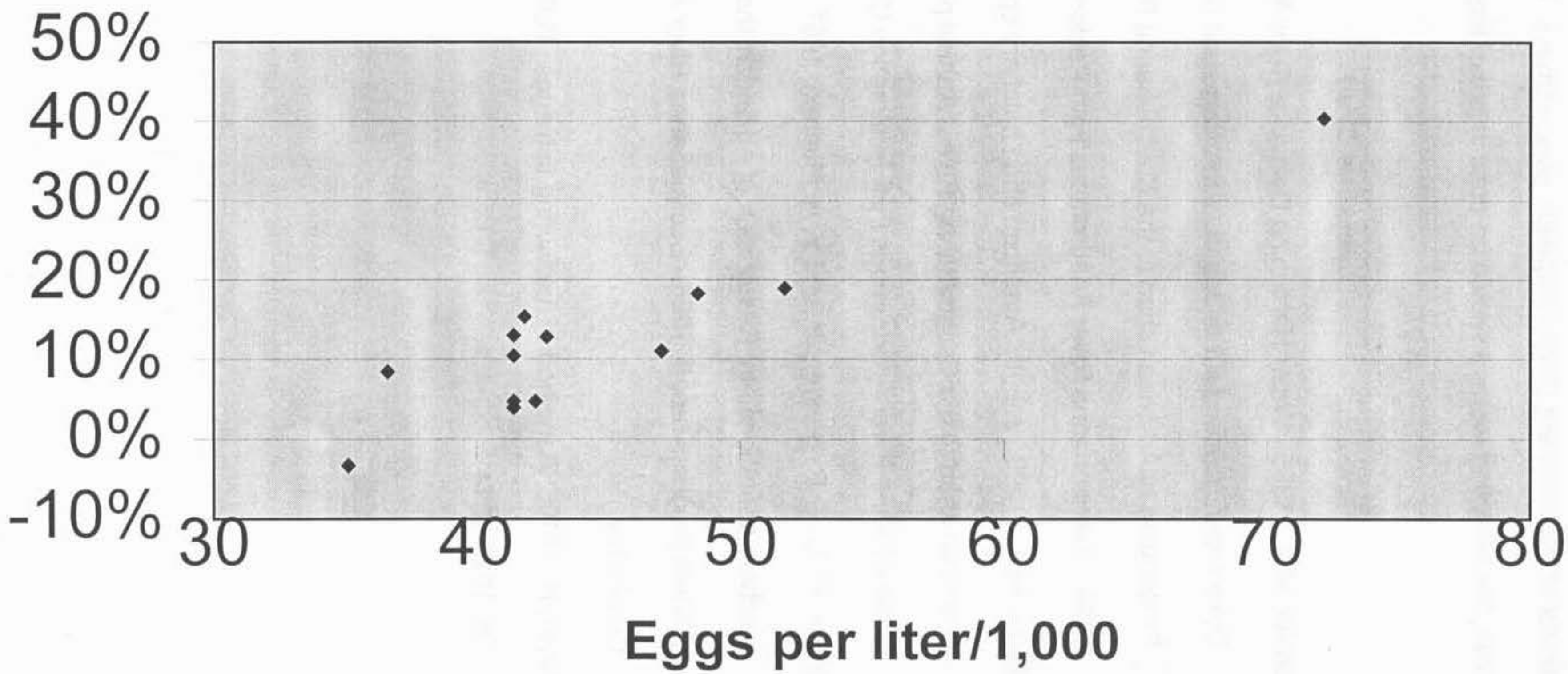

Table 2-1. Viability of Delaware River American shad eggs, estimated by two methods, 1999.

Shipment	Date	Jar	Vol. (L)	No. of Eggs	Eggs/L	Viability: Siphon & Subtract Method	Viability: Sampling Method	Difference
3	5/5/99	306	5.6	186,482	33,300	50%	not tested	-
5	5/6/99	312	7.4	315,643	42,654	47%	34%	13%
		313	7.1	302,847	42,655	combined with jar 312		-
8	5/9/99	326	9.1	452,950	49,775	45%	not tested	-
11	5/10/99	336	10.8	456,122	42,234	47%	42%	5%
12	5/11/99	1	2.7	111,780	41,400	53%	49%	5%
		2	2.7	111,780	41,400	56%	43%	13%
		3	2.7	111,780	41,400	45%	41%	4%
		4	2.6	107,640	41,400	50%	39%	10%
14	5/12/99	454	13	456,599	35,123	*		
		3	3	105,369	35,123	43%	46%	-3%
18	5/16/99	306	7.2	519,378	72,136	50%	9%	40%
20	5/17/99	309	12.6	609,633	48,384	42%	24%	18%
21	5/18/99	310	6.7	346,194	51,671	36%	18%	19%
23	5/19/99	312	11.5	480,877	41,815	45%	29%	15%
24	5/20/99	314	3.6	131,861	36,628	60%	51%	8%
27	5/23/99	317	9.8	401,676	40,987	**		
29	5/24/99	319	3.2	150,460	47,019	66%	55%	11%
31	5/25/99	1	2.2	130,259	59,209	**		
							Mean	12%

*All eggs died due to flow interruption.

** All eggs dead (bad shipment)

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 waters or from upstream releases in Pennsylvania.

In 1999, the Conowingo East Lift was operated in fish passage mode while the West Lift was used to transport adult American shad and river herring to spawning sites above dams. The East Lift passed 69,712 American shad while lifts at Holtwood and Safe Harbor passed 34,702 and 34,210, respectively. These fish had the opportunity to spawn naturally in the river reach below York Haven Dam.

Of the 9,658 adult shad collected at Conowingo West Lift in 1999, 5,508 were transported and stocked at the Tri-County Marina and Columbia Borough boat launch during the period 25 April through 4 June. These fish had the opportunity to spawn naturally in the river reach from York Haven Dam to the Fabri Dam on the main stem and Warrior Ridge or Raystown on the Juniata. Observed transport and delayed mortalities amounted to 232 fish (3.3%). Overall sex ratio (SR) in these transfers was about 1.1:1.0, males:females. During 1999, approximately 1,310 and 795 blueback herring were stocked in Little Conestoga Creek and the Conestoga River, respectively. This compares with approximately 4,755 blueback herring stocked at the Tri-County Marina (1,102) and in Little Conestoga Creek (3,653) during 1998.

During the 1999 shad production season, the PFBC released 13.4 million shad larvae in the Susquehanna watershed. This compares with 3 to 12 million fry stocked each year from 1990 - 1998. Most larvae were released between 17 May to 21 June in the following locations, numbers, days(d) of age (tetracycline marks by days of age in parentheses):

Juniata R.(various sites)	10,229,000	age 5-10d (3)
W. Br. Susq. R.	984,000	age 17-22d (3,6,9,15)
N. Br. Susq. R.	1,211,000	age 19d (3,6,12,15,18)
Conodoguinet Ck.	373,000	age 14d (3,6,9,12)

Conestoga R.	236,000 age 20d (3,9,12,15)
W. Conewago Ck.	219,000 age 19d (3,6,9,12,18)
Swatara Ck.	249,000 age 20d (3,6,9,15,18)

Methods

Juvenile American shad were collected at several locations in the Susquehanna River Basin during the summer and fall of 1999 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 analysis. Otoliths from sub-samples were analyzed for tetracycline marks to determine hatchery verses wild composition of the samples.

<u>Haul Seining - Main Stem</u>

Haul seining was conducted at Columbia by RMC/Normandeau Assoc., Inc. once each week on 15 dates during the period 13 July through 20 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 25 July through 28 August. A total of 300 hauls were conducted at 30 stations in five tributaries (six per tributary) using a seine measuring 30-ft X 6-ft with 3/8 in stretch mesh. In addition, float trips were conducted on four of the five tributaries (excluding Little Conestoga Creek). The purpose of these trips were multifaceted and included verification that seine sampling stations utilized were representative of the various habitat types found in each tributary. If young alosids were observed dimpling, attempts were made to capture them with a 10-ft diameter monofilament cast net.

Push-netting

Push-netting for juvenile alosids was conducted by RMC/Normandeau Assoc., Inc. at various sites in the upper portion of Conowingo Pond 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 Pond.

Electrofishing-juveniles

Electrofishing was conducted by RMC/Normandaeu Assoc., Inc. at two sites, one on the Susquehanna River at Clemson Island, and one on the Juniata River at Mifflintown, using a 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 the Clemson Island site and Mifflintown were sampled on eight dates during the months of August and September.

Electrofishing-adults

Electrofishing was conducted using various gear types in the Susquehanna River, Juniata River, and selected tributaries at or near the base of blockages to migration. Sampling locations were as follows:

Susquehanna R. - Fabri Dam(Sunbury);

Juniata R. - Raystown Dam (Huntingdon), Warrior Ridge Dam (Petersburg);

Tributaries (Lancaster Co.) - Conestoga R., Little Conestoga Ck., Fishing Ck.

Tributaries (York Co.) - Peters Ck., Muddy Ck., W. Conowago Ck.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Sampling at Holtwood Dam Inner Forebay was conducted by RMC/Normandeau Assoc., Inc. using a fixed 8-ft square lift-net beginning mid-September and continuing every three days through mid-December (30 total). Sampling began at sunset and consisted of 10 lifts with 10 minute intervals between lift cycles.

RMC/Normandeau Assoc., Inc. conducted intake screen sampling for impinged alosids at PECO's Peach Bottom Atomic Power Station three times per week from 18 October to 10 December, 1999. SECO's Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosids twice weekly from 4 October to 10 December.

Susquehanna River Mouth and Flats

Maryland DNR sampled the upper Chesapeake Bay using haul seines and by electrofishing in the summer and fall, 1999.

Disposition of Samples

Subsamples of up to 30 fish 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. Otolith analysis of fish captured in the upper Chesapeake Bay were analyzed by Maryland DNR.

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 322 juveniles American shad were collected in 90 hauls for an overall Geometric Mean Catch-Per-Unit-Effort (GM CPUE) of 1.16 (Table 1). Daily Catch-Per-Unit-Effort (D CPUE) ranged from zero (13 July, 20 July, 12 August, 17 August) to 30.03 shad per haul (15 September, Table 2). No sampling occurred during the week of 5 September due to high river flows caused by Hurricane Dennis. Of the total 322 juveniles captured, 264 (82%) were taken the week of 12 September; 182 (56.5%) were taken on 15 September with 137 individuals captured in a single haul; and 81 (25.2%) were taken on 13 September with 76 individuals captured in two hauls combined. A total of 20 species were collected by seine.

Haul Seining - Tributaries

A total of 300 seine hauls were made in the five tributaries between 26 July and 25 August 1999. No American shad or blueback herring were collected or observed. Twenty-six other species were collected. No visual observations of shad were made during sampling.

Push-netting

A total of two American shad was collected in approximately 2031 minutes of push-netting. One individual was collected from Lower Bear Island in Conowingo Pond and another was collected from the west shore of the Safe Harbor impoundment. Two alewife were also collected in Conowingo Pond. The D CPUE for American shad on ranged from zero to 0.5 per hour. A total of 14 species were collected.

Electrofishing-juveniles

Two sites were sampled for a total of 981 minutes of shock time producing 126 juvenile American shad. The Clemson Island site on the Susquehanna yielded 0.2 shad per hour of shock time. The Mifflintown site on the Juniata yielded 15.1 shad per hour of shock time (Table 3). Sixty-eight shad were observed at Mifflintown but avoided capture.

Electrofishing-adults

Boat electrofishing was conducted at the base the Fabri Dam, Susquehanna River; Warrior Ridge Dam, Frankstown Branch of the Juniata River; and Raystown Dam, Raystown Branch of the Juniata River during 1999 spring migratory season. No adult American shad were observed or captured at any site.

No adult American shad or river herring were captured in any of the tributaries sampled by electrofishing during 1999. A single adult American shad carcass was observed on the bank of W. Conewago Creek just below Hykes Mill Dam. The carcass was too badly decomposed for otolith analysis. Numerous large gizzard shad and walleye were observed at the base of the City of Lancaster Water Supply Dam on the Conestoga River, Detter's Mill Dam on W. Conewago Creek, and at the base of the first cataract upstream on Muddy Creek.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam Inner Forebay was initiated on

13 September and continued every three days until 9 December. A total of 490 juvenile American shad were captured in 140 lifts for an overall GM CPUE of 2.18 (Table 4). Highest daily catch occurred on 22 September resulting in a D CPUE of 10.8 fish per lift. D CPUE for lift-net is summarized in Table 5. A total of fifteen species were captured by lift-net in 1999 with gizzard shad being the most numerous. No adult American shad or blueback herring were captured.

Peach Bottom intake screens produced 285 juvenile American shad, 110 juvenile blueback herring, and 2 adult blueback herring. Thirty additional Alosa were captured but could not be identified. Cooling water strainers at Conowingo produced 120 juvenile American shad, 89 blueback herring, and 2 unidentified Alosa spp. A total of 22 and 7 taxa were collected at Peach Bottom and Conowingo, respectively.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 42 juvenile American shad (21 haul seine, 21 electrofisher) in the upper Chesapeake Bay during summer and fall, 1999.

Otolith Mark Analysis

Otoliths from 791 juvenile American shad taken in the summer and fall collections were analyzed for hatchery marks. A total of 245 juvenile shad otoliths from seine and electrofishing collections above Holtwood Dam was successfully processed (Table 6). Overall, 236 (96%) of the fish were marked and the remaining 9 (4%) fish were wild. All the 126 juveniles collected by electrofishing were hatchery produced. Seine collections from Columbia included 110(92%) hatchery fish and 9(8%) wild fish. The single shad captured by push-net in the Safe Harbor Impoundment was wild.

Otoliths from a total of 546 juvenile American shad collected at Holtwood Dam and Conowingo Pond were successfully processed. Overall, 517 (95%) of the fish were marked and the remaining 29 fish (5%) were wild. The single shad captured by push-net in Conowingo Pond was wild. The total percentage of hatchery fish above Conowingo was 95% with 5% being wild. Recapture of shad from various stocking sites is discussed in Job III.

Of the 42 juvenile American shad processed from DNR collections in the upper Bay, 35 were processed for otolith analysis. Only one (3%) was hatchery marked with the remaining 34 fish (97%) being wild.

Discussion

In-Stream Movements and Outmigration Timing

River conditions during 1999 could be characterized by normal spring flows followed by extreme drought conditions and elevated water temperatures in early to mid-summer. Drought conditions were relieved by hurricanes Dennis and Floyd in late summer. At Holtwood Dam, precipitation from Dennis resulted in a ten-fold increase in average daily river flow from 6 September (4,200 cfs) to 8 September (50,900 cfs). A dramatic increase was also associated with Floyd when flows swelled from 6,400 cfs on 15 September to a peak of 54,000 cfs on 18 September. Extremes in river flow during 1999 had implications on the collection of juvenile alosids.

The 1999 drought appears to have had a pronounced impact on the catch of shad at Columbia. Haul seine collections were lowest in July and August, and highest in September and October, in contrast to 1998 when catches were highest in July and August, and lowest in September and October (Table 7). Approximately 93% of the 1999 juvenile shad catch by seine occurred in September and coincided with increased river flow from precipitation associated with hurricane Dennis (Figure 1). Low flows during July and August may have altered juvenile shad distribution in comparison to years with normal flows. Clear water conditions may have influenced catch rates by eliciting net avoidance.

The first marked fish collected at Columbia by seine occurred on 26 August. These included six shad stocked in the Juniata River (various sites) suggesting a movement of approximately 60-80 miles in 87 days or less. In general, the 1999 cohort of juvenile shad required more time than the 1998 cohort to travel a comparable distance suggesting that lower flows inhibit downstream drift prior to the directed emigration.

Based on lift-net catches, peak outmigration of juvenile American shad at Holtwood Dam occurred from 16 September through 25. The first American shad taken by lift-net occurred on 16 September at a water temperature of 22.5 C and a river flow of 23,000 cfs. The majority (82%) of the American shad emigrated past Holtwood early in the season, concurrent with increased river flows stemming from hurricanes Dennis and Floyd (Figure 2). Most American shad were captured when river flows exceeded 15,000 cfs. The peak collection (108) occurred on 22 September at a water temperature of 18 C and a river flow of 27,700 cfs. The last American shad were collected on 25 October at a water temperature of 12.0 C and a river flow of 11,600 cfs.

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 1999, 68% of the outmigration occurred in a three week period when the water temp was between 18.0 C and 16.0 C, and with a seasonally high river flow which was greater than 25,000 cfs. This pattern is consistent with previous years but somewhat earlier than the 1 October through 16 December outmigration period observed in 1998 (Table 8). Shad catches by lift-net and haul seine in 1999 were associated with increases in river flows (Figures 1 and 2) with most juvenile shad being captured when flows exceeded 15,000 cfs. There appeared to no difference between the timing of outmigration for wild verses hatchery juveniles.

Abundance

Comparison of relative abundance of juvenile shad in the Susquehanna River from year to year remains difficult due to the opportunistic nature of net sampling and wide variation in river conditions which may influence catches. Overall, 1999 GM CPUE by seine of 1.16 is the fourth lowest on record since 1990 and the third lowest at Columbia since sampling was standardized at that site in 1992 (Table 1). GM CPUE for lift-netting in 1999 was

2.18, ranking fourth out of the last fourteen years of sampling by this method and higher than the long-term average of 1.95 (Table 4). 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 3). There does appear to be a relationship between lift net GM CPUE and river flow (Figure 4) suggesting that catches of shad at Holtwood may be more influenced by river flow than juvenile abundance.

Tributary seining efforts resulted in the capture no juvenile shad. However, otolith analysis of outmigrants shows the relative survival of shad stocked in tributaries was high. Low flows brought about by the drought may have reduced sampling effectiveness by seine in tributaries. In both 1997 and 1998, seining was effective in collecting juvenile shad in major tributaries.

Since 1996, efforts to use electrofishing to overcome difficulties in net sampling to catch juveniles have experienced marginal success. Total CPUE (fish per hour) for juvenile shad by electrofishing in 1999 (Mufflintown and Clemson Island combined) was 7.7, almost three times than that observed in 1998. Electrofishing CPUE at Mifflintown was 15.2. This compares to zero, 12.6 and 0.3 during approximately the same time period in

1998, 1997 and 1996, respectively. CPUE at Clemson Island was 0.2. This compares to zero, 5.2 and 2.2 during approximately the same time period in 1998, 1997 and 1996, respectively. Higher catches observed at Mifflintown may be the result of stocking five times as many fry in the Juniata verses the upper Susquehanna, proximity of the sampling site to stocking sites on the Juniata River, or low relative survival of shad fry stocked in the North and West Branches of the Susquehanna. 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. Unlike previous years, no electrofishing was conducted at Columbia or Greenwood.

Push-netting has been demonstrated to be successful at catching juvenile alosids in Virginia. It was felt that changes in push-net design and sampling techniques the end of the 1997 sampling season would improve catches in subsequent years. Although increased catches in Conowingo Pond were observed in 1998, they declined in 1999 and remain below anticipated levels.

Nearly 131,000 blueback herring passed the Conowingo East Fish Lift in 1999, yet only 73 passed Holtwood suggesting that most spawned in Conowingo Pool. In addition, large numbers of juvenile herring were impinged at Peach Bottom and Conowingo during October through December. Since no juvenile herring were collected at Holtwood by lift-net, these herring must have been spawned and remained in Conowingo Pond until late fall and would have been expected to be better represented in push-net samples. It is uncertain if lower than anticipated catches are due to poor net design and techniques, low alosid abundance, gear avoidance due to water clarity, or some other undetermined factor(s). Despite concerns over the effectiveness of push-netting for collecting juvenile alosids, it remains the only feasible method of detecting juvenile alosids within a month of spawning. If reproduction is taking place within Conowingo Pond and the progeny are outmigrating before impingement sampling in the fall, this is the only chance to document such reproduction. Continued modifications to the net and sampling techniques as well as increases in alosid abundance may improve push-net sampling effectiveness in future years.

Failure to capture juvenile blueback herring by the Holtwood lift-net in 1999 reflects that fact that few pre-spawn adults were released upriver and, as a result, wild reproduction was most likely low. Similar results were observed in 1998. In 1997, twenty-six juvenile blueback herring were captured by lift-net with approximately six times as many adults transported than in 1998 and 1999. The concurrent high numbers blueback herring collected from intake screens at Peach Bottom and strainers at Conowingo in 1999 suggests that environmental conditions permitted spawning and survival of young blueback herring in Conowingo Pond.

During each of its first two operating seasons, the fish lift at Holtwood Dam lifted less than 30% of the American shad passed at Conowingo Dam. In 1999, the Holtwood lift passed less than 50% of those passed at Conowingo. Reproductive success the adults spawning which passed Conowingo but not Holtwood may be substantial, however poor catches of wild alosids by push-net in the Conowingo pool did not 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.

Approximately 13.4 million American shad were cultured and released in the Susquehanna River Basin above Conowingo Dam in 1999. Both hatchery and wild juveniles were captured by all sampling methods with the exception of upper river electrofishing. If the susceptibility of hatchery and wild juvenile shad to capture by all current sampling methods are the same, hatchery fish were 20 times more abundant (95% hatchery verses 5% wild) than wild fish during 1999.

Growth

Juvenile hatchery shad collected with seines at Columbia averaged 108 mm total length (TL) from 26 August to 31 August (range 98-130mm) and grew to an average 117 mm (range 99-147 mm) by 12 October to 20 October. Wild juveniles captured by seine averaged 79 mm TL from 26 July to 3 August and grew to an average 114 mm TL (range 112-115mm). 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 in the 1999 cohort appeared to be considerably less than that observed in the 1998 cohort. Juvenile shad collected from the Conowingo strainers on 6 December to 10 December, the last samples obtained in 1999, averaged 120mm TL (range 110-145 mm). This compares to the average of 158mm TL (range 140-169 mm) from juveniles collected on 10 December, 1998. However, growth of juvenile shad in 1999 falls within the range observed in previous cohorts.

Stock Composition and Mark Analysis

Of the 791 juvenile shad otoliths analyzed from collections above Conowingo Dam, 38 (5%) were unmarked. This compares to 5% wild fish in 1998 collections, and 11-58% in 1991-1997. The high percentage of hatchery juveniles observed in 1999 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, and the stress associated with these transfers, may have also contributed to low natural reproduction.

Over 34,000 adult American shad were passed at Safe Harbor in 1999. This compares to approximately 6,000 and 20,000 in 1998 and 1997, respectively. These fish had access to a 25 miles section of free flowing river between Safe Harbor and York Haven. It is difficult to assess the contribution this habitat had to the overall production of wild fish. The low contribution of wild fish at Holtwood, Peach Bottom, and Conowingo suggests that larvae spawned below York Haven were not abundant, were swamped by high survival of hatchery fish, or drifted below Conowingo before sampling began. Survival of the 1999 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 stockings sites with the exception of the W. Branch of the Susquehanna River 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 1.16 was the third lowest recorded for that gear since sampling at Columbia was standardized in 1992.
- Electrofishing CPUE for juvenile shad (all sites combined) was 7.7 fish per hour, the highest recorded since electrofishing sampling began in 1996.
- Lift-netting at Holtwood resulted in a GM CPUE of 2.18, the fourth highest on record since 1985.
- Push-netting catches in Conowingo Pond were down compared to 1998.
- Drought conditions may have impacted the ability to sample juvenile alosids.
- Peak out-migration based on seine and lift-net catches occurred during September/October and were associated with increased river flows triggered by hurricanes Dennis and Floyd.
- Otolith analysis determined that only 5% of the juveniles collected above Conowingo Dam were of wild origin.

- Several factors may have impacted ability to catch of juveniles in 1999 including: 1) poor reproductive success of transported adults; 2) high juvenile mortality; 3) ineffective sampling methods due to environmental conditions.
- The full potential for wild reproduction will not be realized until the year 2000 with the completion of the fishway at York Haven and the reopening of over 400 miles of main stem spawning habitat.

Acknowledgments

RMC/Normandeau and Associates (Drumore, PA) were contracted by the PFBC to perform juvenile collections while PFBC Division of Fisheries Management staff conducted electrofishing for adults. Many individuals supplied information for this report. For their contributions, appreciation is extended to Chris Frese and George Nardacci (RMC), and Mike Hendricks, and Larry Jackson (PFBC). Gina Russo and Lou Renolds processed most of the otoliths and Ted Jacobsen (Ecology III) administered the otolith contract.

Table 1. Index of abundance for juvenile American shad collected by haul seine in at Marietta, Columbia and Wrightsville, 1985-1999.

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	77,991
1994	110	390	3.55	2.29	108	23,168	
1995	48	409	8.52	7.89	91	5,741	
1996	105	283	2.70	2.05	92	25,632	
1997	90	879	9.77	6.77	98	7,472	
1998	94	230	2.45	1.03	98	5,960	
1999	90	322	3.58	1.16	100	10,336	

*Mean flow during collections.

Table 2

Juvenile American shad catch per effort (CPUE), standard deviation, variance, and confidence for haul seining at Columbia on the lower Susquehanna River, 1999.

Date	Number of Hauls	Number of American Shad	CPUE	Standard Deviation	Variance	Confidence Interval
13 Jul	6	0	0.00	0.00	0.00	0.00
20 Jul	6	0	0.00	0.00	0.00	0.00
26 Jul	6	1	0.17	0.41	0.17	0.33
03 Aug	6	1	0.17	0.41	0.17	0.33
12 Aug	6	0	0.00	0.00	0.00	0.00
17 Aug	6	0	0.00	0.00	0.00	0.00
26 Aug	6	8	1.33	2.07	4.27	1.65
31 Aug	6	2	0.33	0.82	0.67	0.65
13 Sep	6	82	13.67	20.33	413.47	16.27
15 Sep	6	182	30.33	53.66	2879.87	42.94
23 Sep	6	17	2.83	3.37	11.37	2.70
29 Sep	6	20	3.33	4.08	16.67	3.27
06 Oct	6	1	0.17	0.41	0.17	0.33
12 Oct	6	3	0.50	0.84	0.70	0.67
20 Oct	6	5	0.83	2.04	4.17	1.63

Table 3.

Catch per unit of effort (CPUE), standard deviation, variance, and confidence interval for juvenile American shad collected with a boat-mounted electrofisher from the Juniata River, August through September 1999.

Date	Number of Shad	CPUE (No./hour)	Mean	Standard Deviation	Variance	Confidence Interval
5-Aug	2	2.00	0.50	0.58	0.33	0.33
12-Aug	10	10.00	2.50	2.08	4.33	4.25
19-Aug	12	11.08	3.00	2.58	6.67	6.53
26-Aug	7	7.00	2.33	3.21	10.33	11.69
2-Sep	30	29.03	7.50	5.26	27.67	27.11
7-Sep	19	19.00	4.75	6.95	48.25	47.28
17-Sep	32	32.00	10.67	14.36	206.33	233.48
23-Sep	12	10.91	3.00	3.37	11.33	11.11
TOTAL	*124*	*15.09*	*4.13*	*5.84*	*34.05*	*13.09*

Table 4. Index of abundance for juvenile American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-1999.

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	

*Geometric mean values required by ASMFC.

Table 5.

Catch per unit effort (CPUE), standard deviation, variance, and confidence interval for juvenile American shad collected by an 8 ft x 8 ft lift net at the Holtwood Power Station inner forebay, 13 September to 9 December 1999.

Date	Number of Shad	CPUE	Standard Deviation	Variance	Confidence Interval*
13 Sep	0	0.00	0.00	0.00	NA
16 Sep	7	0.70	0.55	0.30	0.48
19 Sep	85	8.50	6.87	47.17	4.26
22 Sep	108	10.80	19.93	397.07	12.35
25 Sep	4	0.40	0.58	0.33	0.65
28 Sep	2	0.20	0.00	0.00	NA
1 Oct	25	2.50	4.90	24.00	4.29
4 Oct	95	9.50	6.11	37.28	3.99
7 Oct	20	2.00	1.35	1.81	1.00
10 Oct	24	2.40	12.73	162.00	17.64
13 Oct	49	4.90	14.24	202.70	12.48
16 Oct	8	0.80	1.53	2.33	1.73
19 Oct	34	3.40	5.36	28.70	4.70
22 Oct	14	1.40	3.06	9.33	3.46
25 Oct	15	1.50	0.96	0.92	0.94
28 Oct	0	0.00	0.00	0.00	NA
31 Oct	0	0.00	0.00	0.00	NA
3 Nov	0	0.00	0.00	0.00	NA
6 Nov	0	0.00	0.00	0.00	NA
9 Nov	0	0.00	0.00	0.00	NA
12 Nov	0	0.00	0.00	0.00	NA
15 Nov	0	0.00	0.00	0.00	NA
18 Nov	0	0.00	0.00	0.00	NA
21 Nov	0	0.00	0.00	0.00	NA
24 Nov	0	0.00	0.00	0.00	NA
29 Nov	0	0.00	0.00	0.00	NA
1 Dec	0	0.00	0.00	0.00	NA
3 Dec	0	0.00	0.00	0.00	NA
6 Dec	0	0.00	0.00	0.00	NA
9 Dec	0	0.00	0.00	0.00	NA

* 95 percent confidence level

Table 6. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1999.

Collection Site	Coll. Date	Immersion marks: Day 3 Jun. R.	Days 3,6, 9,12 Conodo-guinet Cr.	Days 3,6,9, 12,18 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
Susq. R.	8/10/99							1	1		1
Clemson I.	8/24/99							1	1		1
									0		
Juniata R.	8/5/99	2							2		2
at Mifflintown	8/12/99	10							10		10
	8/19/99	12							12		12
	8/26/99	7							7		7
	9/2/99	30							30		30
	9/7/99	19							19		19
	9/17/99	32							32		32
	9/23/99	12							12		12
Columbia	7/26/99								0	1	1
	8/3/99								0	1	1
	8/26/99	6							6	2	8
	8/31/99	1							1	1	2
	9/13/99	29			2				31		31
	9/15/99	27		1	1				29	1	30
	9/23/99	9	2		3				14	2	16
	9/29/99	13	2	5					20		20
	10/6/99			1					1		1
	10/12/99	1		2					3		3
	10/20/99	3		1	1				5		5
									0		0
Safe Harbor Reservoir	6/16/99								0	1	1
Above Holtwood		213	4	10	7	0	0	2	236	9	245
Percent		87%	2%	4%	3%	0%	0%	1%	96%	4%	

(continued on the next page)

Table 6. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1999.

Collection Site	Coll. Date	Immersion marks: Day 3	Days 3,6, 9,12	Days 3,6,9, 12,18	Days 3,6,9, 15,18	Days 3,9, 12,15	Days 3,6, 9,15	Days 3,6,12, 15,18	Hatchery Total	Wild	Total
		Jun. R.	Conodoguinet Cr.	W. Conewago Cr.	Swatara Cr.	Conestoga Cr.	W. Br. Sus. R.	N. Br. Sus. R.			
Holtwood	9/16/99	6				1			7		7
	9/19/99	25		1	2	2			30		30
	9/22/99	26				1			27	2	29
	9/25/99	1				2		1	4		4
	9/28/99	1							1		1
	10/1/99	19				1		4	24	1	25
	10/4/99	27						3	30		30
	10/7/99	17	1		1				19		19
	10/10/99	18			1			2	21	2	23
	10/13/99	22	3		2				27	5	32
	10/16/99	4	1		2				7		7
	10/19/99	25	2		1	1			29	1	30
	10/22/99	12	1					1	14		14
	10/25/99	12	2			1			15		15
Conowingo Pond Pushnet	6/19/99	(1 alewife)							0		0
	6/25/99	(1 alewife)							0		0
	7/1/99								0	1	1
Conowingo Pond- trawl	10/26/99					1			1		1
Peach Bottom Impingement	10/20/99	1							1		1
	10/29/99							1	1		1
	11/1/99	1							1		1
	11/17/99	15	1						16	2	18
	11/19/99	13	1		1	1			16	3	19
	11/22/99	8							8	1	9
	11/24/99	2	1					1	4		4
	11/29/99	3				1			4	1	5
	12/1/99	2							2		2
	12/3/99	14							14		14
	12/6/99	103	2		1			2	108	7	115
	12/8/99	7							7		7
	12/10/99	7			1			1	9		9
Conowingo Strainers	10/8/99	1	1			1			3		3
	10/15/99	3							3		3
	10/18/99	1							1		1
	10/22/99	3							3		3
	10/28/99	2							2		2
	11/5/99			1		1			2		2
	11/19/99	12							12	2	14
	11/24/99	7							7		7
	12/3/99	11	1						12		12
	12/6/99	11							11		11
	12/10/99	14							14	1	15
Holt./P. Bot./Con.		456	17	2	12	14	0	16	517	29	546
Percent		84%	3%	0%	2%	3%	0%	3%	95%	5%	
Total		669	21	12	19	14	0	18	753	38	791
Percent		85%	3%	2%	2%	2%	0%	2%	95%	5%	

Note: The following collections were omitted due to the potential for misidentification of blueback herring as A shad: Peach Bottom Impingement 10/22- 2 fish, 10/25- 3 fish, 11/3- 3 fish, 11/8- 60 fish, 11/10- 12 fish, 11/12- 42 fish, 11/15- 21fish. Conowingo Strainers: 11/10- 3 fish.

Table 7.

Weekly number of juvenile American shad captured by haul seine on the lower Susquehanna River at Columbia, PA, July-October, 1989-1999.

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

* No sampling this week due to high river flows.

Table 8.

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 1985-1999.

	Historical Years												Year		
Week	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996**	1997	1998	1999
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
Sep 17-23	-	-	0.7	-	2.3	0.0	0.0	0.5	0.0	0.0	-	-	0.0	0.0	9.7
Sep 24-30	-	-	0.3	-	-	7.5	0.0	0.0	0.3	0.1	0.0	-	0.0	0.0	0.3
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
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
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
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
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
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
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
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
Nov 26-Dec 2	15.1	-	-	0.3	-	0.0	1.6	-	0.0	0.0	0.0	-	0.5	0.0	0.0
Dec 3-9	62.8	14.2	0.0	0.0	-	-	-	0.9	-	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
								Total number of lifts for season					300	300	300
								CPUE for entire season					4.6	0.6	1.6

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

Figure 1. River flow and collection of juvenile American shad by seine at Columbia, PA. 1999.

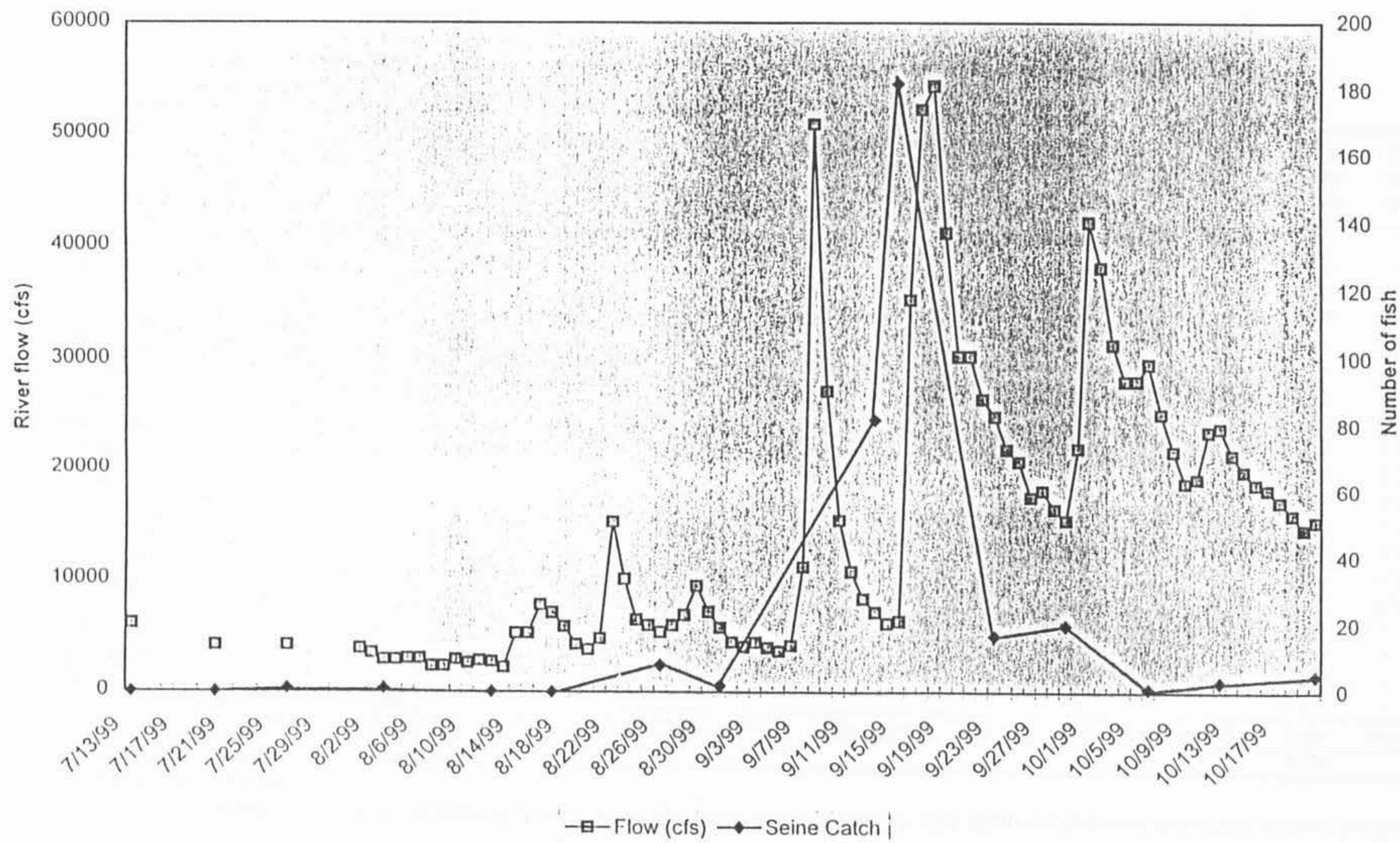


Figure 2. River flow and collection of juvenile American shad by lift net at Holtwood Dam, 1999.

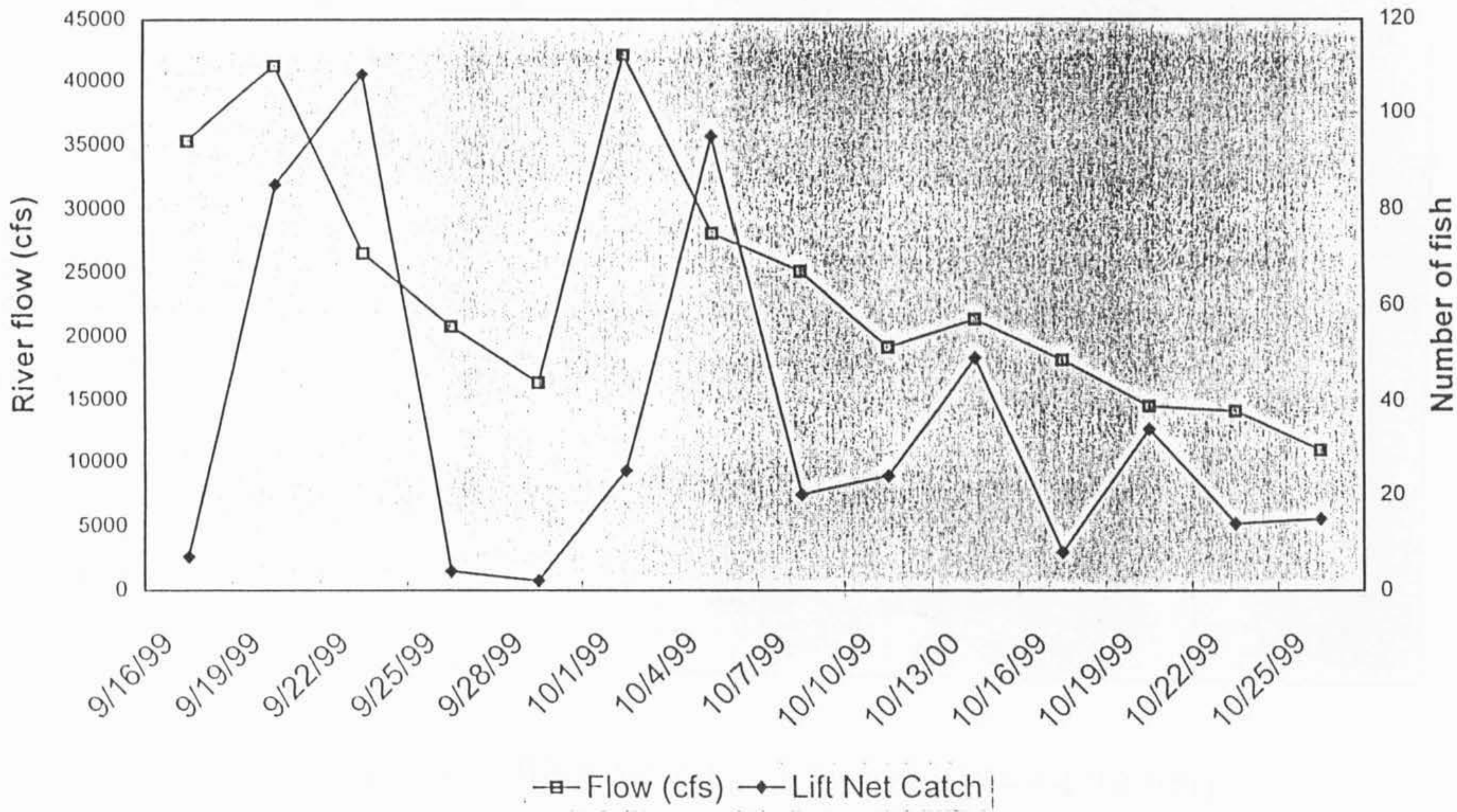


Figure 3. River flow vs. GM CPUE (Holtwood lift net)

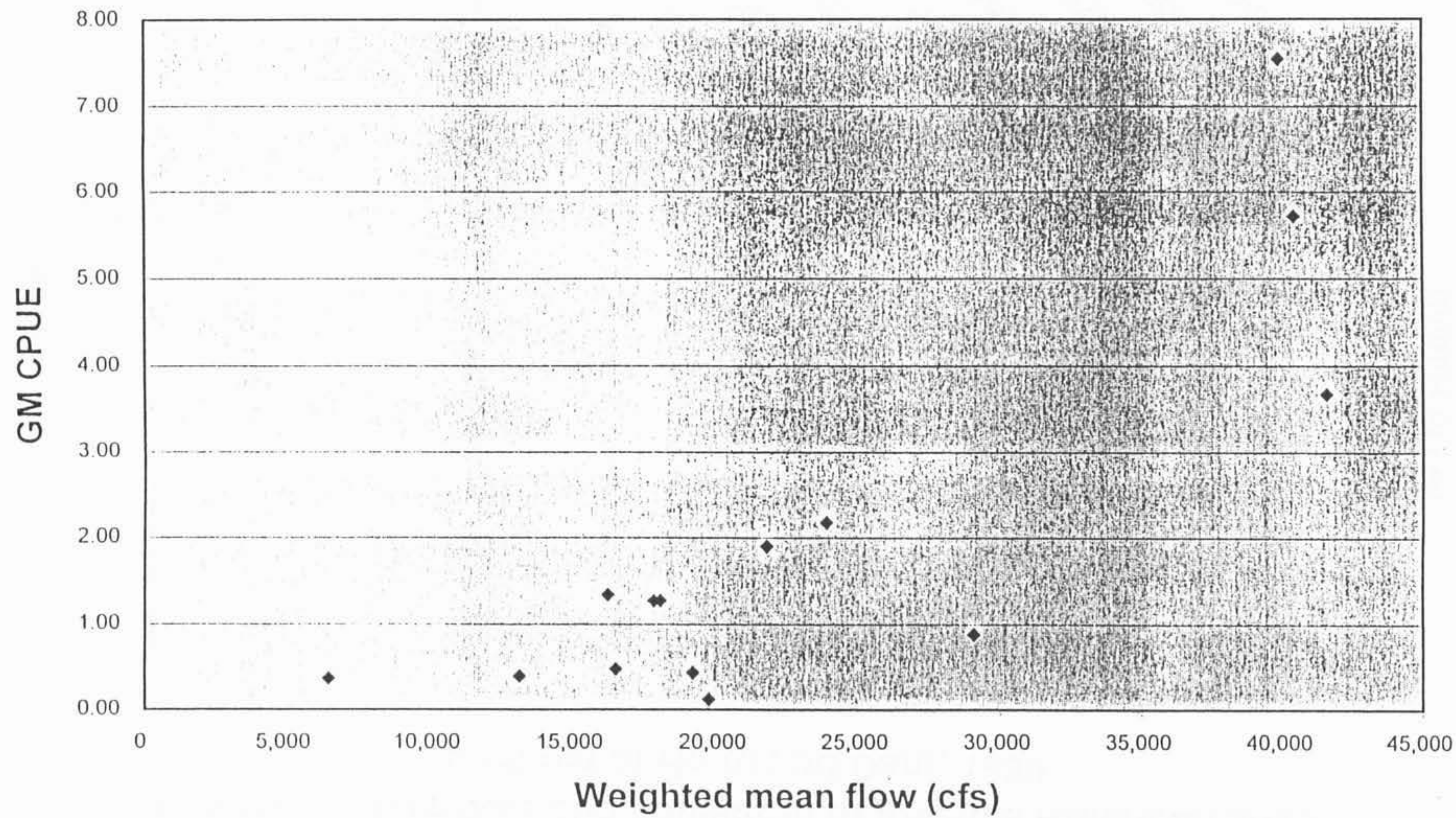
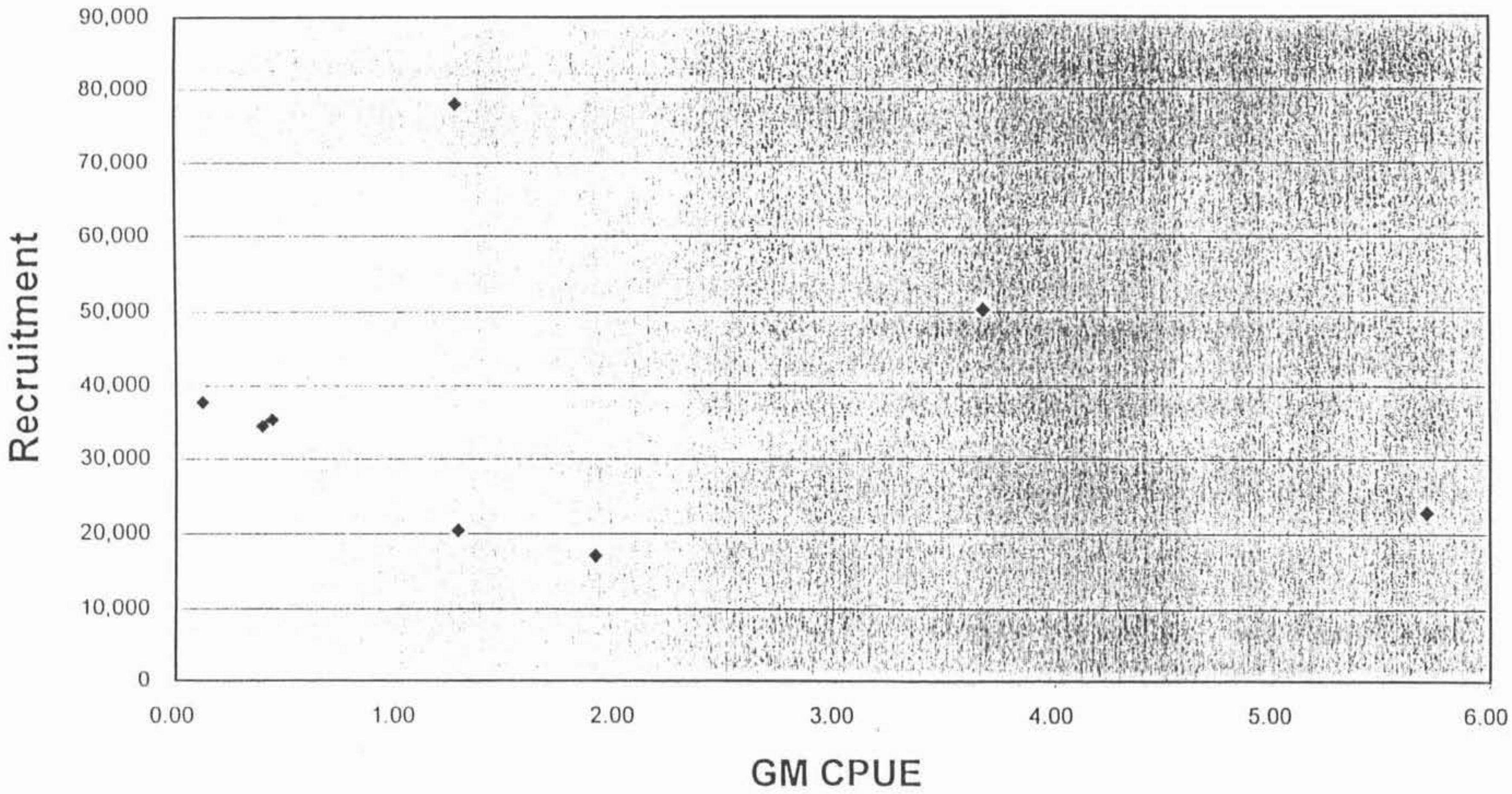


Figure 4. GM CPUE (Holtwood lift net) vs. Recruitment to Conowingo fish lifts



Job V. Task 1 Analysis of adult American shad otoliths, 1999

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Abstract

A total of 193 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 1999. Based on tetracycline marking and otolith microstructure, 47% of the 188 readable otoliths were identified as wild and 53% hatchery. Wild fish represented a statistically significantly lower proportion of the catch in samples collected at Conowingo (47%) than at Safe Harbor Fish Lifts (62%). Double marked fish (released below Conowingo Dam) represented 4.8% 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 1986-1994 year classes, stocking of approximately 337 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 140 fingerlings was

required to return one adult to the lifts. For wild fish, transport of 0.78 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1994 year class is not fully recruited. Actual survival is even higher since not all surviving adults enter the lifts.

Introduction

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). 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 1999.

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad to enter the West lift. Approximately 20 adult shad were collected from the Safe Harbor Dam Fish Lift each week, beginning on May 6 and ending on June 3, 1999. 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 65 otoliths whose age is known based on the presence of a unique tetracycline mark. These were used as reference material.

A Chi-square Test of Independence (Ott, 1973) was used to test the Conowingo and Safe Harbor Lift samples to determine if the frequencies of wild and hatchery fish collected in those samples were the same.

Historical fish lift catch data was compiled from SRAFRC Annual Progress

Reports for the years 1972 through 1998. Age composition data was gathered as follows: for 1996 to 1999, 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 193 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 1999. No samples were collected from the East lift since it was operated in fish passage mode. For 5 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 188 readable otoliths (Table 1). A total of 88 (47%) otoliths exhibited wild microstructure and no tetracycline mark. One hundred otoliths (53%) exhibited tetracycline marks including single, double, triple, quadruple and quintuple immersion marks. One specimen (1%) exhibited a triple immersion mark (days 3, 13, and 17) and a single feed mark, indicative of Upper Spring Creek Pond 3 culture in 1991. 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 1989-1998 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 4.9 years for females. For wild fish, mean ages were 3.9 for males and 4.9 for females (Table 4). For hatchery fish, mean age was 4.1 for males and 4.9 for females. Overall sex ratio was 1.2 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 1993 are not fully recruited, however, recruitment from the 1993 and 1994 year classes were above the long term average, and are included in the analysis. For the period 1986-1994, the number of hatchery larvae required to produce one returning adult ranged from 151 to 620, with a mean of 337 (Table 10). This is a maximum estimate since the 1993 and 1994 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 1986-1993, the number of hatchery fingerlings required to produce one returning adult ranged from 42 to 386, with a mean of 140. Again, this is a maximum estimate since the 1993 and 1994 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 1994, transport of an average of 0.78 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 do so to allow for successful restoration.

Lift catches at Conowingo Dam reached an all-time record in 1997 (103,945), decreased in 1998 (46,481) and rebounded in 1999 (79,370). Hendricks (1999) speculated that the reduced lift catch in 1998 was due high river flows which reduced lift efficiency, rather than simply fewer fish returning to the river. Evidence for this was found in the stock-recruitment data. In contrast, low river flows in 1997 and 1999 produced ideal conditions for attracting shad to the lifts. I analyzed this by calculating the number of hatchery larvae required to return one adult to the lifts for each age group from 3 to 7 (Table 13). This analysis clearly shows the inflated number of larvae required to return one adult for the 1998 spawning run (shaded) as compared to the previous (1997) and subsequent (1999) spawning runs. Table 13 also demonstrates that the 1997 and 1999 spawning runs required fewer larvae to produce one adult for each age group than did most other spawning runs. These data support the hypothesis that lift catch is strongly influenced by river flow.

Wild fish represented a significantly lower proportion of the catch in the samples collected at Conowingo (47%) than at Safe Harbor (62%, Table 1). This is the opposite of what one might expect since wild, Upper Bay stock shad might be expected to stray into the Conowingo Lift, but might not continue migrating upriver as far as wild fish of Susquehanna origin. Similarly, hatchery shad with otolith marks from upriver stockings represented 48% of the catch at Conowingo and only 34% of the catch at Safe Harbor. These fish would be expected to have a strong urge to migrate further upstream and would be expected to represent a higher proportion at Safe Harbor, not Conowingo. We have no explanation for this phenomenon.

The primary stocking area for hatchery shad has been in the Juniata River. The vast majority of transported adults have been stocked at Tri-County Marina near

Middletown and in the the free-flowing river reach between Columbia and York Haven Dam. Over the years, hatchery juvenile shad have been consistently collected in the lower Juniata River and downstream, while few wild juvenile shad have been collected above York Haven Dam. If hatchery juveniles originate from areas further upstream, we might expect them to migrate earlier in order to reach their spawning area before water temperatures become too warm for optimal spawning success.

I used the weeky catch of adult shad at the East lift and adjusted for the weekly composition of adult shad at the Conowingo West Lift, based on otolith marking, to calculate the number of hatchery shad passing the East Lift each week. A similar analysis was done for Safe Harbor.

The number of upriver origin, hatchery shad passing the Conowingo East Lift peaks between the weeks of 4/24 and 5/1, while wild shad at Conowingo peak later, during the week of 5/1 (Figure 3). At Safe Harbor, hatchery shad peak during the week of 5/8, while wild shad peak a week later, during the week of 5/15 (Figure 4). This provides preliminary evidence that hatchery fish are indeed migrating earlier than wild fish. Next year, when shad stocked in the North and West Branches in 1996 begin returning in numbers, we should be aware of the possibility of earlier arrival and passage at Conowingo Dam.

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

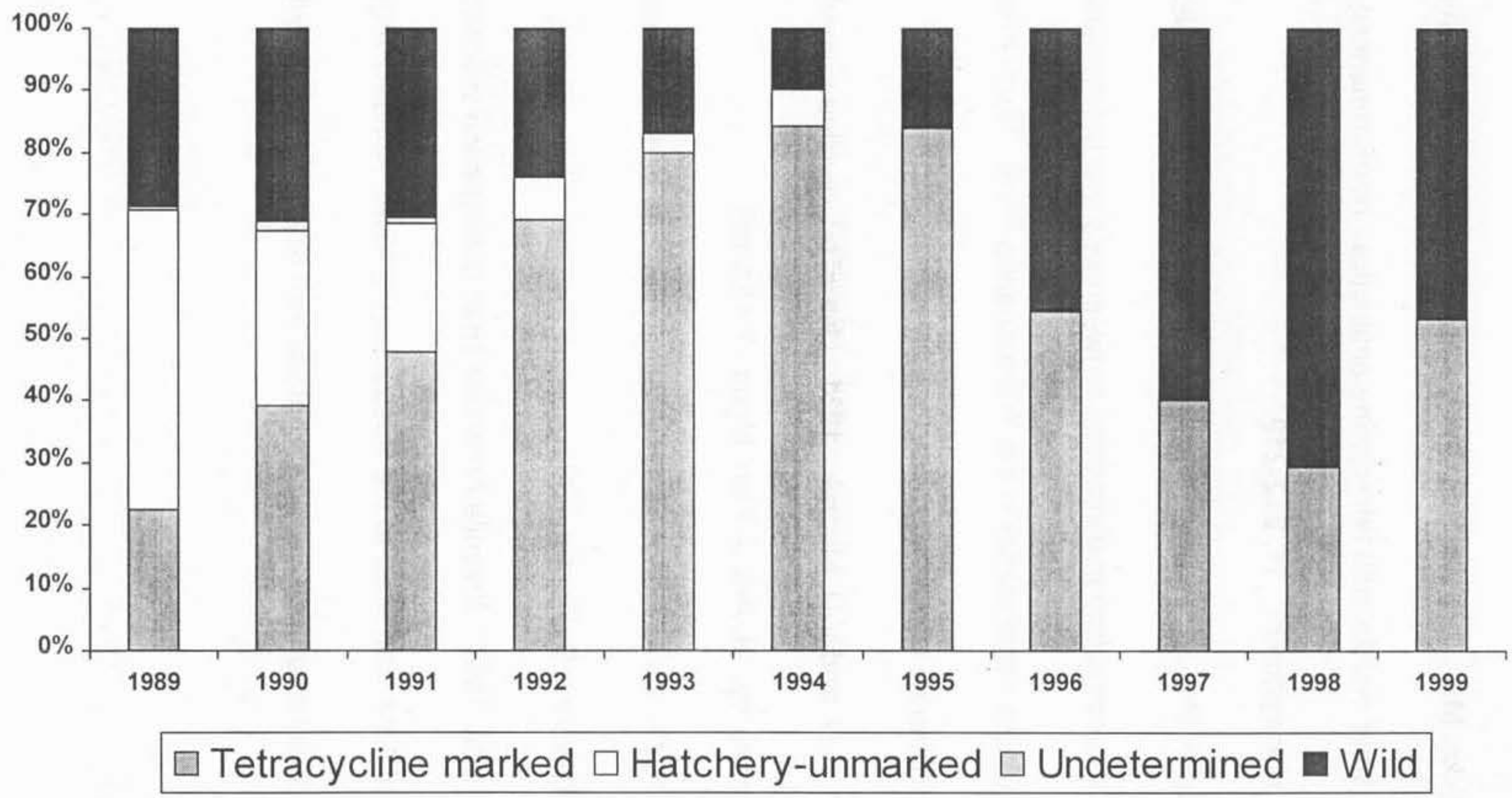


Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts, 1972-1999.

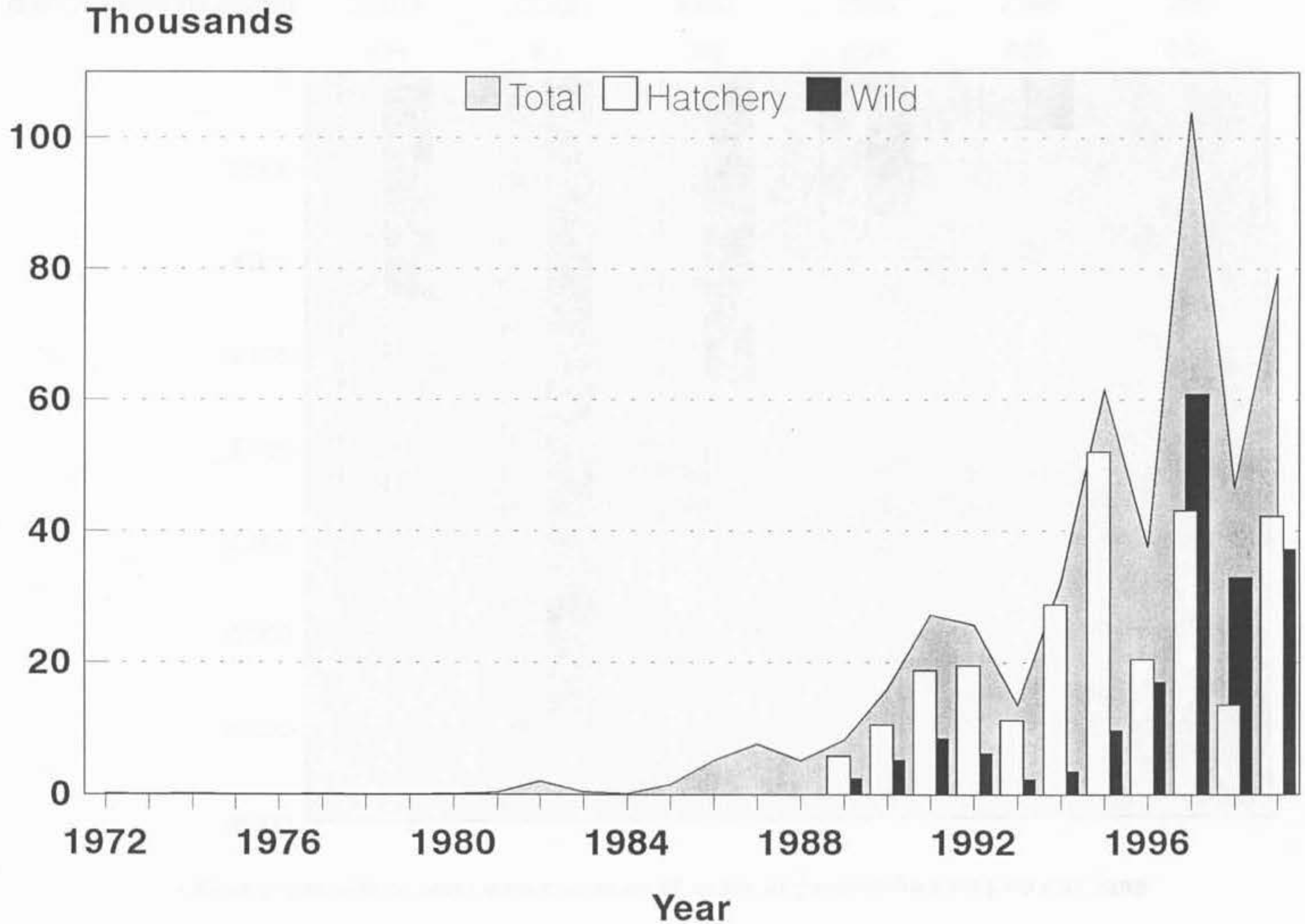
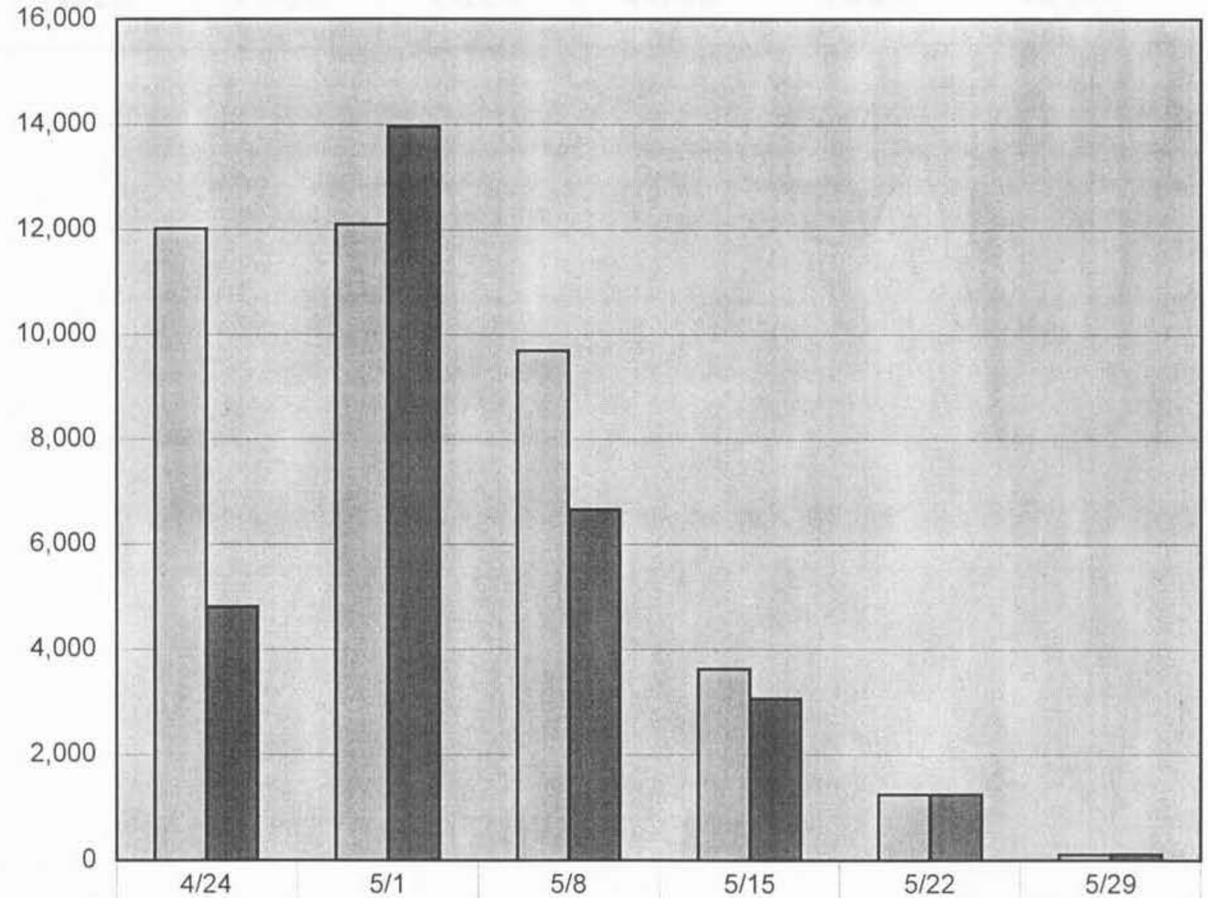


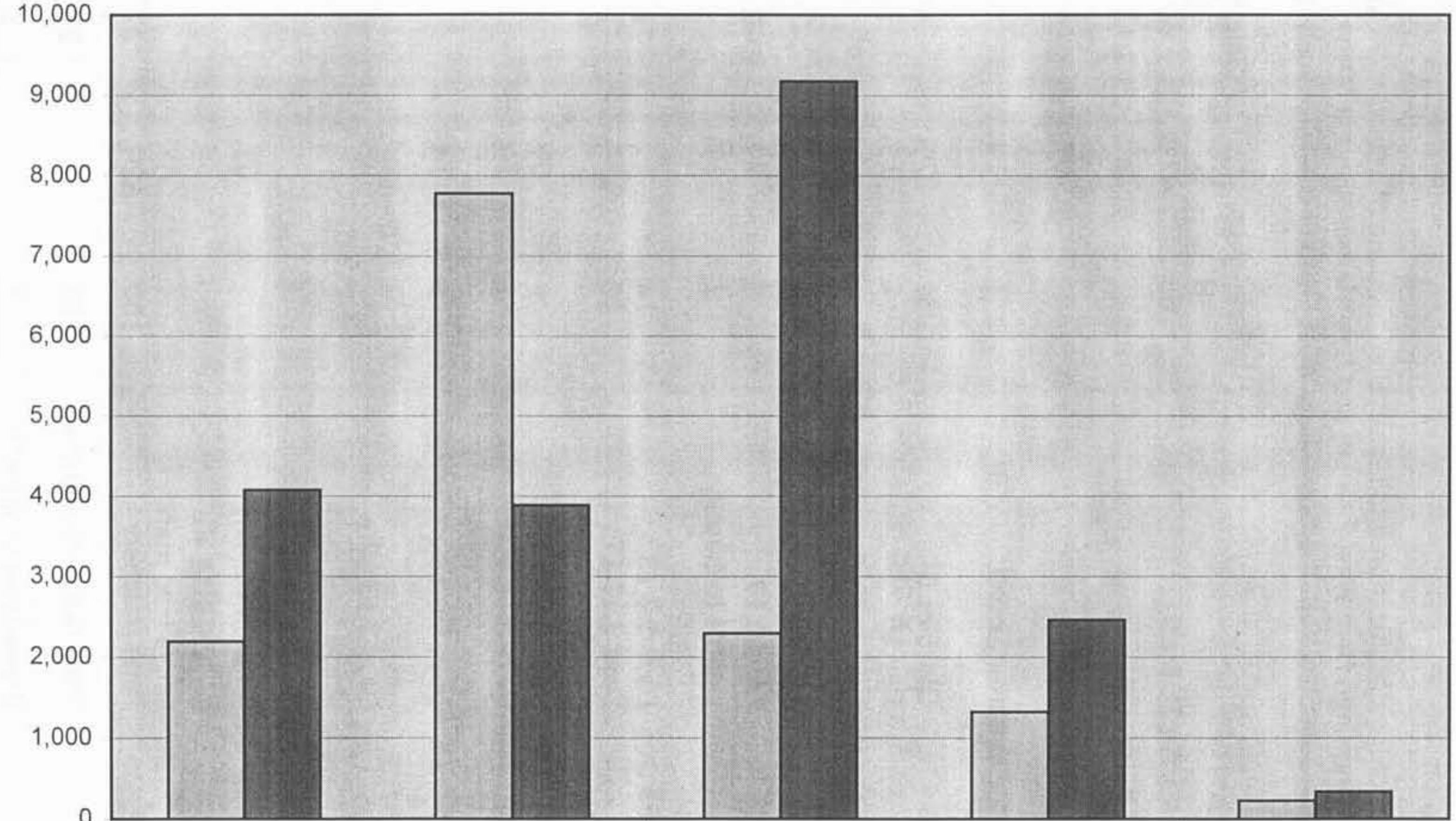
Figure 3. Passage of adult American shad by origin at Conowingo East Fish Lift, 1999



	4/24	5/1	5/8	5/15	5/22	5/29
No. Hatchery fish passed	12,015	12,102	9,691	3,620	1,249	108
No. wild fish passed	4,806	13,963	6,663	3,063	1,249	117

Week beginning

Figure 4. Passage of adult American shad by origin at Safe Harbor Fish Lift, 1999



	5/1	5/8	5/15	5/22	5/29
No. Hatchery fish passed	2,194	7,775	2,293	1,324	226
No. wild fish passed	4,074	3,888	9,173	2,459	339

Week beginning

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam West Fish Lift and Safe Harbor Fish Lift, 1999. One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

		Conowingo		Safe Harbor	
		N	%	N	%
Wild Microstructure, No TC Mark		88	47%	60	62%
Hatchery Microstructure					
No TC Mark*		-	0%	-	0%
Marked- unable to classify mark		1	1%		
Single TC Mark	Day 3 or 5	51	27%	20	21%
	Day 18	2	1%	1	1%
Double TC Mark	Days 5,9 or 3,7	3	2%	1	1%
	Days 3,11	2	1%	1	1%
	Days 3,17	3	2%	2	2%
	Unable to classify	1	1%	-	0%
Triple TC Mark	Days 5,9,13	14	7%	1	1%
	Days 3,13,17	20	11%	11	11%
Quadruple TC Mark	Days 3,13,17,21	-	0%	-	0%
	Days 3,7,15,19	1	1%	-	0%
Quintuple TC Mark	Days 5,9,13,17,21	1	1%	-	0%
Feed Marks	Days 3,13,17 + single feed mark	1	1%	-	0%
	Days 3,17 + single feed mark	-	0%	-	0%
	Days 5,9,13 + single feed mark	-	0%	-	0%
	Total Hatchery	100	53%	37	38%
	Total readable otoliths	188		97	
	Unreadable Otoliths**	5		1	
	Total	193		98	

*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
Totals	1,281	61	129	6	25	1	241	786	32	2,462

*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, 1999.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male		19	62	16	2		1	3	103	4.1
Female			24	46	13	2		4	89	4.9
Unknown								1	1	
Totals	0	19	86	62	15	2	1	8	193	4.4

Table 4. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1999.

Age	2	3	4	5	6	7	8	??	Totals	Mean
Male- Wild		11	22	8					41	3.9
Male- Hatc.		8	40	8	2		1	1	60	4.1
Female- Wild			14	22	8	1		2	47	4.9
Female- Hatc.			10	24	5	1		2	42	4.9
Totals	0	19	86	62	15	2	1	5	190	4.4

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

Sex	301-325	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	576-600	Total
Male	1	8	18	40	22	13	1	1					104
Female		1		4	19	28	22	11	2	3	1		91
Unknown													0
Totals	1	9	18	44	41	41	23	12	2	3	1	0	195

Table 6. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 1999.

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
Male- Wild	1	6	7	11	10	5	1					
Male- Hatc.		1	11	27	12	8		1				
Female- Wild				3	9	14	12	6	2	1		
Female- Hatc.		1		1	10	12	10	5		2	1	
Totals	1	8	18	42	41	39	23	12	2	3	1	0

Table 7. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1999.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male			372	(19)	390	(62)	419	(16)	426	(2)			450	(1)
Female					441	(24)	449	(46)	460	(13)	478	(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, 1999.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)
Male- Wild			361	(11)	392	(22)	424	(8)						
Male- Hatc.			387	(8)	389	(40)	415	(8)	426	(2)			450	(1)
Female- Wild					447	(14)	449	(22)	457	(8)	465	(1)		
Female- Hatc.					432	(10)	449	(24)	466	(5)	490	(1)		

Table 9. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-1999.

									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	4.1	22.1	61.5	11.7	0.6	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%

*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
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	1,954	10,522	29,313	5,561	301	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
1999						200	400	3,000	12,399	17,198
Total recruits to lifts:	15,977	12,028	14,924	27,404	37,322	16,948	14,204	25,043	25,498	17,661
Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00
Number of larvae to return 1 adult:	620	431	432	491	151	426	214	261	252	566

Mean number of larvae to return 1 adult (1986-1994): 337

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
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	31	165	460	87	5	0		
1996			0	3	64	165	134	30	1	
1997				0	0	174	302	744	436	7
1998					0	6	78	344	266	22
1999						2	4	33	138	191
Total recruits to lifts:	285	211	269	423	596	435	522	1,152	841	220
Fingerlings stocked/10,000:	7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95	0.00
Number of fingerlings to return 1 adult:	255	386	238	143	151	125	42	69	166	0
Mean number of fingerlings to return 1 adult (1986-1994):				140						

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
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	397	2,138	5,957	1,130	61	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
1999						196	391	2,933	12,123	16,816
Total recruits to lifts:	5,721	3,730	3,132	4,676	9,327	15,189	21,062	47,955	40,757	18,088
Adults transported/1000:	4.17	7.20	4.74	6.47	15.08	24.66	15.67	11.72	28.68	56.37
No. of adults transported to return 1 adult:	0.73	1.93	1.51	1.38	1.62	1.62	0.74	0.24	0.70	3.12
Mean number of adults transported to return 1 adult (1986-1994):					0.78					

Table 13. Recruitment by age group for hatchery larvae, stocked above dams, to the Conowingo Fish Lifts.

	Cohort										
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	13										
1989	373	16									
1990	1,706	166	-								
1991	6,956	2,250	307	-							
1992	6,652	6,870	2,181	545	-						
1993	277	1,867	4,563	1,867	69	-					
1994	-	859	5,918	14,318	5,059	-	-				
1995		-	1,954	10,522	29,313	5,561	301	-			
1996			-	152	2,881	7,430	6,015	1,365	51		
1997				-	-	3,676	6,363	15,695	9,191	141	
1998					-	80	1,125	4,983	3,858	322	-
1999						200	400	3,000	12,399	17,198	3,800
Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00	7.47
No. of larvae to return one adult as 3 yr old:	26,507	31,271	21,020	24,694	81,271	-	10,108	4,793	699	31,106	1,965
No. of larvae to return one adult as 4 yr old:	5,802	2,302	2,958	7,213	1,111	1,298	505	417	1,664	582	
No. of larvae to return one adult as 5 yr old:	1,423	754	1,414	940	192	971	478	1,313	518		
No. of larvae to return one adult as 6 yr old:	1,488	2,775	1,090	1,280	1,950	1,963	2,701	2,181			
No. of larvae to return one adult as 7 yr old:	35,796	6,029	3,301	88,793	-	89,800	7,599				

(shaded) 1998 spawning run

JOB V - Task 2

Development of American Shad Tank Spawning Techniques

U. S. Fish and Wildlife Service

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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. Traditionally the egg source for AMS culture has involved lethal collection at considerable cost. 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. In 1998, the Northeast Fishery Center (NEFC) began a cooperative effort to develop and conduct tank spawning technology with the goal of establishing a self-sustaining population of American shad imprinted to return and use the West Branch of the Susquehanna River. Annual production goals of 5 to 10 million fertilized shad eggs for the Pennsylvania Fish and Boat Commission (PFBC), Van Dyke Shad Hatchery, and one to two million oxytetracycline marked fry to be stocked by the NEFC in the West Branch of the Susquehanna River have been set for the next five year period.

Review of 1999 Activities

A total of 364 female and 588 male AMS were captured and transported to NEFC by Normandeau Associates of Drumore, Pennsylvania, under contract with SRAFRC from April 27 to June 5 (Table 1). Production resulted in the incubation of 449,475 eggs (7.82 liters) which yielded 17,950 fry. No fry survived past 72 hours. Tank spawning efforts at NEFC were unsuccessful due primarily to handling stressors and associated mortality or hormone injection of non-ripe fish. The general low viability of eggs and non-survival of fry are believed to be related to poor egg quality. In particular, eggs collected were found to be below minimum size guidelines reported for viable eggs (Personal Communication, Mike Hendricks, PFBC). Several system improvements were put into operation in 1999, and a number of concepts were tested to respond to the mortality and egg production issues.

1999 System Modifications

Work modifications developed or adapted in 1999 included: Egg separator; incubation protocol; fry tank modification; and reconstruction of brine shrimp rearing units.

Egg separator - A submersible egg separator was designed and employed to facilitate handling, grading, and cleaning of eggs in water. The egg separator initially cleaned debris (i.e. scales and mucous) from the eggs with a 6.3 mm screen and subsequently sorted the eggs into two size categories with a 2.8 mm screen. The average size of viable eggs range from 3.2 - 3.5 mm (Personal Communication, Mike Hendricks, PFBC). The largest eggs collected in 1999 by the NEFC were 3.07 mm; this fell below the reported size range for viable eggs.

Incubation protocol - In 1998 an incubation temperature of 65 ° F was employed which resulted in a hatch at day three. Also in 1998, no attempt was made to shade ambient light from incubating eggs. Biologists from PFBC and MDNR recommended slowing the rate of egg development with temperature and light manipulation to improve fry viability. In 1999, egg incubation temperature was reduced to 61° F and light was excluded from the eggs until the onset of hatching by wrapping incubation jars in black plastic. Exposure to sunlight then was used to produce a simultaneous hatch at about day seven. The modifications to the egg incubation protocols did result in extending the incubation period and provided synchronous emergence of the fry. Owing to very poor 1999 fry survival, no conclusions can be drawn on the effectiveness of these techniques at NEFC.

Fry tank modification - The American shad fry rearing system constructed in 1998 relied upon six-foot-diameter dark gray fiberglass tanks. A facility tour and review of fry culture procedures at PFBC Van Dyke Shad Hatchery led to two principle modifications of NEFC shad fry culture system, tank color and center screen design. Since shad fry are photo-positive, four of eight NEFC tanks were painted with white epoxy on the vertical sides and the outer circumference of the tank bottom to influence fry distribution within the tank and thereby enhance cleaning and fry removal procedures. A center drain design equipped with top cylinder fabric screens to facilitate cleaning was also adapted from Van Dyke Hatchery designs.

Brine shrimp rearing units - Two 200-liter six-foot-high brine shrimp incubation cylinders (accessed by ladder) were replaced with three shorter 250-liter units mounted on a platform. The change enabled safer operation and allowed a backup culture of *Artemia* to be reared.

Concepts Tested

Ideas tested this year included: Comparison of egg production in green vs. advanced brood, holding of immature brood for later hormone injection, and varying LHRHa implant dosage to increase egg production.

Egg production in green vs. advanced brood - Upon arrival at NEFC in mid-afternoon, shad were individually netted from the transport tank, sexed, carried by net to a treatment table and injected with a hormone implant prior to release into a spawning tank. During the initial April 27 delivery, all females received a 75-*u*g LHRHa implant and all males a 30-*u*g implant. Most females were immature (green), and had no signs of abdominal softness or protruding vents. Based on these observations the decision was made to assess the females from subsequent deliveries for their state of spawning readiness. During the May 4 and May 18 deliveries females were classified into one of two categories - soft (gravid) or hard (green). All females determined to be soft were administered a 75-*u*g implant. For those determined to be hard, approximately half received no implant, with the balance receiving a 75-*u*g implant. On May 5, no eggs were collected from soft and hard implanted females, and 39,862 eggs (0.6 liters) were collected from soft and hard non-implanted females. Conversely, on May 19, 17,351 eggs (0.45 liters) were collected over a 48-hour period from soft implanted females only.

Across the entire 1999 season, few arriving females exhibited signs indicative of spawning readiness such as protruding vents or soft abdomens which were observed in 1998 deliveries. During external examination of mortalities great difficulty was encountered distinguishing males from females. However, necropsies revealed virtually all females, soft and hard, implanted and non-implanted, from the first five deliveries were full of immature eggs. Due to the high mortality among females, little was learned about egg production in implanted hard/green fish versus implanted soft/advanced fish.

Holding of immature brood for later hormone injection - Maturation hormones such as LHRHa administered to immature females will result in no spawn or produce an immature spawn (Personal Communication, Reproductive Specialist, Dr. Jim Powell, Syndell labs, Vancouver, British Columbia). Therefore, a new treatment regime was implemented based on the premise that green females may eventually ripen while being held in captivity. This treatment scenario was in place for the May 20, 27, and 28 deliveries. Several females from the May 20 shipment, during the first five days in captivity, were periodically sampled to assess their state of maturity. Females showed signs of ripening on the fifth day of sampling which led to the decision to administer the implant. Although fish were handled with care, the stress associated with the second handling resulted in immediate mortality. Therefore, only a few fish were implanted before the injection process was ceased. Because fish did appear to steadily ripen while being held, the strategy was not abandoned entirely. The decision was made that the May 27 and 28 deliveries would be held to ripen with no subsequent use of maturation hormones, to assess the feasibility of non-induced spawning. From the May 27 delivery 1,668 eggs (0.027 liters) were produced, while no eggs were produced from the May 28 delivery. Internal examination of those fish which were held and not implanted revealed that most contained masses of deteriorating eggs. Due to high mortality among females no conclusions can be drawn on the feasibility of holding immature brood for later hormone injection.

Varying LHRHa implant dosage - Due to high mortality during the initial deliveries, a reduction of the LHRHa dosage from 75 *u*g to 30 *u*g for females was examined to evaluate hormone level impact upon brood survival and egg production. Twenty females from the May 25 shipment were administered 30-*u*g implants while the remaining fourteen females received 75 *u*g. Although the sample size was small, it does appear that the hormone dosages, 30 *u*g versus 75 *u*g had no effect on survival among female brood. Likewise, there were too few surviving females to determine the effects of varying hormone dosage on egg production.

Summary

American shad broodstock (364 female and 588 male) were captured and transported from Conowingo Dam to NEFC for tank spawning from April 27 to June 5 (Table 1). Problems with brood survival to spawning and state of maturation were encountered. In the first two deliveries, the shad were lethargic and offered little resistance during the implant process; eighty shad in the second shipment were dead upon arrival at NEFC. In subsequent deliveries, the fish appeared to be in good physical condition upon arrival with very little scale loss and few hemorrhages on the head and body.

Mortality for all fish receiving implants at 72 hours was 58 % compared to 32 % for those receiving no implant. Mean mortality for males versus female fish at 72 hours was 48 % and 43 % respectively (Figure 1). Cumulative 72-hour mortality for females receiving the 30 *u*g dose was 20% and 14 % for those receiving the 75-*u*g dose.

Beginning on April 27 and ending on June 8 , a total of 449,475 eggs (7.82 liters) were collected. Of that amount, 14,296 eggs (0.247 liters) came from 153 non-implanted females, resulting in 93 eggs per female. Over the same time frame 435,179 eggs (7.55 liters) were collected from 121 implanted females (75 and 30-*ug* implants) resulting in 3,596 eggs per female. Egg size ranged from 2.3 mm - 3.07 mm. Total egg take resulted in 17,950 fry. No fry survived past 72 hours. The small number of eggs collected is likely the result of handling stress and associated mortality or hormone injection of non-ripe fish. Of the eggs collected, the low percent hatch and low survival of fry is thought to be due to small egg size.

The possibility of an inefficient carrier substance for the spawning hormone has been discussed as an additional obstacle to successful tank spawning. Stresses associated with longer holding and transport times, changes in water quality, and additional handling at NEFC are suspect causes of high shad mortality in the tank spawning system. With one lift available for collecting potential tank spawners in 1999 at the Conowingo Dam, fewer fish were available which sometimes resulted in shad being held more than 24 hours in order to acquire sufficient numbers for transport. Also, there appeared to be a strong handling effect associated with the implant process with 24-hour mortality being highest among implanted fish. (Figure 2). Overall no important difference was seen in mortality rates between implanted males versus implanted females.

Recommendations for 2000

Mitigation of handling stress has been given the highest priority for the upcoming spawning season. The Chesapeake Bay/Susquehanna River Ecosystem Team has submitted a proposal to address this priority and to improve American shad brood fish selection. Brood fish collected at Conowingo Dam in 2000 will be subjected to transport tests to determine effects of stress and ways to minimize stress by comparing various transport parameters including: Effects of sedation, use of salt, temperature reduction and modified handling procedures.

Table 1.

1999 Shad Spawning Results

Delivery Date	No. of Females	Number injected	LHRHa (dosage) ug	No. of Males	Number injected	LHRHa (dosage) ug	Total Volume eggs collected	No. of eggs	Egg diameter (ave. range in mm)	Hatch Results (No. fry)
April 27	49	49	75	89	89	30	0	0	N/A	0
May 04 *	35	16	75	100	79	30	0.6 L **	39,862	2.5	0
May 18	32	3	75	49	9	30	0.45 L	17,351	2.8 to 3.03	4,423
May 20	45	0	N/A	50	0	N/A	0.22 L	12,628	2.25 to 2.94	0
May 25	34	34	20 females @ 30 ug/kg 14 females @ 75 ug/kg	82	82	30	1.41 L	66,898	2.53 to 3.07	0
May 27	41	0	N/A	28	0	N/A	0.027 L	1,668	2.57 to 2.89	0
May 28	38	0	N/A	72	0	N/A	0	0	N/A	0
May 31	46	46	75	66	66	30	4.13 L	256,400	2.30 to 2.83	13,527
June 05	44	44	75	52	52	30	0.98 L	54,668	2.45 to 2.93	0

* In the May 04, 1999, shipment eighty American shad, primarily female, were dead upon arrival at the NEFC
** In the May 04, 1999, shippment 0.6 liters eggs collected from non-implanted females only

Figure 1

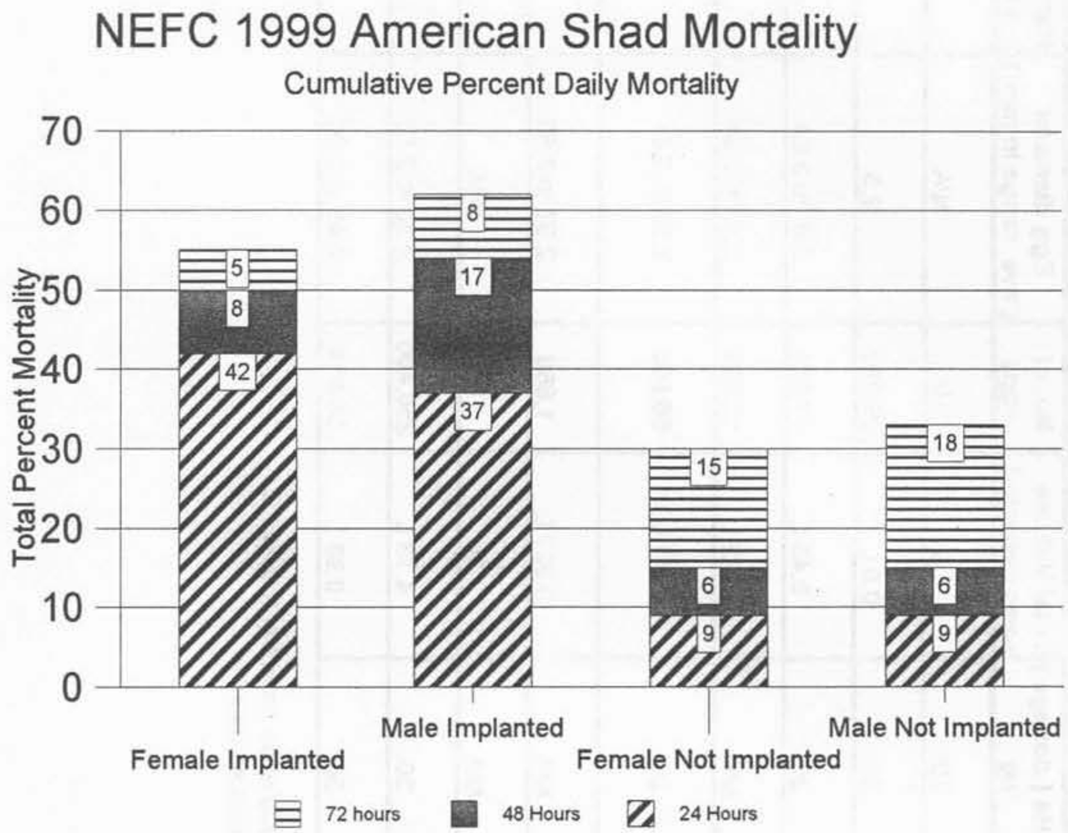
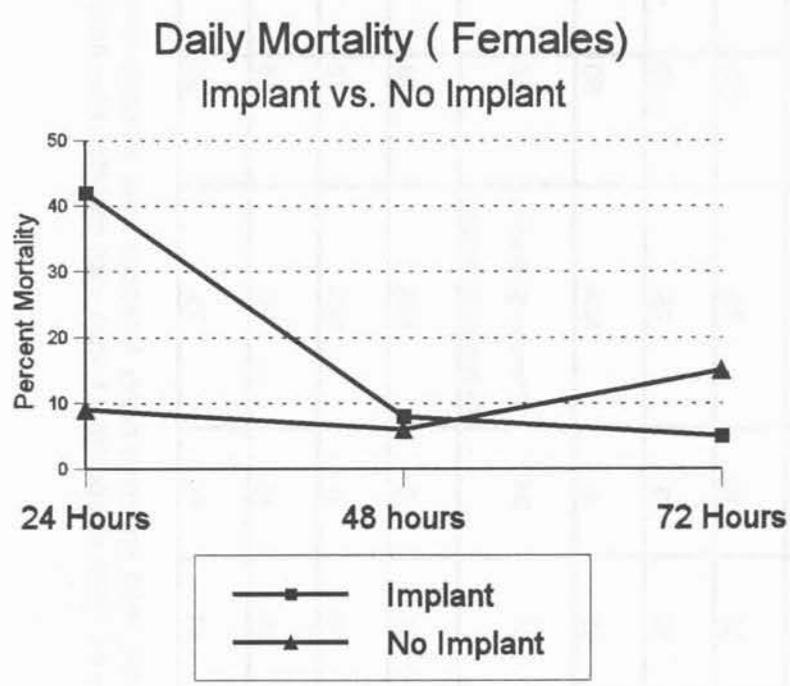


Figure 2



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 1999 were slightly modified to those of 1998 as two pound nets (one in Proving Ground, one in the Susquehanna Flats) were fished (Figure 1). Hook and line sampling in the Conowingo tailrace, however, remained unchanged from 1998. Tagging procedures in 1999 were also unchanged from 1998 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 1999 began on 24 March and continued until 14 May, while hook and line effort commenced on 23 April and ended 20 May. Of the 1,224 adult American shad captured, 963 (79%) were tagged and 109 (11.3%) subsequently recaptured (Table 1). Recapture data for the 1999 season is summarized as follows:

109 fish recaptured by the Conowingo fish lifts

0 fish recaptured by pound net

3 fish recaptured by anglers from the tailrace

1 post-spawned fish recaptured outside the system

5 presumed 1996 marked fish recaptured

The 109 fish total used to calculate the two population indices does not reflect the five fish marked in 1996 and subsequently recaptured, the three tagged fish angled by sport fishermen from the Conowingo tailrace, nor the post-spawned individual recaptured outside the upper Bay.

The 1999 adult American shad Petersen population index for the upper Chesapeake Bay was 685,058 (Table 2, Figure 2), and has been increasing exponentially since 1980 (r^2=0.99, P=0.<003). The Conowingo tailrace population index for 1999 was 583,198 (Table 3, Figure 3), and has also been increasing exponentially since 1984 (r^2=0.99, P=0.<001). 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 1999 and comparison with previous years is presented in Table 4. Relative abundance of American shad can also be estimated and associated trends noted by examining annual CPUE data of these three collecting gears. Measures of relative abundance from pound nets, hook and line, and the Conowingo fish lifts have been 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 (1980-1999) $r^2 = 0.42$, $P = 0.001$; hook and line (1984-1999) $r^2 = 0.68$, $P = <0.001$; fish lifts (1980-1999) $r^2 = 0.67$, $P = 0.001$ (Figure 4). Comparisons of these CPUE estimates to both the upper Bay and tailrace Petersen indices for these respective years indicate that:

(1) pound net, hook and line, and fish lift CPUE's were correlated with log e transformed upper Bay indices (r^2=0.37, P=<0.001; r^2=0.69, P=<0.001; r^2=0.69, P=<0.001, respectively; Table 5, Figure 5); and,

(2) hook and line and fish lift CPUE's were correlated with log e transformed tailrace indices (r^2=0.72, P=<0.001, r^2=0.60, P=<0.01, respectively; Table 5, Figure 6).

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 1999 indicating that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay continued in 1999.

A total of 402 adult American shad (158 pound net, 244 hook and line) were examined for physical characteristics by DNR biologists in 1999 (Table 6). The 1994 and 1995 year-classes (ages 5 and 4, sexes combined) were the most abundant age groups sampled in the upper Bay by pound net and hook and line, each accounting for 35% of the total catch (Table 6). Age frequency modes occurred at age 5 for pound net males and at age 4 for hook and line males. Age frequency modes for females occurred at age 5 for both pound net and hook and line catches. Males (gears combined) were present in age groups 2-7 and 9 while females were found in age groups 4-10. Both sexes, however, were most abundant at ages 4 and 5. The overall incidence of repeat spawning in male American shad decreased from 16.9% in 1998 to 11.4% in 1999. However, female American shad repeat spawning increased from 16.0% in 1998 to 26.8% in 1999.

Juvenile Shad Collection and Analysis

A total of 42 (21 haul seine, 21 electrofisher) juvenile American shad were collected from the Susquehanna Flats by Maryland DNR biologists during the summer and fall of 1999. Of these 42, 7 fish were lost as a result of freezer malfunction. Otoliths from the remaining 35 individuals were extracted, processed, and read by DNR personnel. Only one of these fish was of hatchery origin and carried a double tetracycline mark.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1999.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	343	151
	Gateway	58	11
	TOTALS	401	162
Hook and Line	Conowingo Tailrace	823	801
Fish Lifts	Conowingo Dam	79,370	
	TOTALS	80,594	963

Table 2. Upper Chesapeake Bay relative population index of adult American shad in 1999 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 1999 survey -

C = 80,594
R = 109
M = 934*

Therefore -

$$N = \frac{(80{,}594 + 1)\ (934 + 1)}{(109 + 1)}$$

= **685,058**

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)

$$\text{Upper } N^* = \frac{(80{,}594 + 1)\ (934 + 1)}{93.36 + 1} = 798{,}605$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(80{,}594 + 1)\ (934 + 1)}{135.48 = 1} = 552{,}142$$ @ .95 confidence limits

M* adjusted for 3% tag loss

Table 3. Conowingo Dam tailrace relative population index of adult American shad in 1999 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 1999 survey -

C = 79,805
R = 103
M = 759*

Therefore -

$$N = \frac{(79,805 + 1)(759 + 1)}{(103 + 1)}$$

= 583,198

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)

$$\text{Upper } N^* = \frac{(79,805 + 1)(759 + 1)}{84.93 + 1} = 705,837$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(79,805 + 1)(759 + 1)}{124.91 + 1} = 481,714$$ @ .95 confidence limits

M* adjusted for 3% tag loss

Table 4. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad collected by pound net and hook and line during the 1980-1999 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*

* 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*

* 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*

* tailrace estimates in *italics*
** 1980 - 1990 west lift only
*** 1991 - 1999 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 (1980-1999), annual Conowingo tailrace Petersen population indices, and geometric mean CPUE's for two gear types (1984-1999) where N = number of years.

GEAR TYPE	PETERSEN POPULATION INDICES UPPER BAY	TAILRACE
Pound Net		
r_p	0.74	NA
N	19	
P	0.001	
Hook & Line		
r_p	0.82	0.85
N	16	16
P	<0.0001	<0.0001
Fish Lifts		
r_p	0.87	0.83
N	19	16
P	<0.0001	<0.0001

Table 6. Catch (N), age composition, number and percent of repeat spawners (RPTS), and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1999 upper Chesapeake Bay spring tagging operation.

			MALE				FEMALE	
AGE GROUP	N	RPTS	MEAN	RANGE	N	RPTS	MEAN	RANGE
Pound Net								
II	0	0	-	-	0	0	-	-
III	12	0	340	305-390	0	0	-	-
IV	20	1	378	350-395	20	0	413	380-450
V	29	4	413	380-460	28	6	445	400-500
VI	12	8	434	405-460	25	17	459	430-500
VII	2	2	450	440-460	7	6	476	460-495
VIII	0	0	-	-	3	3	507	490-520
% RPTS	20.0				38.6			
Hook and Line								
II	2	0	287	265-309	0	0	-	-
III	28	0	338	315-369	0	0	-	-
IV	70	1	371	320-388	30	0	406	369-440
V	40	4	405	375-440	44	4	435	400-487
VI	4	4	427	420-444	21	9	463	412-500
VII	0	0	-	-	2	2	473	460-485
VIII	0	0	-	-	0	0	-	-
IX	1	1	460		1	1	540	-
X	0	0	-	-	1	1	505	
% RPTS	6.9				17.1			
Gears Combined								
II	2	0	287	265-309	0	0	-	-
III	40	0	339	305-390	0	0	-	-
IV	90	2	373	320-488	50	0	419	369-450
V	69	8	408	375-460	72	10	440	400-487
VI	16	12	432	405-460	46	26	461	412-500
VII	2	2	450	440-460	9	8	475	460-495
VIII	0	0	-	-	3	3	507	490-520
IX	1	1	460	-	1	1	540	-
X	0	0	-	-	1	1	505	-
% RPTS	11.4				26.8			

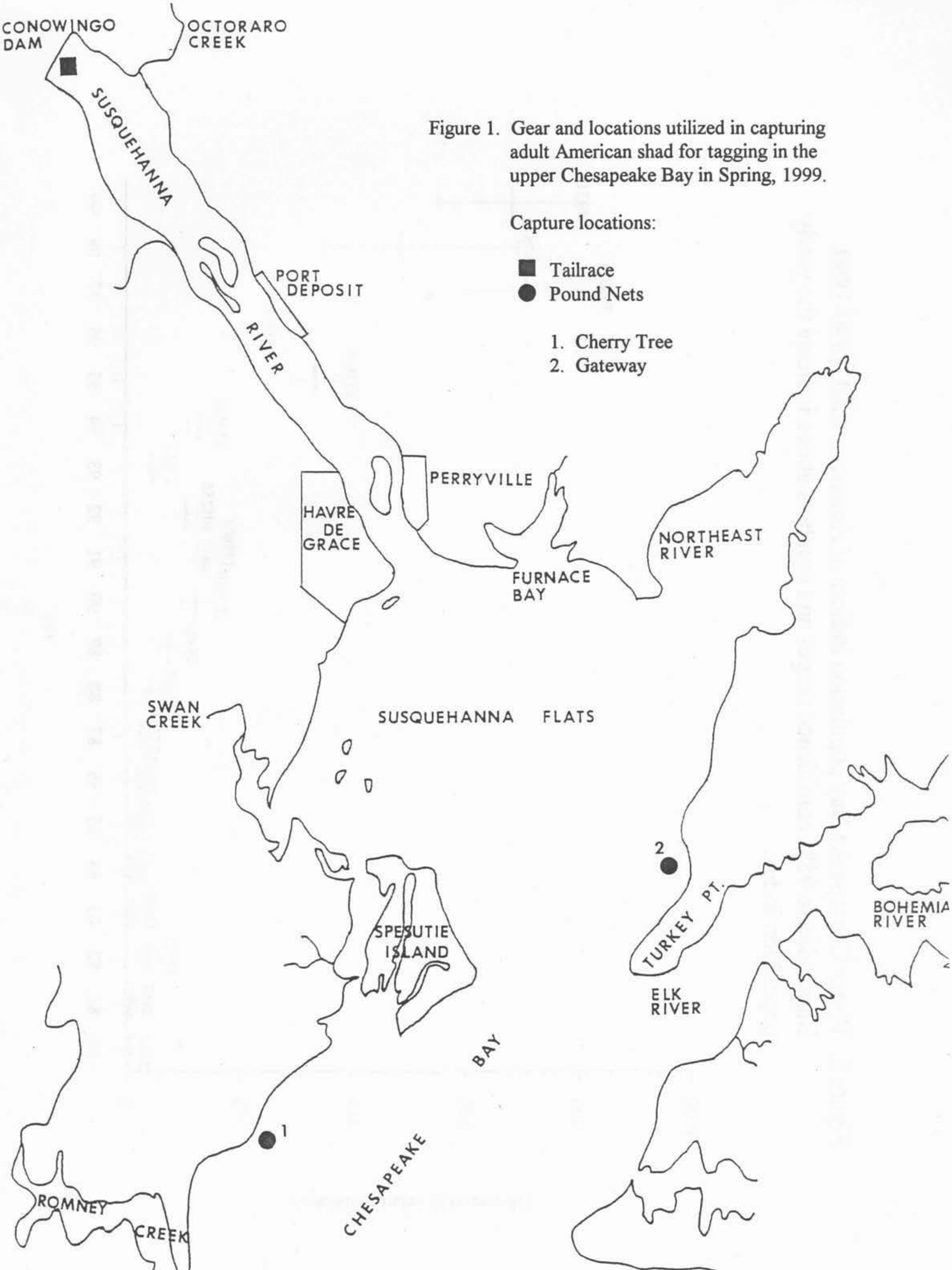


Figure 1. Gear and locations utilized in capturing adult American shad for tagging in the upper Chesapeake Bay in Spring, 1999.

Figure 2. Upper Chesapeake Bay population indices of American shad, 1980-1999. Bars indicate 95% confidence ranges and numbers above indicate the yearly population index.

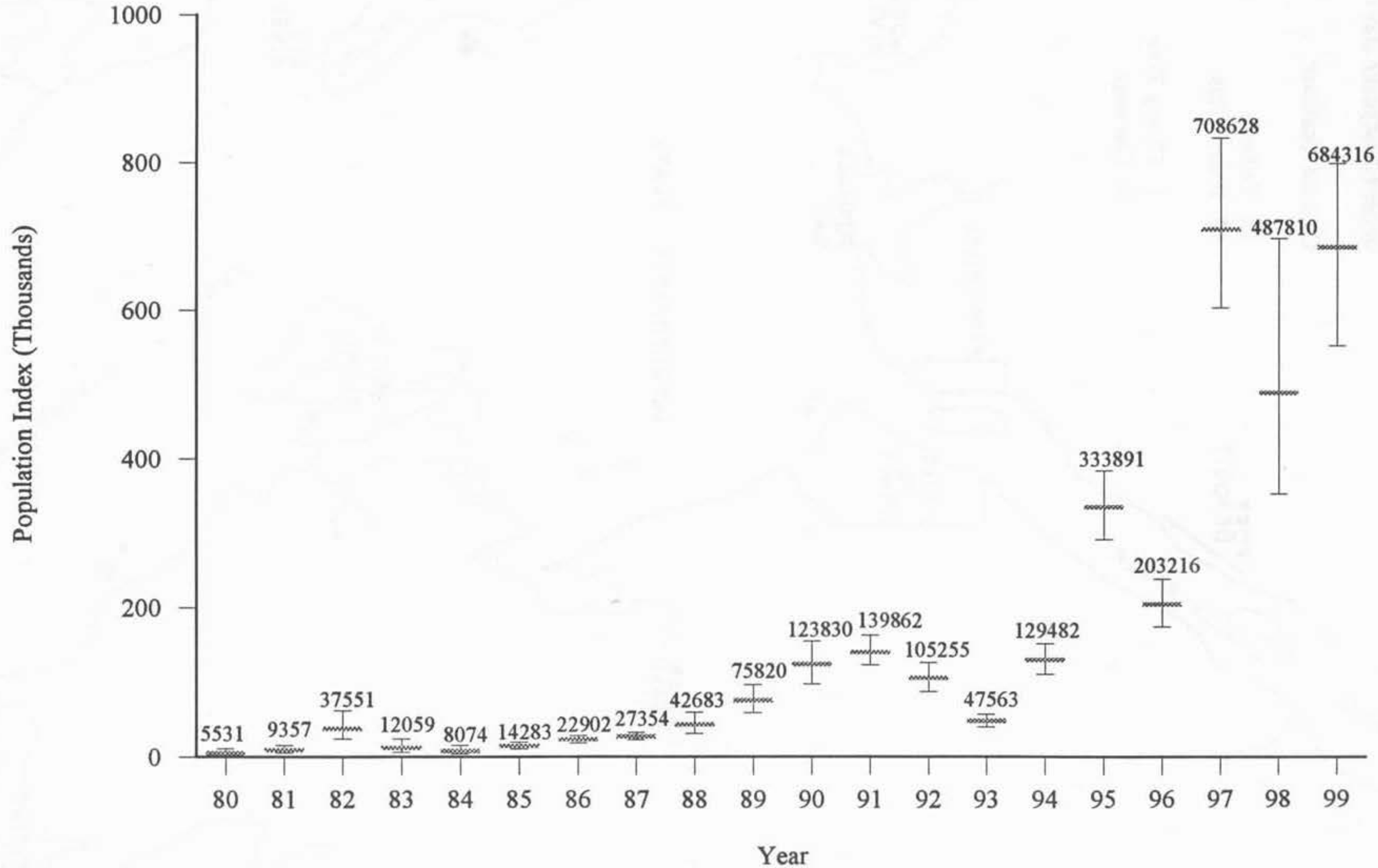


Figure 3. Conowingo Dam tailrace population indices of American shad, 1984-1999. Bars indicate 95% confidence ranges and numbers above indicate the yearly population index.

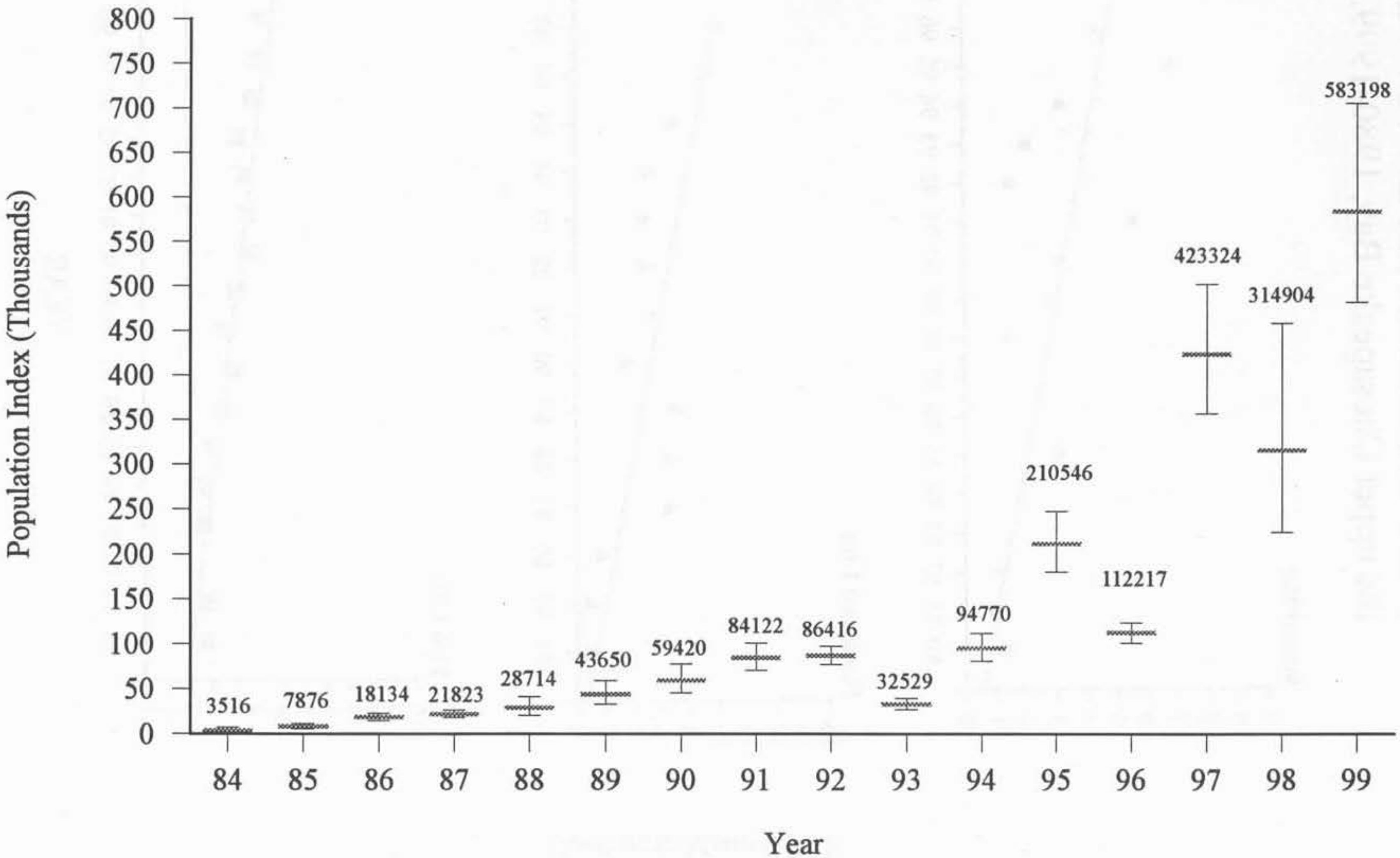


Figure 4. Regression analysis of geometric mean catch-per-unit-efforts (CPUEs) of American shad sampled by pound net, hook and line and Conowingo fish lifts in the upper Chesapeake Bay, 1980-1999.

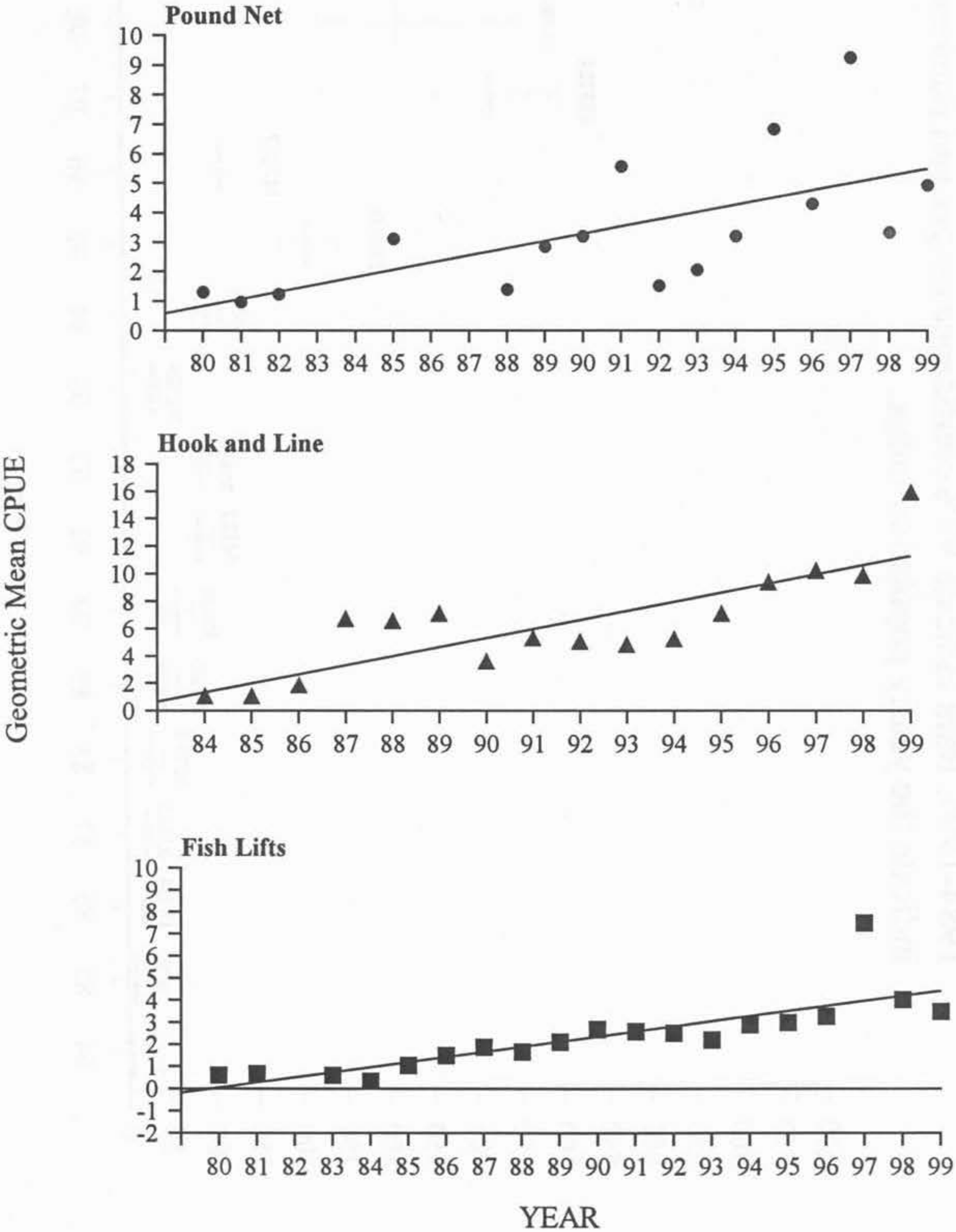


Figure 5. Pound net, hook and line, and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus population indices of American shad in the upper Chesapeake Bay, 1980-1999.

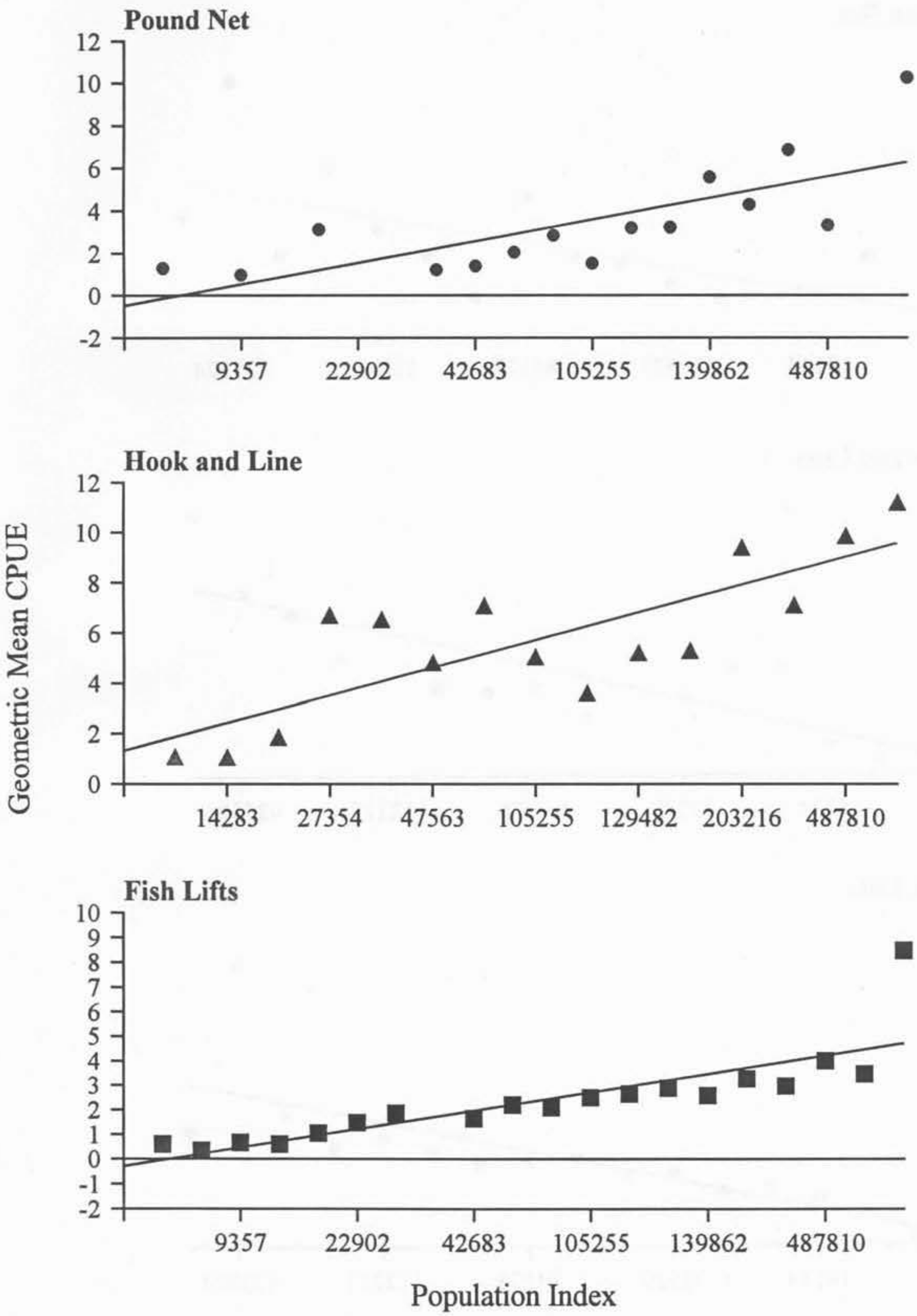
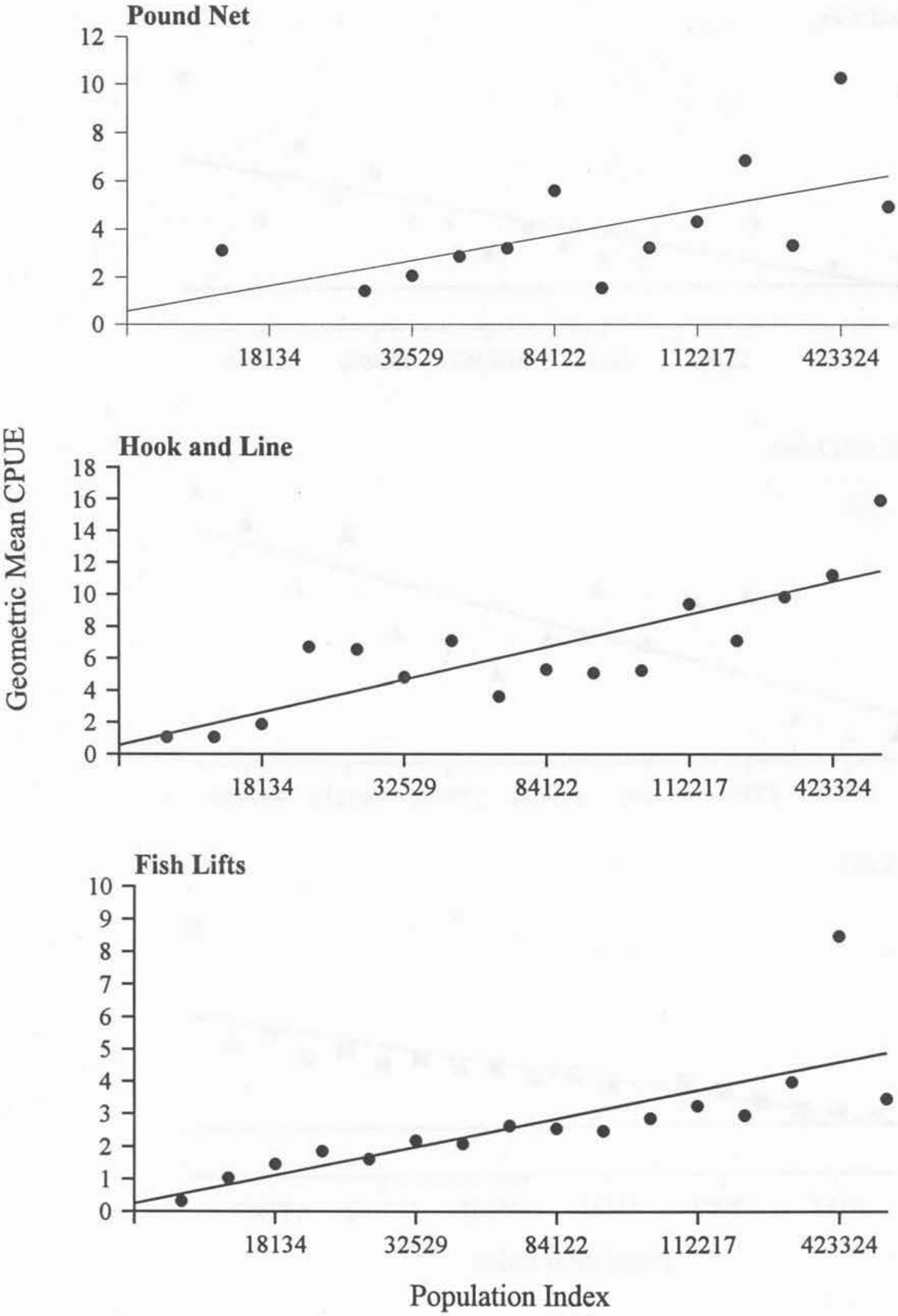


Figure 6. Pound net, hook and line, and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus Conowingo Dam tailrace population indices of American shad, 1980-1999.



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