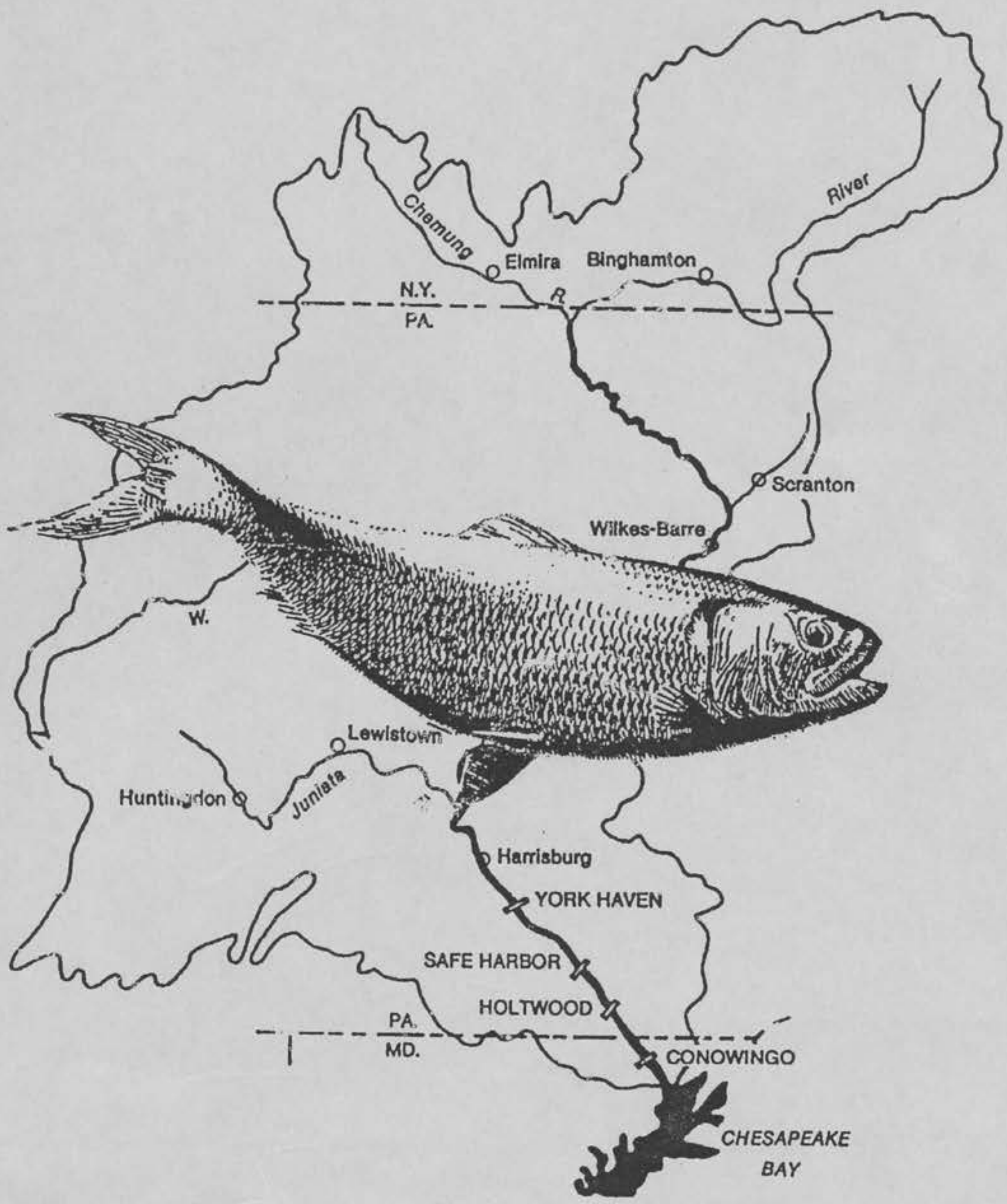
Restoration of American Shad to the Susquehanna River

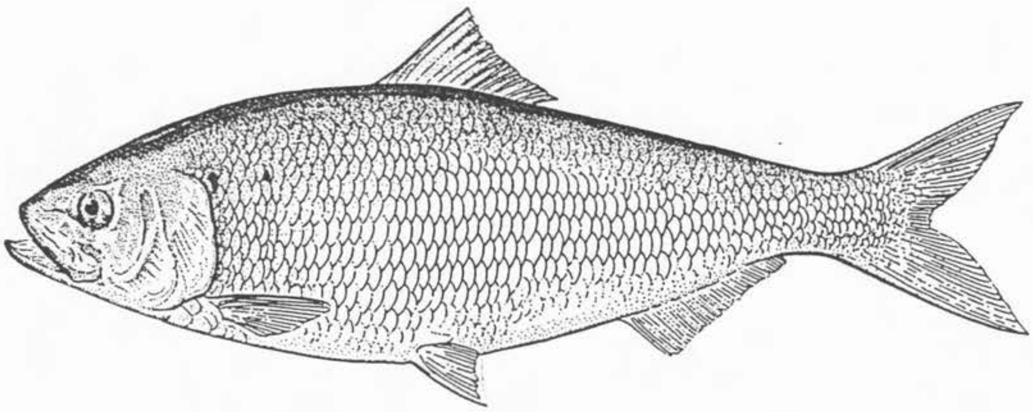
Annual Progress Report
1998



Susquehanna River
Anadromous Fish Restoration Committee

February 1999

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1998

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 1999

EXECUTIVE SUMMARY

This 1998 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 the Conowingo Dam fish lifts and recently completed passage facilities at 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.

Passage of shad and herring at all hydroelectric projects in 1998 was adversely affected by high river flows. Spilling occurred at Conowingo Dam on 19 dates and at the smaller Holtwood project spilling was continuous through all of April and the first 3-weeks of May. Peak flow events occurred on April 12 (161,000 cfs), April 23 (158,000 cfs), and May 14 (218,000 cfs). During the record 1997 passage year, spring flows never exceeded 60,000 cfs.

The West lift at Conowingo Dam was operated for 34 days between April 30 through June 9, with a break for high water during May 12-17. Trap fishing time was 226 hours with 476 separate lifts. Total catch amounted to 575,220 fish representing 38 taxa including 6,577 American shad, 5,511 blueback herring, 31 alewives and 6 hickory shad. Sex ratio in the shad run was 0.9 to 1 favoring females and 23 Maryland DNR tags were recovered. Every 50th shad collected during the season was killed for otolith analysis.

A total of 4,593 shad was stocked at Tri-County Boat Club in Middletown and at Columbia with only 74 observed trucking and delayed mortalities. About 500 shad were delivered to the USFWS Northeast Fishery Center at Lamar, PA and 588 were provided to Maryland DNR , both for tank spawning. Blueback herring were stocked at Tri-County Marina (1,102) and Little Conestoga Creek (3,653).

As was the case in 1997, the Conowingo East lift operated to pass all fish into Conowingo Pond. It operated on 50 days for a total of 433 hours and made 459 lifts from April 1 through June 8. Fish were identified and counted as they passed the viewing window and observations were supplemented with video recordings. Passage totals included 39,904 American shad, 700 blueback herring and 6 alewives along with 673,000 other fishes, mostly gizzard shad. Peak shad passage occurred in mid- to late May with a new single day record of 9,151 on May 21.

The tailrace and spillway fish lifts at Holtwood Dam operated 41 days between April 27 and June 12. Each lift operated for 322 hours with the tailrace facility making 341 lifts and the spillway making 282 lifts. Based on counts at the viewing window, total passage amounted to 162,600 fish including 8,235 American shad, 62 bluebacks, and 138,700 gizzard shad. Of the total American shad passed about 6300 (77%) used the tailrace lift and 1,900 (23%) used the spillway lift. Peak shad passage of 6,586 fish occurred during May 26-June 5.

The fish lift at Safe Harbor Dam operated for 28 days between May 8 and June 12, fishing for 242 hours and making 539 lifts. Total fish passage was 135,600 fish including 6,054 American shad, 20 blueback herring, and 102,700 gizzard shad. Most American shad (5,057) passed Safe Harbor between May 27 and June 6 with a peak day of 1,200 fish on June 2. For the second year in a row Safe Harbor lifts passed almost 75% of all shad which passed Holtwood.

Maryland DNR conducted a tag and recapture population assessment for the upper Chesapeake Bay and the Conowingo tailrace. During late March through late May 552 shad were caught and 373 were tagged from an upper Bay pound net and by angling in the Conowingo tailrace. A total of 34 1998 tagged fish were collected or seen in the Conowingo fish lifts. Using Peterson techniques, population estimates for the upper Bay and tailrace were calculated to be 487,810 and 314,904, respectively. Trend analyses of catch per unit effort from pound nets, angling, and Conowingo fish lifts all indicate that the shad population has continued to grow since the early 1980s.

Age analysis and spawning history was derived from scale samples taken from 465 adult shad (157 pound net and 308 angling). Age 4 and 5 fish (1993-94 year-classes) made up 80% of the combined sample. Most males were ages 4-5 and females 4-6. The amount of repeat spawning was down from 1997 at about 17% of both sexes from combined pound net and angling samples.

Based on otolith analysis of 130 adult shad taken at Conowingo West lift in 1998, 38 (29%) were of hatchery origin and 92 (71%) were wild. This continued a 4-year increasing trend in relative abundance of wild fish which only amounted to 16% in 1995. The majority of hatchery fish carried triple tetracycline marks of both Hudson and Delaware River egg sources. Otoliths from 44 shad taken from upper Bay pound nets were also examined and 6 of these (14%) were hatchery fish. This compares to 22% hatchery fish in 1997, 30% in 1996, and 58% in 1995 - again, an increasing trend in wild production. A sample of 69 shad was taken from the exit trough at Safe Harbor Dam to determine if marked hatchery fish displayed a propensity to move upstream in the Susquehanna. The hatchery versus wild components here (29% - 71%) were identical to that at Conowingo.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River in 1998. Between April 29 and May 21 two fishing crews gill netted spawners, stripped and fertilized eggs, and shipped these to Van Dyke hatchery. A total of 15.68 million eggs were taken, mostly from two sites (Coxsackie and Cheviot), with overall viability of 74.6%. PFBC and Ecology III used anchored gill nets to collect ripe shad and take eggs from the Delaware River near Smithfield Beach on May 4 through May 28. A total of 10.38 million were delivered to Van Dyke in 11 shipments. Overall egg viability was unusually low at about 33%. The USFWS used hormone-induced tank spawning of Conowingo shad to take about 3.2 million eggs of which 1.66 million were delivered to Van Dyke with 51% viability.

For the season a total of 27.724 million shad eggs were delivered to Van Dyke with 57.4% viability. These produced 12.7 million fry of which 7.70 million were stocked at several sites in the Juniata River; 1.79 million were stocked at Montgomery Ferry on the mainstem Susquehanna above Clarks Ferry; 1.13 million into the North Branch at Berwick; and 1.08 million into four lower river tributaries. Almost one million Delaware River fry were stocked into the Lehigh River and 16,000 were placed into Benner Springs ponds for mark retention analysis (100%). From the latter, 2,200 fingerlings were later released into Standing Stone Creek. Fry were released at 6 to 20 days of age and received one to five unique mark combinations. USFWS-Lamar produced 56,000 specially marked shad fry which were stocked in the West Branch Susquehanna a few miles below Lock Haven.

Under contract to PFBC, Normandeau Associates conducted weekly haul seine collections at Columbia, PA during mid-July through October and caught 230 American shad fingerlings in 90 hauls. The overall catch per unit effort (CPUE) of 2.55 fish per haul was only about one-fourth that from 1997. Normandeau Associates also conducted lift netting at Holtwood Dam's inner forebay on 30 dates during mid-September through mid-December, taking only 180 juvenile shad. The CPUE of 0.78 compares to 8.6 fish per lift in 1997. Most fish (93%) were taken during the peak of outmigration from October 11 to November 10. Electrofishing, push nets and seines took an additional 35 juvenile shad at various locations. Maryland DNR collected 144 young shad in 58 seine hauls during their summer-fall upper Bay juvenile finfish survey. In strong contrast to river collections the CPUE here was the highest observed for American shad in 35 years.

Otoliths from a total of 321 juvenile shad were examined for hatchery marks from combined collections made above Conowingo Dam. Of these, 304 (95%) were hatchery marked of which the majority (67%) carried the single day 3 mark indicating that they were stocked at Montgomery Ferry and various locations in the Juniata River. Other hatchery components of the total catch included 40 fish from the North Branch (13% of hatchery total); 32 fish from West Conewago Creek stocking (10.5%); and 16 fish stocked into the Juniata River from Susquehanna egg source (5%). The remaining fourteen hatchery fish originated from stockings in Conodoguinet Creek (6) and Swatara Creek (8). Only two of 113 fish taken in DNR seine collections were hatchery origin, both taken in the upper Bay on July 20 and single-marked on day 3.

American shad egg collections, hatchery culture and marking, and otolith mark analysis were funded by GPU-Genco from 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.

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). This account also paid for equipment and set-up costs and hormone implants for shad tank spawning at Lamar. Contributions to the special account came from upstream utilities (balance from 1984 agreement), PECO Energy, Maryland DNR, and PFBC. DNR funded the adult shad population assessment and juvenile shad seining in the upper Chesapeake Bay.

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.

Richard St. Pierre
Susquehanna River Coordinator
U.S. Fish and Wildlife Service
1721 N. Front Street, Room 105
Harrisburg, Pennsylvania 17102

717-238-6425; fax 717-238-0495
e-mail: R5FFA_SRC@mail.fws.gov

TABLE OF CONTENTS

JOB I - Part 3. <u>SUMMARY OF OPERATION AT THE HOLTWOOD FISH PASSAGE FACILITY IN 1998</u>

Normandeau Associates
1921 River Road
Drumore, PA 17518

JOB I - Part 4. <u>SUMMARY OF OPERATION AT THE SAFE HARBOR FISH PASSAGE FACILITY IN 1998</u>

Normandeau Associates
1921 River Road
Drumore, PA 17518

JOB II - Part 1. **AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER IN 1998**

The Wyatt Group, Inc.
1853 William Penn Way
P. O. Box 4423
Lancaster, PA 17604

JOB II - Part 2. **COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 1998**

Ecology III, Inc.
RR 1, Box 1795
Berwick, PA 18603

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

Job II - Part 3. DEVELOPMENT OF AN AMERICAN SHAD TANK SPAWNING SYSTEM

John W. Fletcher
U. S. Fish and Wildlife Service
Northeast Fishery Center
P. O. Box 75
Lamar, Pennsylvania 16848

JOB III. **AMERICAN SHAD HATCHERY OPERATIONS, 1998**

M. L. Hendricks
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, PA 16801

Job III - Appendix A. **Survival of American shad larvae released at various sites in the Susquehanna River drainage, 1998**

Michael L. Hendricks
PA Fish and Boat Commission
Benner Spring Fish Research Station
1225 Shiloh Road
State College, PA 16801

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

R. S. Carney
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, PA 16801

JOB V. ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 1998

M. L. Hendricks
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, PA 16801

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

Fisheries Service
Maryland Department of Natural Resources
301 Marine Academy Drive
Stevensville, MD 21666

JOB I - Part 1
SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY IN SPRING 1998

Normandeau Associates, Inc.
1921 River Road
Drumore, Pennsylvania 17518

1.0 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 resources 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 was operated to pass fish directly into Conowingo Pond. To facilitate this mode of operation, several capital improvements to the facility were made prior to the season. Objectives of 1998 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.

2.0 CONOWINGO OPERATION

2.1 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 old 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 9 June, respectively.

2.2 Fishway Operation

East lift operation began on 1 April on an every other day basis through 17 April. Daily lift operation began on 18 April, was discontinued between 22 and 25 April due to high river flow (>100,000 cfs), and was restarted on 26 April, continuing thereafter through 8 June, excepting 12 to 16 May, when high river flow again suspended operation. Half-day lift operation (1100 to 1900 h) occurred from 1 April through 3 May. Based on numerous factors including the number of American shad passed and water temperature, full day operation began on 4 May and continued (except for 12 to 16 May) through 8 June. Generally, full day operation began between 0700 and 0800 h continuing to approximately 2000 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 27 hours of lost fishing time versus 640 hours of operation. The crowder drive cables were replaced three times and accounted for 15 hours of lost fishing time. Debris problems with the hopper resulted in three hours of lost operation, until the debris could be flushed out of the hopper area. Air line hoses for the hopper door and the sheeve block were twisted. The guide cable for the sheeve block and air hoses were both replaced and accounted for nine hours of lost time.

The mechanical aspects of East lift operation in 1998 were similar to those described in RMC (1992). 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.

Effective and efficient operation of the facility requires control of two inter-dependent primary hydraulic variables: volume and velocity. To assure efficient passage of fish into Conowingo Pond operational matrices developed (RMC 1992) and refined from 1991 to 1996 (during the trap and transport mode of facility operation) were modified to include trough operation. Operational matrices were adjusted to incorporate a 60% setting of the 36-inch butterfly valve, which based on prior operating experience created a velocity of approximately 1 fps in the trough. Both the volume and velocity of attraction flow utilized during this year's operation remained the same as that employed and developed in prior years. This was accomplished by (1) reducing the volume of flow into the facility through spillway gates A and B by the volume of water discharged through the 36-inch butterfly valve; and (2) maintaining the same entrance and diffuser gate settings utilized in previous years for a particular station discharge scenario. A maintenance flow of 45 cfs (25% butterfly valve setting) was maintained in the trough overnight, although this valve was closed during shutdowns.

Water velocities at the entrances and within the crowder channel at the East lift were maintained to maximize the American shad catch and were within established guidelines. USFWS guidelines recommended water velocities of 0.5 to 1.0 fps in the crowder channel, 3.0 to 8.0 fps at the entrances, and 0.5 to 1.5 fps in the trough. Velocities that appeared to be most effective in the trough, crowder channels, and the entrances, ranged from 0.75 to 1.0, 0.75 to 1.5, and 4.0 to 8.0 fps, respectively.

The facility has three entrances designated A (upstream weir gate A), B (upstream weir gate B), and C (downstream weir gate). The three entrance gates are telescoping weir gates that can be used independently or in concert to create specific attraction velocities. The facility was designed to have one, a combination, or all three entrance gates opened, and to release attraction flows of 300 to 900 cfs over tailrace elevations between 14 and 25 ft.

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 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 primary entrance used during the majority of the season to attract fishes was C. Entrances A and C were used in combination from 27 May through 8 June; entrance B was not used this season.

2.3 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 camera was mounted on a tripod set approximately 5 ft off the floor and normally positioned 1.5 ft from the back wall of the counting room. The camera was aimed at the fish viewing window. Fish passage was recorded in 12 hour time-lapse mode, on video tape with a setting that yields 3.3 video records per second. During recording, the recorder imprinted the time and date on each frame of video tape, providing a record of the time for all fish passed.

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.

Fish were counted as they appeared in the field of view while moving upstream past the window. The reviewer had to be able to distinguish the American shad from gizzard shad as they passed the window. This was especially difficult during times when viewing conditions were poor (*i.e.*, low light and high turbidity). During these periods the tapes had to be played back in slow motion (frame by frame) which greatly increased the time required to complete the review.

3.0 RESULTS

3.1 Relative Abundance

The number of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 1. A total of 712,993 fish of 33 taxa was passed upstream into Conowingo Pond. Gizzard shad (654,575) was the dominant species passed and comprised almost 92% of the catch. Other common fishes included American shad (39,904), carp (6,205), channel catfish (4,135), white perch (2,731), and striped bass (1,467). Alosids (American shad, blueback herring, and alewife) comprised 5.7% of the total catch. Peak passage occurred on 18 May when 51,565 fish, or 7.2% of the season total, were passed; American shad passage was 1,720 (3.3%) and gizzard shad passage was 49,686 (96.3%) for the day.

3.2 American Shad Passage

The East lift captured and passed 39,904 American shad (Table 1). The first shad was passed on 3 April. Collection and passage of shad varied daily with 83.8% (33,454) of the shad captured and passed between 3 and 26 May. The lift captured and passed over 1,000 American shad per day on 12 separate days and on five of these days more than 2,000 shad were passed. Daily passage exceeded 3,000 shad on three days. Peak passage occurred on 2 May when 9,151 American shad were passed. Most (93.2%) of the shad passage occurred during May.

American shad were collected at water temperatures of 54.7°F to 77.0°F and at natural river flows of 16,600 to 126,900 cfs (Table 2 and Figure 2). Over 61% of the shad were collected at water temperatures >65°F (Table 2). Generally, water temperature was less than 65°F until 18 May.

The hourly passage of American shad in the East lift is given in Table 3. Most shad passed (31,808) through the fishway from 1100 to 1859 h. Peak hourly passage of shad (4,997) occurred between 1400 to 1459 h. Generally, shad passage increased hourly until it peaked. Following the peak, passage declined steadily until operation ended each night. Typically, catch of shad declined precipitously each evening prior to sunset.

3.3 Other Alosids

Only 706 river herring were captured and passed (Table 1). No hickory shad were collected. Six alewife were captured and passed throughout the 1998 season; one on 30 April and five on 4 May. A total of 700 blueback herring was captured and passed (Table 1). Most blueback herring (93.2%) were passed between 29 and 31 May. Peak passage (424 herring) occurred at a water temperature of 76.5°F and river flow of 29,900 cfs on 30 May.

3.4 Video Record

A limited review of the video records showed that fish passage was not adequately captured on the tape record. Data in Table 4 lists by date and time the shad count, the 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 4 to 278 shad or from 0.4 to 37.3%. These video counts were derived via a frame by frame review of the time period.

Generally, the difference between the video and visual counts resulted from poor tape quality. The majority of video tapes contained images of fish passing the window that were nothing more than grainy silhouettes that were extremely difficult to identify. The poor tape quality was caused by turbidity, changing light, and inconsistent lighting throughout the channel, making it difficult and practically impossible to distinguish fish species. These conditions resulted in tape derived counts that were questionable.

Although it was not possible to precisely determine fish passage counts from the video tape due to poor tape quality, 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.

4.0 SUMMARY

High river flow during the 1998 operating season substantially reduced the lift operating time and affected the American shad catch. However, the American shad catch ranked third highest since 1991 (Table 6). The high river flow events (>85,000 cfs) suspended operation in late April and mid-May, periods when the shad catch is usually increasing. The catch of river herring was likewise affected by these conditions.

The viewing of fish was enhanced in 1998 with the addition of adjustable/variable underwater lighting, which improved visibility in low light conditions. Also, the addition of an adjustable screen in the trough reduced the width of the exit channel from 36 to 18 inches at the viewing window. This kept the fish closer to the window, which improved species identification and did not inhibit fish passage.

5.0 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) Improve tape recording quality by creating consistent light intensity throughout the entire water column by either mounting a light at the top of the water column or by using the existing light at the bottom of the channel sparingly.

3) Install back-up stop limit switches, preferably mechanical, on forward and reverse movement of the crowder drive system to prevent breakdowns caused by control failures.

4) Inspect all cables to meet design specifications.

6.0 LITERATURE CITED

RMC. 1992. Summary of the operations of the Conowingo Dam fish passage facilities in spring 1991. Prepared for Susquehanna Electric Company by RMC Environmental Services, Inc., Muddy Run Ecological Laboratory, Drumore, PA. 78 pp.

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 1998.

Date	*1 Apr*	*3 Apr*	*5 Apr*	*7 Apr*	*9 Apr*	*11 Apr*	*14 Apr*	*16 Apr*	*18 Apr*
Hours Of Operation	*7.00*	*6.00*	*7.00*	*7.00*	*7.00*	*6.30*	*7.00*	*6.75*	*8.00*
Numbers Of Lifts	*7*	*6*	*7*	*8*	*7*	*6*	*7*	*7*	*9*
Water Temperature	*59.0*	*61.2*	*57.8*	*54.5*	*54.5*	*56.3*	*53.1*	*58.1*	*60.8*
American shad		2			12	3		3	194
Gizzard shad	2,892	13,765	10,980	10,400	2,100	4,828	4,880	22,800	25,915
Blueback herring									3
Alewife									
striped bass				1	1			1	2
American eel									
Rainbow trout	3	3	1						3
Brown trout		1	3		1			1	
Muskellunge									
Carp	1		2		2				1
Quillback	1	1						3	
Comely shiner									
White sucker	33	21	3						1
Shorthead redhorse	35	7	5		1	2	1	1	12
White catfish	1				1				1
Brown bullhead									
Yellow bullhead									
Channel catfish	14	1	3	1		1	1,186	12	
White perch									1
Rock bass		1							2
Redbreast sunfish	1								
Green sunfish	2								
Pumpkinseed									
Bluegill	3				3		1	1	
Smallmouth bass	1	1	1	1		1		1	6
Largemouth bass					1		2	5	1
White crappie			1				2		
Black crappie									
Yellow perch					1		2	1	
Walleye		11	16	7	4	3	10	10	4
Sea lamprey		1							
Atlantic needlefish									
Hybrid striped bass									
TOTAL	*2,987*	*13,815*	*11,015*	*10,410*	*2,127*	*4,838*	*6,084*	*22,839*	*26,146*

Note: operation was on an every other day basis through 17 April.

East_Rpt.98.fnl.xls/Tb 1 - 2/9/99

Table 1

Continued.

Date	*19 Apr*	*20 Apr*	*21 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*
Hours Of Operation	*8.25*	*7.75*	*7.00*	*7.00*	*8.25*	*8.00*	*7.25*	*7.00*	*8.00*
Numbers Of Lifts	*8*	*8*	*7*	*7*	*8*	*8*	*7*	*7*	*8*
Water Temperature	*60.0*	*58.1*	*58.1*	*58.1*	*58.1*	*58.1*	*58.1*	*58.1*	*60.0*
American shad	1,231	245	16	63	260	320	6	4	468
Gizzard shad	13,330	16,135	6,520	14,460	22,643	24,770	12,430	8,240	16,134
Blueback herring		4	8	2	1	2	1		2
Alewife								1	
striped bass	1	3	7	4	3	5	11	9	3
American eel									
Rainbow trout									
Brown trout	6	4	1	1	3		7	4	3
Muskellunge									
Carp		2	2		1	4	2		1
Quillback									2
Comely shiner									
White sucker	4	3							
Shorthead redhorse	20	7	26	4	15	13	64	318	114
White catfish									
Brown bullhead			1						
Yellow bullhead						4			
Channel catfish	17	30	310	70	360	18	13	155	60
White perch	31	4	14	5	1		1		3
Rock bass	6					9			1
Redbreast sunfish									
Green sunfish									
Pumpkinseed									
Bluegill	1				1		1		
Smallmouth bass	12	12	9	2	4	2	14	10	7
Largemouth bass	1	1			2		1		
White crappie		1							
Black crappie									
Yellow perch	3					10			
Walleye	25	19	11	8	13	24	22	17	13
Sea lamprey							1		
Atlantic needlefish									
Hybrid striped bass									
TOTAL	*14,688*	*16,470*	*6,925*	*14,619*	*23,307*	*25,181*	*12,574*	*8,758*	*16,811*

Note: operation suspended 22 through 25 April due to high river flow.

Table 1

Continued.

Date	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*
Hours Of Operation	*8.25*	*8.25*	*11.00*	*11.00*	*10.75*	*10.30*	*9.75*	*9.25*	*7.50*
Numbers Of Lifts	*8*	*8*	*11*	*11*	*11*	*11*	*10*	*10*	*7*
Water Temperature	*60.0*	*60.0*	*60.8*	*61.7*	*61.2*	*62.6*	*61.7*	*61.7*	*61.7*
American shad	930	2,096	1,882	2,990	3,670	512	469	20	1
Gizzard shad	29,972	16,563	16,550	26,850	22,552	23,305	14,045	16,324	13,850
Blueback herring	3	1		5	1				5
Alewife			5						
striped bass	5	7	11	7	10	21	5	2	2
American eel				2					
Rainbow trout				1					
Brown trout	3		4	3	1				
Muskellunge									
Carp	1		11	3	6	8	3		2
Quillback			5	5		1	10		100
Comely shiner									
White sucker			5						
Shorthead redhorse	51	3	12	18	13	42	37	13	14
White catfish									
Brown bullhead				1					
Yellow bullhead									
Channel catfish	10	4	116	28	28	198	338	122	450
White perch	3	694	128	105	18	86	144	127	350
Rock bass	5	1		27	3		1		1
Redbreast sunfish	1							2	
Green sunfish									
Pumpkinseed									
Bluegill		1		2		1	1	2	1
Smallmouth bass	23	19	37	12	29	75	15	9	
Largemouth bass		2	2						
White crappie			1						
Black crappie									
Yellow perch		2							
Walleye	21	17	14	51	33	39	22	7	9
Sea lamprey							2		
Atlantic needlefish									
Hybrid striped bass									
TOTAL	***31,028***	***19,410***	***18,783***	***30,110***	***26,364***	***24,288***	***15,092***	***16,628***	***14,785***

Table 1

Continued.

	11 May	*17 May*	*18 May*	*19 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*
Hours Of Operation	*7.00*	*7.25*	*8.00*	*10.00*	*10.50*	*11.00*	*3.80*	*10.75*	*10.25*
Numbers Of Lifts	*7*	*8*	*8*	*6*	*24*	*12*	*4*	*19*	*11*
Water Temperature	*60.5*	*64.6*	*68.0*	*70.7*	*72.5*	*71.6*	*73.4*	*72.5*	*73.4*
American shad			1,720	1,170	9,151	1,866	583	4,675	1,505
Gizzard shad	5,890	30,904	49,686	14,075	30,100	31,260	1,814	18,145	12,142
Blueback herring								1	
Alewife									
striped bass		3	10	6	21	73	17	151	122
American eel									
Rainbow trout									
Brown trout	5		3	1	1	2		1	
Muskellunge					1				1
Carp	1	3	38		14	30	2	2,954	716
Quillback			1		24			2	15
Comely shiner									
White sucker					3	4			4
Shorthead redhorse		3	4	4	1				
White catfish									
Brown bullhead			2						
Yellow bullhead									
Channel catfish	77	72	58	2	22	54	4	21	39
White perch	240	5	3	2	8	81	17	185	176
Rock bass		1	2	3	1	3		1	2
Redbreast sunfish		1		2	2		3	8	2
Green sunfish									
Pumpkinseed						1			1
Bluegill		5	7		13	40	9	55	11
Smallmouth bass	1	5	15	13	22	46	18	17	16
Largemouth bass			2		4	6	1	6	2
White crappie								4	1
Black crappie									2
Yellow perch				1	1	3	1	7	8
Walleye	3	5	14	5	11	31	2	55	49
Sea lamprey	1				1	2			
Atlantic needlefish									
Hybrid striped bass									
TOTAL	***6,218***	***31,007***	***51,565***	***15,284***	***39,401***	***33,502***	***2,471***	***26,288***	***14,814***

Note: operation suspended 12 through 16 May due to high river flow and 20 May due to mechanical problems.

Table 1

Continued.

Date	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*
Hours Of Operation	*10.20*	*10.50*	*10.50*	*10.25*	*10.25*	*10.40*	*7.00*	*10.50*	*10.25*
Numbers Of Lifts	*13*	*10*	*11*	*10*	*11*	*11*	*7*	*11*	*10*
Water Temperature	*74.3*	*73.4*	*73.4*	*74.3*	*76.5*	*77.0*	*77.0*	*77.0*	*77.0*
American shad	1,144	823	441	500	194	401	18	101	99
Gizzard shad	10,325	6,850	2,760	6,900	4,172	2,773	2,760	2,560	1,535
Blueback herring		3	1	210	424	19		1	
Alewife									
striped bass	63	49	84	85	98	52	41	47	23
American eel								1	
Rainbow trout									
Brown trout		1					1		
Muskellunge									
Carp	673	22	8	8	7	5	17	5	17
Quillback	4	18		2	2	5		4	4
Comely shiner			164						
White sucker									
Shorthead redhorse									25
White catfish									
Brown bullhead	3	5			1				
Yellow bullhead									1
Channel catfish	96	32	23	4	14	4	18	19	6
White perch	69	13	25	4	20	74	57	7	
Rock bass	3	1							
Redbreast sunfish		3		1	3	1		2	2
Green sunfish									
Pumpkinseed	1				1				
Bluegill	14	5	11	6	7	11	1	18	9
Smallmouth bass	10	5	8	7	2	3	2	3	
Largemouth bass	5		2	1		4	2	3	
White crappie									
Black crappie					1				
Yellow perch	1		1	1				4	
Walleye	24	8	1		4	3	1	2	6
Sea lamprey				1					
Atlantic needlefish		1				1			
Hybrid striped bass	1							1	
TOTAL	*12,436*	*7,839*	*3,529*	*7,730*	*4,950*	*3,356*	*2,918*	*2,778*	*1,727*

Table 1

Continued.

Date	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*TOTAL*
Hours Of Operation	*9.90*	*10.50*	*10.00*	*7.70*	*10.00*	***640.00***
Numbers Of Lifts	*10*	*11*	*11*	*6*	*10*	***652***
Water Temperature	*77.0*	*75.2*	*76.1*	*76.1*	*74.3*	
American shad	79	5	5	18	9	***39,904***
Gizzard shad	720	770	1,980	1,879	1,342	***654,575***
Blueback herring			3			***700***
Alewife						***6***
striped bass	46	43	120	58	134	***1,467***
American eel				1	1	***5***
Rainbow trout						***11***
Brown trout						***61***
Muskellunge						***2***
Carp	1,026	480	125	1	1	***6,205***
Quillback	3	6				***218***
Comely shiner						***164***
White sucker						***81***
Shorthead redhorse						***885***
White catfish						***3***
Brown bullhead			2			***15***
Yellow bullhead						***5***
Channel catfish	1	3	10	2	9	***4,135***
White perch	2	20	2	2	4	***2,731***
Rock bass						***74***
Redbreast sunfish	8		1	2	1	***46***
Green sunfish						***2***
Pumpkinseed						***4***
Bluegill	24	38	23	16	12	***354***
Smallmouth bass	4	1	2	3	2	***508***
Largemouth bass		1	2	1	2	***62***
White crappie		1		1		***12***
Black crappie	1	1				***5***
Yellow perch		3			1	***51***
Walleye	6	4	10	4	7	***685***
Sea lamprey		1		1		***11***
Atlantic needlefish						***2***
Hybrid striped bass			1		1	***4***
TOTAL	***1,920***	***1,377***	***2,286***	***1,989***	***1,526***	***712,993***

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 1998.

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	70,200	59.0	16+	10	C	310	23.0-23.5	108.9-108.1	1
2 Apr			67,100	60.1							
3 Apr	2	0	68,400	61.2	15	10	C	310	22.0-23.0	107.8-108.1	0
4 Apr			67,100	57.9							
5 Apr	0	0	66,600	57.8	16+	10	C	310	21.5-23.0	106.7-106.8	0
6 Apr			58,900	56.1							
7 Apr	0	0	53,900	54.5	16+	10	C	310	22.0-21.5	107.2-108.0	0
8 Apr			48,700	54.3							
9 Apr	12	0	46,700	54.5	16+	10	C	310	22.5-23.0	107.9-107.9	0
10 Apr			64,300	55.0							
11 Apr	3	0	126,900	56.3	15	10	C	310	24.0-25.5	108.4-108.1	5
12 Apr			155,400	55.0							
13 Apr			122,100	54.5							
14 Apr	0	0	92,800	53.1	6	10	C	310	25.5-24.0	108.7-108.4	3
15 Apr			75,600	54.0							
16 Apr	3	0	65,600	58.1	16	10	C	310	23.0-22.5	107.5-107.9	0
17 Apr			64,400	58.1							
18 Apr	194	0	60,800	60.8	16+	10	C	310	22.5	107.9-108.3	0
19 Apr	1,231	0	57,400	60.0	16+	10	C	310	23.0-22.5	107.4-108.6	0
20 Apr	245	0	84,800	58.1	16+	10	C	310	23.0-24.5	106.4-108.4	4
21 Apr	16	0	129,800	58.1	16+	10	C	310	25.0-24.0	108.4-108.6	4
22 Apr			155,600	56.1							
23 Apr			145,200	56.1							
24 Apr			109,200	55.0							
25 Apr			85,500	56.1							
26 Apr	63	0	70,600	58.1	16	10	C	310	23.0	106.8-107.8	0
27 Apr	260	0	74,110	58.1	16	10	C	310	22.5-23.0	107.2-108.3	0
28 Apr	320	0	88,800	58.1	16	10	C	310	23.0	108.4-108.6	2
29 Apr	6	0	74,260	58.1	16	10	C	310	23.5	108.5-108.3	2
30 Apr	4	0	79,700	58.1	16	10	C	310	24.5-24.0	108.4-108.2	2
1 May	468	0	65,700	60.0	16	10	C	310	22.5-23.0	107.2-107.9	0
2 May	930	0	59,400	60.0	16	10	C	310	22.0-23.0	106.9-108.1	0

East_Rpt.98.fnl.xls/Tb 2 - 2/9/99

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	2,096	1P	62,700	60.0	16	10	C	310	22.5-23.0	107.4-107.9	0
4 May	1,882	0	61,000	60.8	16	10	C	310	22.0-23.5	106.7-108.5	0
5 May	2,990	1P	61,000	61.7	16	10	C	310	23.0	106.2-107.6	0
6 May	3,670	0	81,400	61.2	16	10	C	310	23.0	105.5-108.0	0
7 May	512	0	85,100	62.6	16	10	C	310	23.0-25.0	108.2-108.7	3
8 May	469	0	84,700	61.7	8	10	C	310	22.0-23.5	106.7-108.5	1
9 May	20	0	115,200	61.7	10	10	C	310	23.0-24.0	108.5-108.7	2
10 May	1	0	105,600	61.7	6	10	C	310	23.0-23.5	108.5-108.6	2
11 May	0	0	150,200	60.5	8	10	C	310	24.0-24.5	108.7-108.5	3
12 May			212,400	58.7							
13 May			197,000	58.1							
14 May			150,600	59.0							
15 May			111,200	60.0							
16 May			87,700	62.3							
17 May	0	0	87,700	64.6	16+	10	C	310	23.0-23.5	108.4-108.6	1
18 May	1,720	0	67,700	68.0	16+	10	C	310	22.5-23.0	107.3-108.5	0
19 May	1,170	0	60,600	70.7	16+	8	C	310	22.0-22.5	105.6-107.4	0
20 May			47,500	71.6							
21 May	9,151	2Y,1P	43,000	72.5	16+	8	C	310	16.5-22.0	108.4-107.4	0
22 May	1,866	1Y,1G	35,300	71.6	16+	8	C	310	18.5-22.0	107.9-107.5	0
23 May	583	0	35,300	73.4	16+	5	C	310	16.0-21.0	107.3-108.4	0
24 May	4,675	0	31,800	72.5	16+	5	C	310	18.0-22.0	107.4-108.6	0
25 May	1,505	1Y	28,500	73.4	16+	6	C	310	17.5-21.0	106.8-108.3	0
26 May	1,144	2Y	26,300	74.3	16+	8	C	310	18.0-22.0	108.0-107.9	0
27 May	823	1Y,1G	24,400	73.4	16+	7	A,C	310	18.0-22.0	107.7-108.2	0
28 May	441	0	23,000	73.4	16+	7	A,C	310	17.5-21.5	107.5-108.3	0
29 May	500	1Y,1G	20,700	74.3	16+	7	A,C	310	18.0-22.0	107.4-107.6	0
30 May	194	0	29,900	76.5	16+	8	A,C	310	16.0-22.0	107.1-108.5	0
31 May	401	0	20,400	77.0	16+	5	A,C	310	16.5-20.0	106.4-107.0	0
1 Jun	18	0	19,600	77.0	16+	7	C	310	15.5-21.5	107.9-108.6	0
2 Jun	101	0	19,800	77.0	16+	8	A,C	310	16.0-21.5	106.6-108.4	0
3 Jun	99	0	17,200	77.0	16+	7	A,C	310	16.5-22.0	106.9-108.0	0
4 Jun	79	0	18,600	77.0	16+	5	A,C	310	16.5-20.0	106.8-108.3	0
5 Jun	5	0	21,000	75.2	16+	6	A,C	310	16.0-21.0	107.1-106.6	0
6 Jun	5	0	27,900	76.1	16+	6	C	310	20.0-18.5	107.5-107.1	0
7 Jun	18	0	21,300	76.1	16+	5	A,C	310	18.0-20.0	107.6-108.0	0
8 Jun	9	0	16,600	74.3	16+	7	C	310	21.0-20.0	107.8-108.0	0

East_Rpt.98.fnl.xls/Tb 2 - 2/9/99

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 1998.

Date	*1 Apr*	*3 Apr*	*5 Apr*	*7 Apr*	*9 Apr*	*11 Apr*	*16 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*26 Apr*	*27 Apr*
Observation Time - Start	*12:00*	*13:35*	*11:55*	*11:20*	*11:00*	*12:03*	*11:33*	*11:10*	*11:00*	*11:27*	*11:05*	*11:25*	*11:03*
Observation Time - End	*18:20*	*18:20*	*18:15*	*18:15*	*18:16*	*17:20*	*18:18*	*19:30*	*19:15*	*19:15*	*18:05*	*18:25*	*19:18*
Military Time (hrs)													
0800 to 0859													
0900 to 0959													
1000 to 1059													
1100 to 1159	-	-	-	-	-	-	-	1	44	40	5	-	20
1200 to 1259	-	-	-	-	-	1	-	2	61	70	1	-	16
1300 to 1359	-	1	-	-	1	1	-	2	60	30	4	-	3
1400 to 1459	-	-	-	-	3	1	-	4	105	20	-	-	3
1500 to 1559	-	1	-	-	4	-	-	1	185	35	-	-	6
1600 to 1659	-	-	-	-	2	-	1	28	95	10	4	3	24
1700 to 1759	-	-	-	-	2	-	2	45	400	15	2	11	87
1800 to 1859	-	-	-	-	-	-	-	78	200	20	-	49	61
1900 to 1959								33	81	5			40
Total	*0*	*2*	*0*	*0*	*12*	*3*	*3*	*194*	*1,231*	*245*	*16*	*63*	*260*

Note: operation was on an every other day basis through 17 April; operation was suspended 22 through 25 April due to high river flow.

Table 3

Continued.

Date	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*
Observation Time - Start	*11:08*	*11:03*	*11:19*	*11:15*	*11:13*	*11:05*	*8:10*	*8:00*	*8:43*	*8:25*	*8:35*	*8:47*	*10:45*
Observation Time - End	*19:13*	*18:18*	*18:19*	*19:15*	*19:28*	*19:20*	*19:10*	*19:00*	*19:25*	*18:45*	*18:15*	*18:00*	*18:15*
Military Time (hrs)													
0800 to 0859							64	242	80		7		
0900 to 0959							29	54	50	316	4	15	
1000 to 1059							10	42	40	117	3	2	1
1100 to 1159			-	-	-	158	25	18	110	36	9	-	-
1200 to 1259	81	3	-	1	100	55	60	89	260	16	12	3	-
1300 to 1359	18	1	-	1	41	236	183	393	330	5	22	-	-
1400 to 1459	49	1	-	6	26	216	300	276	350	7	159	-	-
1500 to 1559	54	-	-	17	126	431	265	602	520	3	180	-	-
1600 to 1659	65	1	-	102	100	573	380	365	550	1	53	-	-
1700 to 1759	23		1	126	190	187	230	638	600	8	16	-	-
1800 to 1859	24		3	194	215	177	270	271	600	3	4	-	-
1900 to 1959	6			21	132	63	66		180				
Total	*320*	*6*	*4*	*468*	*930*	*2,096*	*1,882*	*2,990*	*3,670*	*512*	*469*	*20*	*1*

Table 3

Continued.

Date	*11 May*	*17 May*	*18 May*	*19 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Observation Time - Start	*11:36*	*11:32*	*11:06*	*8:21*	*8:57*	*8:12*	*15:25*	*8:37*	*8:40*	*8:56*	*8:21*	*8:37*	*8:31*
Observation Time - End	*18:19*	*18:17*	*19:16*	*18:15*	*19:30*	*19:12*	*19:15*	*19:15*	*19:00*	*19:15*	*18:45*	*19:07*	*18:45*
Military Time (hrs)													
0800 to 0859				100		250		7				2	
0900 to 0959				30	621	250		455	360	320	130	13	200
1000 to 1059	-			140	200	350		900	310	210	250	80	150
1100 to 1159	-	-		350	650	100		1,250	200	100	200	130	80
1200 to 1259	-	-	60	60	830	250		650	150	130	110	100	30
1300 to 1359	-	-	300	75	1,150	205		400	100	100	20	40	10
1400 to 1459	-	-	520	55	2,045	250		300	90	40	10	20	10
1500 to 1559	-	-	300	-	1,400	130	2	100	120	110	65	15	11
1600 to 1659	-	-	250	170	450	-	49	100	90	92	20	10	5
1700 to 1759	-	-	150	190	500	-	185	250	20	30	10	10	2
1800 to 1859	-	-	50		1,000	80	214	100	50	-	8	-	2
1900 to 1959			90		305	1	133	163	15	12		21	
Total	*0*	*0*	*1,720*	*1,170*	*9,151*	*1,866*	*583*	*4,675*	*1,505*	*1,144*	*823*	*441*	*500*

Note: operation suspended 12 through 16 May due to high river flow and 20 May due to mechanical problems.

East_Rpt.98.fnl.xls/Tb 3 - 2/9/99

Table 3

Continued.

Date	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	
Observation Time - Start	*8:25*	*8:23*	*11:35*	*8:23*	*8:26*	*8:50*	*8:19*	*8:42*	*11:05*	*8:27*	
Observation Time - End	*18:40*	*18:45*	*18:35*	*18:53*	*18:45*	*18:45*	*18:49*	*18:45*	*18:45*	*18:15*	*TOTAL*
Military Time (hrs)											
0800 to 0859		1		1	5						*759*
0900 to 0959	80	94		4	-			2		2	*3,025*
1000 to 1059	-	70		11	20	2		-		2	*2,908*
1100 to 1159	60	25	3	13	20	7		2	1	1	*3,654*
1200 to 1259	35	45	4	19	23	31	3	-	2	1	*3,358*
1300 to 1359	-	30	3	15	11	20	2	-	6	-	*3,811*
1400 to 1459	10	95	1	2	15	8		-	6	-	*4,997*
1500 to 1559	-	25	1	5	1	10		1	-	2	*4,725*
1600 to 1659	7	7	1	6	2	-			3	1	*3,616*
1700 to 1759	2	-	1	8	-	1					*3,942*
1800 to 1859		9	4	17	2						*3,705*
1900 to 1959											*1,367*
Total	*194*	*401*	*18*	*101*	*99*	*79*	*5*	*5*	*18*	*9*	*39,904*

Table 4

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods at the Conowingo Dam East Fish Passage Facility in 1998.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
21 May	16+	0900 - 0957	621	663	42 (6.8%)
21 May	16+	1200 - 1259	830	827	-3 (0.4%)
21 May	16+	1641 - 1750	500	489	-11 (2.2%)
24 May	16+	1055 - 1154	1250	1528 (1521)[a]	278 (22.2%)
24 May	16+	1154 - 1256	650	730	80 (12.3%)
24 May	16+	1351 - 1454	300	328	28 (9.3%)
25 May	16+	1200 - 1259	150	206 (210)[a]	56 (37.3%)
25 May	16+	1300 - 1359	100	104	4 (4.0%)

[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 1998.

Year	River Flow (x 1,000) *			Number of Days Operated	Number of Lifts	Operating Time (hrs)	Catch (millions)	Number of Taxa	American shad	Blueback herring	Alewife	Hickory shad
	Mean	Minimum	Maximum									
1991	34.9	6.9	106.5	60	1,168	647.2	0.7	42	13,897	13,149	323	0
1992	47.7	12.4	100.1	49	599	454.1	0.5	35	26,040	261	3	0
1993	115.3	12.5	438.2	42	848	463.5	0.5	29	8,203	4,574	0	0
1994	76.8	15.5	245.3	55	955	574.8	1.1	36	26,715	248	5	1
1995	27.1	15.6	60.4	68	986	706.2	1.8	36	46,062	4,004	170	1
1996	67.7	16.6	198.2	49	599	454.1	0.5	35	26,040	261	3	0
1997	35.6	19.2	77.5	64	652	640.0	0.7	36	90,971	242,815	63	0
1998	69.2	15.0	218.3	50	652	640.0	0.7	33	39,904	700	6	0

* River flow at Holtwood Steam Electric Station, 1 April through 15 June.

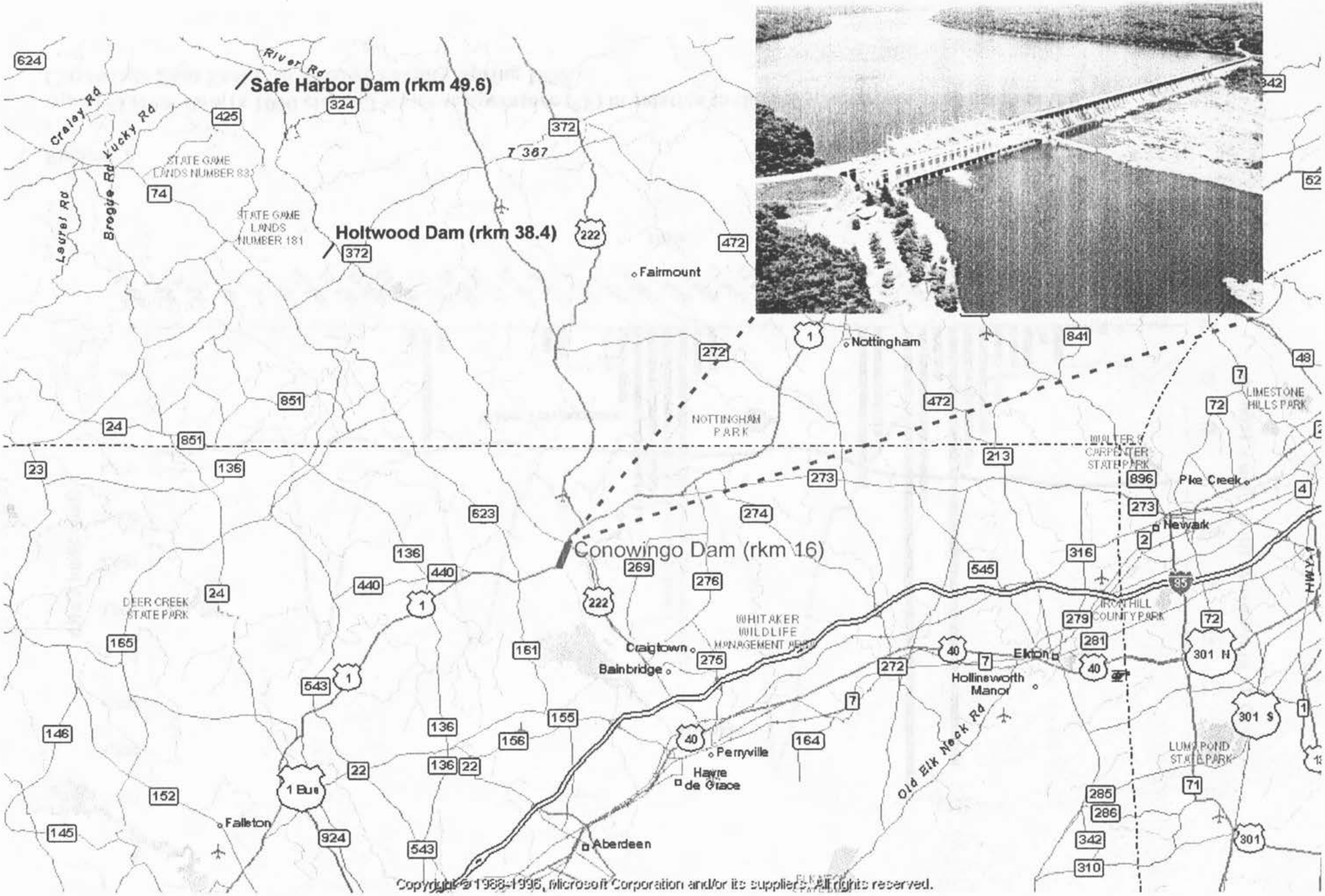


Figure 1

General location of the Conowingo Dam, Susquehanna River.

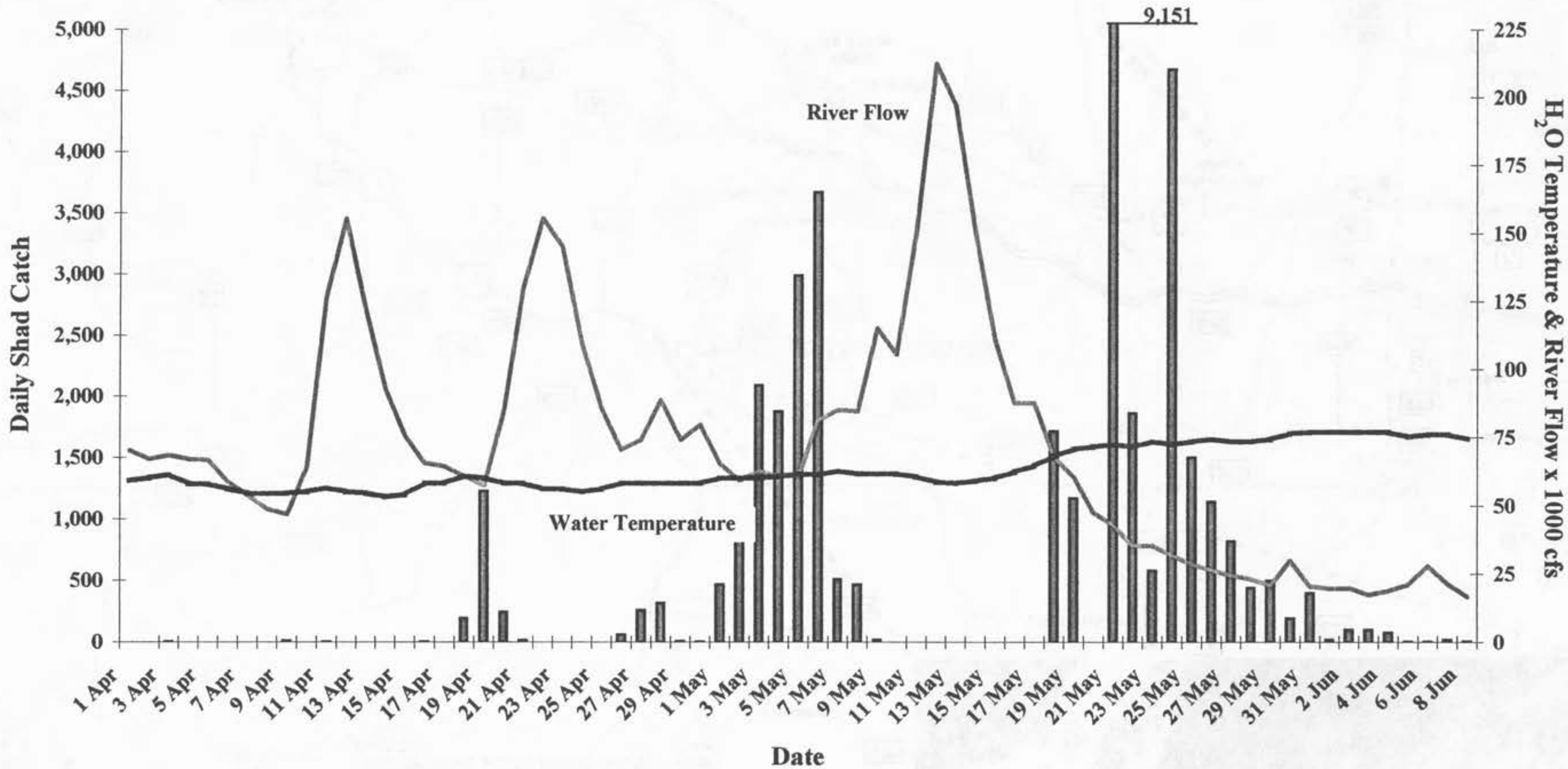


Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo Dam East Fish Passage Facility, spring 1998.

Job I - Part 2
Summary of Conowingo Dam West Fish Lift Operations - 1998

Richard St. Pierre
U. S. Fish and Wildlife Service
Harrisburg, Pennsylvania

Chris Frese[1]
Normandeau Associates
Drumore, Pennsylvania

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 now available at Holtwood and Safe Harbor dams, the Conowingo East lift was operated to pass all fish into the project head pond in 1998 (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 (about $120,000 in 1998) was derived from several sources including 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.

[1] Current address: Kleinschmidt Associates, Strasburg, PA

The objectives of Conowingo West lift operations in 1998 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; 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.

Although the winter of 1997-98 was very mild with little snowfall in the Susquehanna Basin, higher than normal precipitation occurred during March through mid-May and was followed by unusually warm temperatures in mid- to late May. These factors combined to adversely affect the start-up date and attraction and collection of shad and herring at the Conowingo West lift. In spite of unusually high flows, daily trapping began at the West lift on April 30 and continued through May 11. The facility was then shutdown for a week as flows increased rapidly to over 200,000 cfs. Operations resumed on May 18 and continued daily through June 9. Total fishing effort over 34 operating days in 1998 included 476 lifts and a fishing time of 226 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 both at Tri-County and in Little Conestoga Creek. Fish that died during transport were recovered at the stocking site upon release and delayed transport mortalities were recovered at Tri-County several times each week during the stocking season. Live shad were also provided to USFWS Northeast Fishery Center and Maryland DNR for tank spawning on a total of nine occasions. 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

Catch of shad and herring at the Conowingo Dam West lift was affected by high river flows in spring 1998. Fish attraction works best here at flows under 60,000 cfs when competing units 1 and 2 are turned off. In 1998, river flow at Conowingo averaged 87,200 cfs in April and 75,300 cfs in May, remaining above 60,000 until May 20. In several past years a substantial portion of shad returns to Conowingo Dam have occurred when water temperatures were less than 18°C. However, in 1998, temperature warmed rapidly from 15 to 22°C in only 6 days in mid-May as flows subsided and thereafter never fell below 21°C through the end of the trapping season. Figure 1 shows daily shad catch, river flow and temperatures.

Total catch for the season at the West lift amounted to 575,220 fish of 38 taxa (Table 1). Gizzard shad, white perch and channel catfish comprised 95% of this total. Alosid catch included 6,577

American shad, 5,511 blueback herring, 31 alewives, and 6 hickory shad. Through May 11, alosid catches amounted to 119 shad, 31 alewives, and 4,681 bluebacks. Following resumption of operations on May 18, shad catch averaged over 200 fish per day and substantial catches, amounting to 71% of the season total (4,669 fish), occurred in only 8 days - May 20-27. Peak day catch of 1,029 shad was on May 25 (Table 2).

Transfers included 4,309 shad stocked at Tri-County Boat Club above York Haven Dam, 284 stocked at Columbia, and 507 to USFWS-Lamar for tank spawning (Table 3). Total mortalities for transported shad were 75 fish (1.5%). Another 588 shad were provided to Maryland DNR for tank spawning. A total of 1,102 blueback herring were stocked at Tri-County and 3,653 in the Little Conestoga River (Table 4).

Otoliths were taken from 130 shad and provided to PFBC for mark and age analysis. Overall sex ratio of shad in the West lift was 0.9:1.0 favoring females. Average size of male shad was 408 mm (FL) and 803 g, whereas females averaged 458 mm and 1279 g.

Discussion

In 1998, unusually high April-May river flows and a sudden rise in water temperature dictated that our collection and stocking objectives for the Conowingo West lift would not be met. Less than half the desired 10,000 shad were released above York Haven Dam and only one of three targeted tributaries was stocked with herring. Maryland DNR and USFWS-Lamar each requested about 1,000 adult shad for tank spawning with a stated preference for early season fish. These facilities received only about one-half their need and all fish were taken in mid- to late season.

West lift catch per effort of about 37.5 shad per fishing hour was the third highest capture rate recorded at this facility, exceeded only by the 1996 and 1997 seasons (Table 5). Average catch per effort of all fishes for the 34 operating days in 1998 was almost 17,000/hour, the second highest value since 1991 when the Conowingo East lift began competing for tailrace catch (Table 6).

Based on analysis of 130 otolith samples, hatchery-marked shad comprised only 29% of the 1998 run, the lowest such fraction recorded since marked hatchery fish first became available in 1989 (see Job V). Of the total shad collected, 87% were either hauled to upstream spawning waters or provided to hatcheries for spawning. Upstream stocking of blueback herring also amounted to 87% of the total collection.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 1998.

Number of days	*41*
Number of lifts	*476*
Operating time (hours)	*238.6*
Fishing time (hours)	*225.9*
Number of taxa	*38*
American eel	89
BLUEBACK HERRING	5,511
HICKORY SHAD	6
ALEWIFE	31
AMERICAN SHAD	6,577
GIZZARD SHAD	497,375
Rainbow trout	4
Brown trout	30
Muskellunge	2
Common carp	8,206
Golden shiner	1
Comely shiner	570
Spotfin shiner	79
Quillback	280
White sucker	14
Shorthead redhorse	357
White catfish	216
Yellow bullhead	19
Brown bullhead	398
Channel catfish	17,250
White perch	32,891
STRIPED BASS	2,570
Rock bass	126
Redbreast sunfish	259
Green sunfish	10
Pumkinseed	15
Bluegill	381
Smallmouth bass	812
Largemouth bass	49
White crappie	119
Black crappie	6
Yellow perch	109
Walleye	827
Atlantic needlefish	4
Sea lamprey	7
Hybrid striped bass	18
Chain Pickerel	1
Margined Madtom	1
TOTAL	**575,220**

west Final 98.XLS/tb1 - 11/3/98

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 1998.

Date	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*
Number of lifts	*8*	*	*15*	*17*	*18*	*18*	*20*	*19*	*18*	*18*
Time of first lift	*11:14*		*13:15*	*10:50*	*11:00*	*10:45*	*11:00*	*10:45*	*10:45*	*10:45*
Time of last lift	*15:55*		*18:00*	*17:50*	*18:30*	*18:10*	*18:55*	*18:00*	*18:00*	*18:00*
Operating time (hours)	*4.7*		*4.8*	*7.0*	*7.5*	*7.4*	*7.9*	*7.3*	*7.3*	*7.3*
Fishing time (hours)	*3.1*		*3.9*	*7.0*	*7.5*	*7.4*	*7.9*	*6.9*	*7.3*	*7.3*
Average water temperature (°C)	*14.2*		*15.8*	*16.2*	*16.0*	*16.9*	*16.8*	*17.3*	*17.0*	*17.5*
Blueback herring	13		518	6	809	8	3	0	1	0
Hickory shad	0		0	0	6	0	0	0	0	0
Alewife	28		3	0	0	0	0	0	0	0
American shad	1		20	2	36	46	3	0	0	0
Gizzard shad	10,250		37,600	40,100	28,200	35,400	46,500	35,500	36,725	36,695
Common carp	733		16	12	33	43	5	6	20	81
Striped bass	11		13	32	77	64	15	40	9	9
Other species	5,452		782	4,401	7,180	2,681	4,139	3,914	2,146	1,663
TOTAL	**16,488**	**0**	**38,952**	**44,553**	**36,341**	**38,242**	**50,665**	**39,460**	**38,901**	**38,448**

* Lift operations suspended due to mechanical failure

Date	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
Number of lifts	*18*	*10*	**	**	**	**	**	**	*4*	*21*
Time of first lift	*10:45*	*10:30*							*14:45*	*10:45*
Time of last lift	*18:00*	*18:05*							*18:10*	*18:10*
Operating time (hours)	*7.3*	*7.6*							*3.4*	*7.4*
Fishing time (hours)	*7.3*	*7.6*							*3.4*	*7.4*
Average water temperature (°C)	*16.1*	*16.2*							*20.5*	*21.0*
Blueback herring	153	3,170							0	0
Hickory shad	0	0							0	0
Alewife	0	0							0	0
American shad	10	1							4	22
Gizzard shad	18,500	19,145							30,500	37,200
Common carp	100	25							401	1,110
Striped bass	44	17							41	170
Other species	4,478	1,710							1,869	3,373
TOTAL	**23,285**	**24,068**	**0**	**0**	**0**	**0**	**0**	**0**	**32,815**	**41,875**

** Lift operation suspended due to high water flow

west Final 98.XLS/tb2 - 11/3/98

Table 2

Continued.

Date	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Number of lifts	*8*	*9*	*10*	*18*	*14*	*11*	*10*	*14*	*15*	*15*
Time of first lift	*10:45*	*10:40*	*14:00*	*11:00*	*11:10*	*10:45*	*11:00*	*10:30*	*11:05*	*10:45*
Time of last lift	*13:50*	*13:45*	*18:50*	*18:55*	*18:40*	*18:15*	*18:15*	*18:50*	*18:52*	*18:35*
Operating time (hours)	*3.1*	*3.1*	*4.8*	*7.9*	*7.5*	*7.5*	*7.3*	*8.3*	*8.1*	*7.8*
Fishing time (hours)	*3.1*	*3.1*	*4.8*	*7.9*	*7.5*	*7.5*	*7.3*	*7.8*	*7.0*	*7.6*
Average water temperature (°C)	*22.4*	*22.5*	*21.5*	*22.5*	*22.0*	*22.0*	*24.1*	*23.1*	*25.8*	*23.2*
Blueback herring	3	0	3	1	1	5	3	7	33	509
Hickory shad	0	0	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0	0	0
American shad	591	16	194	702	860	1,029	863	414	117	90
Gizzard shad	17,900	9,400	7,700	11,310	4,050	5,625	2,990	7,705	1,965	970
Common carp	4	0	212	481	690	20	8	66	10	13
Striped bass	110	9	288	31	16	26	68	200	162	183
Other species	737	158	218	116	112	179	186	221	285	438
TOTAL	**19,345**	**9,583**	**8,615**	**12,641**	**5,729**	**6,884**	**4,118**	**8,613**	**2,572**	**2,203**

Date	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*04 Jun*	*05 Jun*	*06 Jun*	*07 Jun*	*08 Jun*
Number of lifts	*15*	*15*	*14*	*15*	*14*	*15*	*15*	*13*	*11*	*10*
Time of first lift	*10:40*	*10:45*	*10:45*	*10:50*	*10:50*	*10:30*	*10:45*	*10:35*	*11:00*	*10:50*
Time of last lift	*18:45*	*19:00*	*18:52*	*18:47*	*18:47*	*18:50*	*18:42*	*18:05*	*18:35*	*18:22*
Operating time (hours)	*8.1*	*8.3*	*8.1*	*8.0*	*8.0*	*8.3*	*8.0*	*7.5*	*7.6*	*7.5*
Fishing time (hours)	*7.1*	*7.5*	*8.0*	*7.3*	*7.2*	*7.3*	*7.4*	*6.3*	*6.8*	*7.2*
Average water temperature (°C)	*24.5*	*24.0*	*24.6*	*25.5*	*24.7*	*24.6*	*24.3*	*24.2*	*23.9*	*23.8*
Blueback herring	218	44	0	0	0	0	0	0	1	1
Hickory shad	0	0	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0	0	0
American shad	377	166	76	74	129	178	234	195	31	40
Gizzard shad	2,865	3,185	459	1,775	358	1,531	1,725	310	722	1,770
Common carp	73	120	3,587	47	18	93	51	48	58	19
Striped bass	205	113	71	103	97	139	22	62	46	51
Other species	274	496	761	690	390	2,428	203	304	533	288
TOTAL	**4,012**	**4,124**	**4,954**	**2,689**	**992**	**4,369**	**2,235**	**919**	**1,391**	**2,169**

west Final 98.XLS/tb2 - 11/3/98

Table 2

Continued.

Date	*09 Jun*	*Total*
Number of lifts	*11*	*476*
Time of first lift	*10:45*	-
Time of last lift	*18:00*	-
Operating time (hours)	*7.3*	*238.59*
Fishing time (hours)	*6.5*	*225.92*
Average water temperature (°C)	*22.4*	-
Blueback herring	1	*5,511*
Hickory shad	0	*6*
Alewife	0	*31*
American shad	56	*6,577*
Gizzard shad	745	*497,375*
Common carp	3	*8,206*
Striped bass	26	*2,570*
Other species	2,139	*54,944*
TOTAL	**2,970**	***575,220***

Table 3. Summary of American shad transport from the Conowingo West lift, 1998

Date	Number hauled	Location	Mortalities
5/11	13	Tri-County Marina	0
5/20	176	Tri-County Marina	4
5/21	137	USFWS-Lamar	1
5/22	167	Tri-County Marina	0
5/23	168	Tri-County Marina	1
	284	Columbia	3
5/24	700	Tri-County Marina	12
5/25	671	Tri-County Marina	23
5/26	658	Tri-County Marina	12
	135	USFWS-Lamar	0
5/27	511	Tri-County Marina	4
5/28	135	USFWS-Lamar	0
5/29	46	Tri-County Marina	0
5/30	284	Tri-County Marina	5
5/31	235	Tri-County Marina	1
6/02	54	Tri-County Marina	0
6/03	58	Tri-County Marina	0
6/04	138	Tri-County Marina	8
	100	USFWS-Lamar	0
6/05	197	Tri-County Marina	0
6/06	142	Tri-County Marina	1
6/09	91	Tri-County Marina	0
Totals	5,100		75

Note: At delivery points dissolved oxygen levels in the tanks ranged from 9.3 to 13.8 ppm and temperature of receiving waters for all but the first stocking was 19-25°C.

Table 4

Summary of blueback herring transported from the Conowingo Dam West Fish Lift, 1998.

Date	Number Blueback Collected	Water Temp. (°C)	Number Blueback Transported	Stocking Location	Observed Mortality	Percent Survival	D.O. (ppm) Start	D.O. (ppm) Finish	Water Temp. (°C) at Stocking Location
04 May	809	16.8	271	Little Conestoga Creek	0	100.0%	11.6	11.6	17.0
05 May	8	18.0	565	Little Conestoga Creek	2	99.6%	11.0	11.4	19.5
11 May	3,170	16.5	997	Little Conestoga Creek	0	100.0%	11.0	12.2	16.5
		16.0	1,000	Little Conestoga Creek	0	100.0%	10.0	9.8	12.5
		16.8	820	Little Conestoga Creek	1	99.9%	9.2	12.8	17.0
		16.0	500	Tri-County Marina	0	100.0%	13.2	13.8	14.0
29 May	509	24.5	461	Tri-County Marina	7	98.5%	12.2	11.8	24.0
30 May	218	25.0	100	Tri-County Marina	2	98.0%	11.5	12.6	25.0
31 May	44	25.0	41	Tri-County Marina	1	97.6%	8.7	11.8	25.1
TOTAL	*4,758*		*4,755*		*13*				

west Final 98.XLS/tb4 - 11/3/98

Table 5. Catch and effort for American shad taken at the Conowingo Dam West fish lift during primary collection periods[1] in 1985-1998.

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**

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

Table 6. Operations and Fish Catch at Conowingo West Lift, 1985-1998

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**

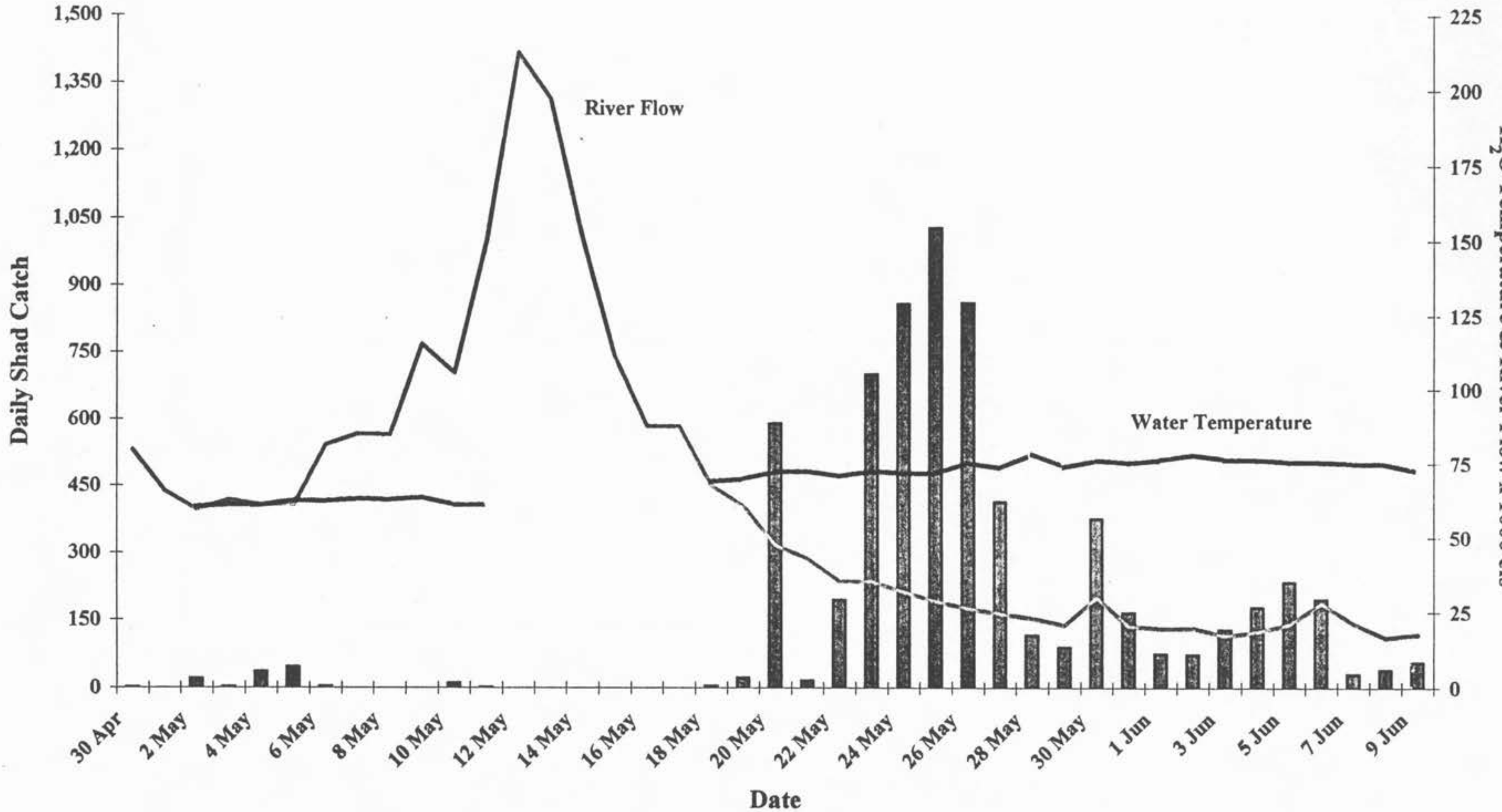


Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo West Fish Lift, spring 1998.

west Final 98.XLS/Fg 3 - 11/3/98

Job I - Part 3
SUMMARY OF OPERATION AT THE HOLTWOOD FISH PASSAGE FACILITY IN 1998

Normandeau Associates, Inc.
1921 River Road
Drumore, Pennsylvania 17518

1.0 INTRODUCTION

On June 1, 1993 representatives of PPL, Inc. (PPL), 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 the Holtwood Hydroelectric Project (Holtwood) and the two upstream hydroelectric projects to provide migratory fish passage at their project by the spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction of the fishway in April 1995 and it was operational for the 1997 spring spawning migration. The upstream facility includes a tailrace and spillway lift.

On 9 March 1998 prior to the start of fishway operation, a meeting of the Holtwood Fish Passage Technical Advisory Committee (FPTAC) 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 by PPL at Holtwood. The meeting included discussions and consensus on operation of the fishway during the 1998 spring migration season.

Objectives of 1998 upstream fishway operation were (1) monitor passage of migratory and resident fishes through the fishway; and (2) continue to assess fishway efficiency and effectiveness. Also, utilization of the fishway as a downstream passage route for post-spawned American shad was investigated. These findings will be summarized in a separate downstream passage report being prepared for submittal to the Federal Energy Regulatory Commission (FERC) in the spring of 1999.

2.0 HOLTWOOD OPERATIONS

2.1 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 with 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 station capacity.

Hydraulic conditions in the spillway at the project are controlled by numerous factors in combination with factors that change hourly, daily and throughout the fishway operating season. The primary factors that control spills and hydraulics in the spillway are river flows, operation of two power stations at Holtwood, installation/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. In 1998, before the installation of summer flash boards on 26 May, flows that exceeded station capacity were spilled over the entire length of the spillway since winter flows had knocked down all the winter flash boards (El. 169.0 ft). The two rubber dams were always inflated during fishway operation to reduce the volume of flow discharged into the east channel of the spillway.

The following formula was used to determine the approximate volume of flow discharged over the spillway: $Q = C \times L \times H^{3/2}$ Terms used in the equation are:

Q = volume (cfs);

C = constant (3.33);

L = length of dam (ft) over which spill occurred; and

H = head (ft); dam crest minus forebay elevation (ft).

In 1998, prior to installation of summer flash boards (El. 169.75 ft), water spilled over some 2,028 ft of the spillway when forebay elevations exceeded the spillway crest (165.0 ft). In addition, when the forebay elevation exceeded 169.75 ft, water spilled over the 4 ft rubber dam, which is 300 ft long. The above information combined with forebay elevations during spring fishway operation was utilized to calculate the approximate volume of water discharged into the spillway.

2.2 Fishway Design and Operation

2.2.1 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 incorporated numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998).

The 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 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 over the hopper(s) (6,700 gal capacity). Fish are then lifted in the hopper(s) and sluiced into the trough. Fish swim upstream through a counting facility and into the forebay through a pre-existing 14 ft wide debris chute.

Two inflatable rubber dams, operated from the hydro control room, are an integral component of effective spillway lift operation. Based on 1997 operation, to improve hydraulic conditions in the spillway, both the 40 ft long, 10 ft high rubber crest dam and the 300 ft long, 4 ft 9 in high rubber crest dam were kept inflated throughout the 1998 fish passage season.

Design guidelines for fishway operation included three entrance combinations. They 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 development of new operating protocols and guidelines that were flexible and utilized experience gained in the first year of operation. All three entrances (A, B, and C) or a combination of A and C were used in 1998.

2.2.2 Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch and managed in a flexible fashion. Daily management by PPL ensured that if/when maintenance activities and mechanical and/or electrical problems were encountered they were dealt with in a fashion so interruptions to fishway operation were minimized. Both lifts were operational 100% of the time throughout the 1998 season. A maintenance program that included periodic cleaning of the exit channel, nightly inspections and cleaning of picket screens and bimonthly lubrication of the hopper doors contributed to this excellent operating performance. Fishway operation was conducted by a staff of three people including a lift operator, supervising biologist, and a biological technician who counted fish.

Preparation of the fishway began in late March and even though it was considered operational in early April, natural river flows were above normal and prevented operation from starting until 27 April. Both lifts operated daily through 11 May when high river flows canceled operation. Operation resumed on 18 May and continued daily through 12 June. Generally, the fishway was operated from 1100 hrs to 1830 hrs from 27 April to 21 May. Based on an increase in the American shad catch lift operation was extended and it was operated from 0900 hrs to 1830 hrs from 22 May to 12 June. Lift operation was terminated for the year on 12 June.

Operation of the fishway's two main systems, attraction water and fish handling systems, are controlled by two Programmable Logic Controllers (PLCs). The attraction water system (seven motor operated valves and three entrance gates) can be operated automatically, manually, or remotely as needed. The fish handling systems for both lifts, including the hopper, crowder, separation screen, and a telescoping trough gate normally maintained 1 ft above forebay elevation to facilitate sluicing of fish into the trough, could be operated in the automatic or manual mode. The fish handling system mode of operation is based on equipment availability and fish abundance, and is selected by operating personnel. Generally, fish handling equipment is operated in the automatic mode if/when the equipment for each lift is available. Although improvements to the attraction water system were completed prior to the start of the 1998 season, it was operated in the manual mode for the entire season.

Hydraulics in the lift are generally a function of forebay and tailwater elevation, position of valves, and depth of entrance gates. A schematic diagram of the Holtwood fishway attraction water system is provided in Figure 3. Seven motor operated valves control the distribution, volume, and velocity of water in the fishway. Flow control in and from the fishway is accomplished by adjusting the position of the valves and three entrance gates. Valves 1 and 7 control the total volume of water in the fishway and the velocity of water in the trough. Valve 1 controls velocities in the downstream portion of the trough. Valve 7 controls the supply of water to the main attraction water supply distribution pipe and velocity in the fishway exit. Control of hydraulics in the tailrace crowder channel and from entrances A and B is based on the operation/position of valves 2, 3, and 4 and gates A and B. Flow through the tailrace crowder channel is controlled by Valve 4. Valves 2 and 3 control flow of water from the diffusers located upstream of each entrance. Valves 5 and 6 and entrance gate C control hydraulics of the spillway lift. Valve 5 controls flow of water through the crowder channel. Valve 6 regulates the volume of attraction water to a diffuser upstream of entrance C. Position of gate C controls the velocity of water from the spillway entrance.

The volume of attraction flow utilized in the fishway varies from 300 to 520 cfs and is based on the combination of entrances utilized. Three-entrance operation (A, B, and C) utilized an attraction flow of 520 cfs. Entrance C discharges 220 cfs and the other 300 cfs is split equally between entrances A and B. Two-entrance operation (A and C) utilizes a discharge of 150 cfs from each entrance.

Conceptually, the fishway was to be operated with some 800 cfs of attraction water when all three entrances were utilized. Although utilization of 800 cfs or attraction water is possible, flow conditions created in the upstream portion of the exit channel become impassable. Based on this year's operating experience 520 cfs is close to the maximum volume of attraction flow that can be utilized. When the facility is operated so the valves and gates are set to pass the design volume of attraction water two conditions are created that limit and/or deny fish passage through the upstream portion of the fish exit trough. They are: (1) velocities exceed 8 ft/sec in the upstream section of the exit trough which exceeds the sustained swimming speed of most fishes targeted for restoration; and (2) a vortex is created just upstream of the counting window, which based on visual observations of fish movement within the area, delayed and/or denies fish passage into the exit channel upstream of the counting window.

Late in the season it was found that by lowering gate 8 approximately 1.5 ft below the surface elevation of the water improvement to fish passage occurred. Improvements included the reduction of water velocities in portions of the upstream section of the fishway exit and a simultaneous reduction in the size/intensity of the vortex directly upstream of the counting window. In addition, this action reduces the volume of small surface trash that enters the fishway.

Water velocity in the fishway is a function of the total volume of water utilized, project hydraulics (*i.e.*, tailwater and forebay elevation), and valve and gate position. Velocities at the fishway exit, in the trough, crowder channels, and at the entrance are maintained and/or modified as necessary to maximize the American shad catch and are within established USFWS guidelines. Based on visual observations of fish movements, operating experience, and equipment availability, velocities are manipulated throughout the spring to facilitate the collection and passage of American shad and other fishes. Velocities that appear to be most effective at the exit, in the trough, crowder channels, and at the entrances range from 2.0 to 4.0, 0.75 to 1.0, 1.0 to 1.5, and 4.0 to 6.0 ft/sec, respectively.

Fishing time and/or lift frequency is determined by fish abundance. Normally, when all the equipment is available, the fish handling system was cycled in the automatic mode otherwise the lift(s) are operated manually. Prior to conducting a lift in the automatic mode, the equipment has to be set in the "fish position". Equipment is considered in the fish position when: (1) the crowder is parked and the doors are set in the trap position; (2) both the separation screen and the hopper are fully lowered; and (3) the trough gate is positioned 1 ft above forebay elevation. Once the equipment is positioned, operating personnel enter the desired fishing time into the PLC. When the fishing time ends, the equipment cycles. Cycling includes raising the separation screen, closing the crowder doors, crowding fish over the hopper, raising the hopper, and sluicing fish into the trough. Manual operation occurs early in the season to ensure the equipment is functioning properly and/or when difficulties with various pieces of equipment are encountered. Normally, the lift(s) are cycled at least hourly throughout the day and more frequently (e.g., every half hour) during periods of increased fish abundance.

Debris is sluiced from the fishway at two locations, the exit/entrance of the trough and the downstream end of the trough. Small floating debris that enters the fishway is sluiced out of the trough through gate 6 and into the tailrace on an as needed basis throughout the operation each day. Large wood debris that accumulates at the exit of the fishway on the 4 in adjustable trash screen and/or the 12 in fixed trash screen is sluiced into the spillway through gate 9. For most of the season, sluicing debris from the exit/entrance of the fishway is conducted on an as needed basis every few days prior to the start of lift operation. This required about 1½ hours to complete since it involves a series of seven steps and sounding the Hydro Station Warning System.

Beginning on 6 June 1998, following installation of a "slick bar" in front of the fishway exit, trash was spilled by the hydro control room operator via the 10 ft rubber dam. The "slick bar" is a 2 ft high floating skimmer boom installed on an angle upstream of the fishway exit. It was designed to reduce clogging of the exit channel by trash, which impacts hydraulics in the fishway, and to enhance debris management. Although the "slick bar" was installed late in the season, and its utilization was limited, it appears that it will enhance future fishway operations.

In an effort to safely maintain fish in the trough overnight and minimize the amount of trash that could enter the trough overnight, the volume of flow utilized for fish maintenance was changed throughout the 1998 season. Early in the season when water temperature and fish abundance was low, no maintenance flow was utilized. Beginning on 22 May and continuing until the end of the season a small volume (<25 cfs) of water was passed through the fishway by opening MOV 1 and 2 to a setting of 2%.

2.3 Fish Counts

Fish lifted and sluiced into the exit channel trough are identified to species and enumerated as they pass the counting window by a biologist and/or 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 enumerated prior to passage from the fishway. 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.

Two capital improvements were completed prior to the 1998 season to improve fish counts and the video record of fish passage. Improvements included installation of an adjustable 500 watt underwater pool light in the middle of the viewing window and an adjustable screen capable of reducing the channel width from 36 in down to 18 in at the counting window area of the exit trough. Screen design enables this gate to be set at several intermediate positions between 18 and 36 in. The adjustable screen was set at 18 in for the entire season. Pool light intensity was adjusted daily, based on the constantly changing ambient light conditions in an effort to adequately capture fish passage on video tape.

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 fish counter as fish pass the viewing window on a digital note pad, a ScriptWriter XL, which 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 provided a hard copy 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 operation 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).

The camera is mounted on a tripod set approximately 5 ft off the floor and positioned 1.5 ft from the back wall of the counting room. The camera is aimed at the fish viewing window. Fish passage is recorded in 12 hr time-lapse mode, a video tape recording setting that yields 3.3 video records per second. During recording, the recorder imprints the time and date on each frame of video tape, providing a record of the time for all fish passed.

The recorded tapes are reviewed using a video cassette recorder/player equipped with a jog/shuttle control. This feature allows a day's tape to be reviewed at different speeds during playback, including slow motion and frame by frame. Selected segments of tape are reviewed by a biologist who counts the number of shad passing the window during the selected time period.

3.0 RESULTS

3.1 Relative Abundance

The relative abundance of fishes collected and passed by the Holtwood fishway is presented in Table 1. A total of 162,584 fish of 29 taxa passed upstream into Lake Aldred. Gizzard shad (138,713) was the dominant fish species passed and comprised over 85% of the catch. Some 8,235 American shad were collected and passed upstream through the fishway. Other predominant fishes passed included channel catfish (3,604), walleye (3,109), shorthead redhorse (2,188), quillback (1,603), and smallmouth bass (1,565). Peak passage occurred on 21 May when 16,318 fish were passed.

Other resident important species passed by the fishway included 62 blueback herring and 116 striped bass (Table 1). The majority of these fish were passed after fishway operation resumed on 18 May following a high flow event.

3.2 American Shad Passage

The Holtwood fishway captured and passed 8,235 American shad during 41 days of operation in 1998 (Table 1). Some 400 shad passed before a high flow event (river flows >218,000 cfs) that cancelled operation for six days. Starting on 12 May collection and passage of shad varied daily with approximately 80% (6,586) captured and passed between 26 May and 5 June. During this period over 75% of the shad were passed in four days. Peak passage occurred on 1 June when 1,729 shad were captured and passed in 9.6 hrs of operation.

American shad were passed at water temperatures of 56.3°F to 79.5°F and river flows of 15,000 cfs to 107,800 cfs (Table 2 and Figure 4). Water temperature and river flows from 26 May to 5 June during the period when the majority of shad were passed averaged 74.6°F (70.8°F to 79.5°F) and 21,400 cfs (19,000 cfs to 27,400 cfs), respectively.

The capture of shad at the fishway occurred over a wide range of station operation and discharge conditions (Table 2). Shad were captured and passed by the tailrace lift at tailwater elevations that ranged from 111.3 ft. to 120.2 ft. Generally, tailrace elevations correspond to unit operation, which varied from 2 to 10 main turbine units. Excluding brief periods of reduced station operation on 23 and 24 May caused by an equipment malfunction most tailrace fishway operation coincided with the operation of 10 turbines. Operation of the spillway lift occurred at spillway discharges that ranged from leakage (El. 116.0 ft) to spills that exceeded 90,000 cfs.

Passage of shad into Lake Aldred occurred at forebay elevations that ranged from 164.1 ft to 170.6 ft (Table 2). Visual observations indicated that shad readily passed through the fishway into Lake Aldred at this range of forebay elevations. On 26 May and for a short period of time on 27 May 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 (6,153) passed through the fishway before 1600 hrs. Peak hourly passage of shad (1,282) occurred between 1100 hrs and 1159 hrs. Generally, shad passage increased throughout the day, peaked by 1600 hrs, and declined steadily until operation was ended each evening.

A qualitative assessment of the relative number of shad collected in the tailrace and spillway lift 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 that was captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 6,311 and 1,924 shad (76.6% and 23.4%), were captured in the tailrace and spillway lift, respectively (Table 4). The contribution of each lift's catch to daily passage varied considerably throughout the season. Both lifts appeared to catch shad effectively based on visual observations of fish movement up to and/or in the vicinity of the entrances to the lifts.

Catch of shad in the spillway lift was dependent on flow conditions in the spillway, particularly the east channel. Most shad (1,568; 81%) were captured in the spillway lift after 25 May (Table 4). Discharges into the spillway during this period were generally limited to leakage. Prior to 26 May and the installation of summer flash boards spillway lift operation coincided with spills that changed daily based on river flow and project inflow. Based on forebay elevations the calculated volume of water spilled during this period varied from 8,877 cfs to 90,275 cfs (Table 5). Shad were captured over a wide range of river flows and discharges in the spillway lift, however, over 61% (170) of the 280 shad captured during spill were captured on 26 and 27 May.

3.3 Passage Evaluation

In 1998, fishway monitoring efforts focused on visual observations of immigrating fish movements below and in the tailrace and spillway lifts to optimize safe and efficient utilization of the fishway. The number of fishes observed in the tailrace were higher than those in the spillway. Fish survival in the fishway was excellent as 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. 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.

Throughout the season, 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 utilized during the season. Major improvements in flow were achieved from installation of the "slick bar" and utilization of gate 8 to reduce the vortex in the fish trough. The combination of these factors enabled operation to be conducted with a maximum volume of flow.

Five surveys were conducted in the east channel of the spillway from the shore of Piney Island during 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 26 May when spills at Holtwood were stopped for the first time in 1998. Three shad were observed during this survey and they were not stranded indicating shad can move freely in and about this area when spills into the area are stopped.

3.4 Video Record

An underwater light and adjustable screen installed prior to the season improved counting conditions and the video record of fish passage. A review of the video record showed that fish passage at times was adequately captured on the tape record. Data in Table 6 list by date and time, visually and taped derived counts of shad, and the difference between the two counts. Differences between the counts were negligible with counts either identical or differing by 0.9% to 3.9%. These results verify that at this level of passage visual counts conducted during daily operation accurately reflect shad passage.

4.0 SUMMARY

In 1998, excluding a six day cancellation of fishway operation caused by high flow, the fishway operated without interruption for 41 days during the spring spawning season. Both lifts were operational 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.

Some 8,235 American shad were passed into Lake Aldred. Sixty-two blueback herring were captured and passed the fishway. Observations indicated fish that reached the project area were effectively captured and passed upstream. Although the level of impact high river flows and rapidly rising water temperatures had on the upstream movement of shad in Conowingo Pond is unknown these factors did affect shad passage at Holtwood. High river flows and the limited catch of shad early in the season at Conowingo Dam delayed the start of operation until 27 April. Shad passage at Holtwood from 27 April to 11 May was limited to 400 fish. During this period of operation river flows were at least 30% and 95% higher than median river flows for April and May which are approximately 62,000 cfs and 42,000 cfs, respectively. A high flow event (river flows >218,000 cfs) cancelled fishway operation beginning on 12 May and operation did not resume until 18 May. Generally, shad passage increased during this period as river flows declined and water temperature increased. In four days from 18 May to 21 May the average water temperature increased over 8°F, from 64.4°F to 72.7°F. Following the rapid increase in water temperature, shad passage (6,856) increased at the fishway, with the majority (80%) passed from 26 May to 5 June. During this period spills at the project had stopped and water temperatures varied from 70.8°F to 78.5°F.

At the present level of American shad passage, based on the tape review, there is no reason to continue the expenditure of resources to verify visual counts of shad passage. Not only was the accuracy of visual counts high, these counts enable nightly and weekly distribution of passage numbers in a timely fashion, where as, tape derived counts would occur after the fact and are very labor intensive. To review just one hour of 1998 passage up to six hours was required to review and determine the numbers of shad passed depending on various factors including the number and type of fish passed and tape quality. In addition, if tape quality is poor as it was on some days in 1998 determination of shad passage numbers would not be possible. However, the video record of fish passage should be continued. It provides a backup and the means to verify the accuracy of visual counts as the shad population grows and hourly passage of shad increases. In the future, when hourly passage of shad exceeds 1,000 fish per hour, a limited review of the passage record should be conducted to determine the accuracy of visual counts. Also, continued taping of fish passage could provide fishway operators flexibility to respond, on an as needed basis, to other aspects of fishway operation for limited periods of time.

Although the shad catch this year was less than half the 1997 catch numerous insights into fishway operation were gained during the season. Many of these will be utilized in future fishway operation.

5.0 RECOMMENDATIONS

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 operation and performance.

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

As river flow conditions permit install the "Slick Bar" in front of the fishway exit channel to deflect debris from entering and accumulating at the exit/entrance of the trough. This will increase the volume of water that can be used in the fishway, and enhances flow patterns in the trough. Also, it reduces clogging of screens in the fishway and as a result increases the time the fishway can be operated.

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.

Continue the video tape record of fish passage as it provides a backup of fish passage. However, discontinue tape review unless hourly passage exceeds 1,000 shad.

6.0 LITERATURE CITED

Normandeau Associates, Inc. 1998. Summary of operation at the Holtwood Fish Passage Facility in 1997. Prepared for PPL, Inc. by Normandeau Associates, Inc., Muddy Run Ecological Laboratory, Drumore, Pennsylvania.

Table 1

Summary of the daily number of fish passed by the Holtwood fish passage facility in 1998.

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*
Hours of Operation - Spillway:	*5*	*8*	*7*	*7.5*	*7*	*7*	*7.75*	*5.5*	*8*	*7.5*	*6.75*	*. 6.5*
Hours of Operation - Tailrace:	*5*	*8*	*7*	*7.5*	*7*	*7*	*7.75*	*5.5*	*8*	*7.5*	*6.75*	*6.5*
Number of Lifts - Spillway:	*6*	*8*	*8*	*7*	*7*	*8*	*7*	*4*	*7*	*7*	*6*	*4*
Number of Lifts - Tailrace:	*6*	*11*	*6*	*9*	*7*	*6*		*7*	*8*	*9*	*7*	*7*
Water Temperature (°F):	*58.1*	*55.4*	*56.3*	*57.8*	*58.8*	*58.7*	*59.5*	*60.8*	*60.8*	*61.4*	*61.1*	*61.7*
American Shad	12	5	10	2		2	5	4	16	146	188	4
Gizzard Shad	1,272	2,301	1,457	2,590	1,350	2,662	4,870	4,250	6,104	4,725	3,840	1,587
Blueback Herring												
Striped Bass	2			2		1	2		1	12	1	
Rainbow Trout	3	5	1	3	3	3	2	2	3		2	2
Brown Trout	5		1	4			1				22	3
Muskellunge												
Carp	2		2	5	2	1	7	1	2	21	9	2
Quilback				115	142	48	61	15	109	100	54	
White Sucker							3	2				
Shorthead Redhorse	8	12	43	356	195	90	140	55	213	277	10	9
White Catfish							1					
Brown Bullhead												
Channel Catfish	72	19	58	102	75	100	201	61	67	104	230	318
White Perch	4							2				
Rock Bass		1	19	3	8	2	6	7	1	3	9	6
Redbreast Sunfish	4							2		3		
Green Sunfish										3	2	
Pumpkinseed												
Bluegill	6	1	5					3	4	1		2
Smallmouth Bass	15	2	1	32	17	26	27	10	24	22	25	8
Largemouth Bass	13	5	2	8	8	1	7	6	2	8	3	
White Crappie					2	1			1			1
Black Crappie	4				3				1			
Tessellated Darter												
Yellow Perch				1						3		
Walleye	60	7	54	174	68	85	117	70	107	201	145	23
Atlantic Needlefish												
Hybrid Striped Bass												
Total	***1,482***	***2,358***	***1,653***	***3,397***	***1,873***	***3,022***	***5,450***	***4,490***	***6,655***	***5,629***	***4,540***	***1,965***

hfinal98.xls/Tb 1 - 1/14/99

Table 1

Continued.

Date:	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*
Hours of Operation - Spillway:	*6.5*	*6*	*6.5*							*7*	*7*	*7*
Hours of Operation - Tailrace:	*6.5*	*6*	*6.5*							*7*	*7*	*7*
Number of Lifts - Spillway:	*4*	*5*	*4*							*6*	*6*	*6*
Number of Lifts - Tailrace:	*7*	*5*	*4*							*8*	*8*	*8*
Water Temperature (°F):	*60.7*	*59.9*	*59.4*							*64.4*	*69.9*	*71.6*
American Shad	4	2								54	39	191
Gizzard Shad	2,490	292	75							6,637	15,380	9,180
Blueback Herring			1								7	50
Striped Bass	1									1	2	10
Rainbow Trout	3	2								7		5
Brown Trout		8								39	1	10
Muskellunge												
Carp	6	1	2							19	18	17
Quilback	2	1								149	66	35
White Sucker	1											
Shorthead Redhorse	9	13	10							42	33	112
White Catfish												40
Brown Bullhead												
Channel Catfish	270	192	150							239	82	97
White Perch											1	2
Rock Bass	3	5	1							22	22	17
Redbreast Sunfish		1								3		15
Green Sunfish			1							2		10
Pumpkinseed												6
Bluegill	3	1	2							10	21	22
Smallmouth Bass	9	5	1							44	66	17
Largemouth Bass	2									69	19	42
White Crappie		1								17	10	53
Black Crappie	1											
Tessellated Darter												
Yellow Perch	1									4	2	14
Walleye	53	84	15							45	86	144
Atlantic Needlefish												
Hybrid Striped Bass										2		
Total	***2,858***	***608***	***258***	***0***	***0***	***0***	***0***	***0***	***0***	***7,405***	***15,855***	***10,089***

Table 1

Continued.

Date:	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*
Hours of Operation - Spillway:	*7*	*8.75*	*8*	*9*	*9*	*6.25*	*9.6*	*9*	*8.75*	*10*	*9.5*	*9.67*
Hours of Operation - Tailrace:	*7*	*8.75*	*8*	*9*	*9*	*6.25*	*9.6*	*9*	*8.75*	*10*	*9.5*	*9.67*
Number of Lifts - Spillway:	*6*	*8*	*8*	*8*	*11*	*10*	*12*	*8*	*9*	*6*	*7*	*8*
Number of Lifts - Tailrace:	*7*	*10*	*9*	*10*	*10*	*6*	*10*	*9*	*8*	*7*	*6*	*12*
Water Temperature (°F):	*72.7*	*72.4*	*70.7*	*71.3*	*70.5*	*70.8*	*71.9*	*73*	*73.4*	*73.5*	*77.3*	*77.5*
American Shad	39	160	30	113	245	1,223	1,020	168	279	41	80	1,729
Gizzard Shad	15,181	13,811	3,900	2,701	2,750	8,975	5,620	3,790	2,334	818	900	1,749
Blueback Herring												1
Striped Bass	18		2	3	4		12	6	2	7	3	3
Rainbow Trout	2			3	5		14	4			2	
Brown Trout	6	3	1	5	15		39		1	2		
Muskellunge	2										1	
Carp	180	41	95	51	266	100	65	12	16	41	46	9
Quilback	11	28	2	12	57	250	332	10	1			
White Sucker	5	7										
Shorthead Redhorse	145	44	130	50	10		116		12	4	6	4
White Catfish											1	
Brown Bullhead			1							2		
Channel Catfish	92	28	17	161	137	5	97	38	57	83	125	17
White Perch		11	9		1		8					
Rock Bass	27	8	7	9	3	3	10	4	4	9	3	
Redbreast Sunfish	15	24	25	15	19	2	11	1	9	5	20	18
Green Sunfish	18		7		16		7					1
Pumpkinseed	10	1	2	25	6	1	5			2	5	1
Bluegill	30	10	20	30	11		14	5	6	12	3	3
Smallmouth Bass	78	22	26	45	82	305	280	98	73	47	24	25
Largemouth Bass	84	35	42	32	13	14	24	2		2	3	3
White Crappie	118	10	43	52	27	1	14	4		5	7	2
Black Crappie		5			20		3					
Tessellated Darter							2					
Yellow Perch	88	5	5	13	15		7	2	2			
Walleye	169	115	40	121	103	21	334	159	80	70	45	73
Atlantic Needlefish									1			
Hybrid Striped Bass												
Total	***16,318***	***14,368***	***4,404***	***3,441***	***3,805***	***10,900***	***8,034***	***4,303***	***2,877***	***1,150***	***1,274***	***3,638***

Table 1

Continued.

Date:	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	**TOTAL**
Hours of Operation - Spillway:	*8.5*	*8*	*8.75*	*8.66*	*9*	*7.5*	*8.9*	*8.75*	*9*	*8.5*	*8.5*	**322**
Hours of Operation - Tailrace:	*8.5*	*8*	*9*	*8.66*	*9*	*7.5*	*8.9*	*8.75*	*9*	*8.5*	*8.5*	**322**
Number of Lifts - Spillway:	*7*	*8*	*7*	*8*	*8*	*5*	*6*	*6*	*7*	*6*	*5*	**284**
Number of Lifts - Tailrace:	*14*	*11*	*9*	*10*	*11*	*9*	*10*	*7*	*7*	*8*	*7*	**330**
Water Temperature (°F):	*78.5*	*77.3*	*73.5*	*74.2*	*71.8*	*70.5*	*68.9*	*69.4*	*68.4*	*68.6*	*67.3*	**-**
American Shad	983	442	321	300	164	98	55	32	12	7	10	**8,235**
Gizzard Shad	1,111	600	740	373	206	103	131	147	143	474	1,094	**138,713**
Blueback Herring	1		1					1				**62**
Striped Bass	7	3	1	1	2	3	1	1	1	1		**116**
Rainbow Trout												**76**
Brown Trout												**166**
Muskellunge												**3**
Carp	1	1	3	2	8	3		3	2		3	**1,065**
Quilback						2				1		**1,603**
White Sucker												**18**
Shorthead Redhorse	12	8	3	3	7	1	1	2	1	1	1	**2,188**
White Catfish												**42**
Brown Bullhead												**3**
Channel Catfish	41	76	71	9	26	2		14	21	16	34	**3,604**
White Perch								4	7	1		**50**
Rock Bass		2		2	1				1			**228**
Redbreast Sunfish	13	18	9	9			1	13	4		1	**260**
Green Sunfish							1					**68**
Pumpkinseed	2					1	1					**68**
Bluegill	7	1	6	3	1	1	2	5	6	3		**260**
Smallmouth Bass	26	17	24	5	8	3	2	9	5	6	4	**1,565**
Largemouth Bass	1	5	5	1	10	5		20	5			**501**
White Crappie		1							1	1		**372**
Black Crappie												**37**
Tessellated Darter												**2**
Yellow Perch	2	2	1									**167**
Walleye	37	34	25	20	17	11	7		20	41	29	**3,109**
Atlantic Needlefish												**3**
Hybrid Striped Bass												**2**
Total	***2,244***	***1,210***	***1,210***	***728***	***450***	***233***	***202***	***251***	***229***	***552***	***1,176***	**162,584**

hfinal98.xls/Tb 1 - 1/14/99

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 1998.

Date	River Flow (cfs)	Water Temp. (°F	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
27 Apr	77,500	58.1	16	10	150	150	220	119.2-119.6	127.0-128.0	169.1-169.9
28 Apr	88,800	55.4	12	10	150	150	220	119.2-119.7	127.0-128.0	169.6-170.0
29 Apr	87,700	56.3	14	10	150	150	220	119.5-119.8	127.0-128.0	169.9-170.1
30 Apr	81,600	57.8	12	10	150	150	220	119.6-119.8	127.0-128.0	169.8-170.2
1 May	69,000	58.8	18	10	150	150	220	119.1-119.2	128.0-129.0	169.1-168.9
2 May	62,700	58.7	16	10	150	150	220	118.9119.4	128.0-129.0	169.5-168.1
3 May	64,500	59.5	18	10	150	150	220	118.8-119.2	129.0-132.0	168.0-169.2
4 May	66,100	60.8	16	10	150	150	220	119.2-119.4	131.0-131.0	168.8-169.5
5 May	64,500	60.8	18	10	150	150	220	119.2-118.8	128.0-130.0	169.1-168.0
6 May	84,300	61.4	12	10	150	150	220	119.3-119.8	130.0-134.0	169.7-170.2
7 May	85,800	61.1	3	10	150	150	220	120.1-119.7	132.0-134.0	170.2-169.9
8 May	88,700	61.7	6	10	150	150	220	119.6-119.5	130.0	169.9-169.8
9 May	102,000	60.7	10	10	150	150	220	119.8-119.9	134.0	170.3-170.4
10 May	107,800	59.9	10	10	150	150	220	119.9-120.0	133.0-134.0	170.4-170.5
11 May	109,500	59.4	8	10	150	150	220	120.2-120.1	135.0	170.6-170.5
12 May	157,200	58.7								
13 May	218,300	58.2								
14 May	200,400	59.3								
15 May	150,500	60.4								
16 May	109,600	62.3								
17 May	89,300	65.0								
18 May	71,800	64.4	18	10	150	150	220	119.2-119.6	130.0-131.0	169.2-169.8
19 May	60,400	69.9	22	10	150	150	220	118.9-119.2	129.0-127.0	168.3-169.5
20 May	52,600	71.6	20	10	150	150	220	118.7-119.1	126.0-129.0	168.9-167.9
21 May	43,600	72.7	24	10	150	150	220	118.3-118.9	121.0-129.0	166.2-168.5
22 May	39,600	72.4	24	10	150	150	220	118.8-119.0	127.0-122.0	168.1-166.7
23 May	35,500	70.7	22	3 to 10	150	150	220	113.2-118.7	126.0-128.0	167.7-168.3
24 May	32,400	71.3	22	4 to 10	150	150	220	112.7-118.7	124.0-127.0	168.1-166.9
25 May	29,100	70.5	20	10	150/300	150/0	220	111.3-118.7	128.0-124.0	167.5-168.5
26 May	27,400	70.8	24	10	150		150	118.4	117.0-118.0	164.1-164.4
27 May	25,300	71.9	24	10	150		150	115.2-118.6	117.0-118.0	164.1-169.0
28 May	23,000	73.0	24	10	150	150	220	118.8-118.9	117.0-118.0	167.9-168.4
29 May	21,100	73.4	24	10	150	150	220	115.5-118.9	116.0-119.0	168.0-169.0
30 May	21,100	73.5	25	10	150	150	220	118.8-118.7	118.0-117.0	169.0-168.2
31 May	19,800	77.3	25	10	150	150	220	117.0-118.8	117.0	167.9-168.9
1 Jun	20,200	77.5	26	8 to 10	150		150	115.8-118.8	118.0-117.0	167.5-168.9
2 Jun	19,200	78.5	22	10	150		150	118.7-117.5	118.0-117.0	167.7-168.3
3 Jun	19,200	77.3	24	10	150		150		118.0-117.0	
4 Jun	19,100	73.5	24	10	150		150	115.3-118.7	118.0-117.0	168.2-168.8
5 Jun	20,000	74.2	18	10	150		150	115.4-118.7	118.0-117.0	168.3-168.9
6 Jun	24,100	71.8	18	10	150		150	118.4-118.7	118.0-117.0	167.8-169.5
7 Jun	20,900	70.5	18	10	150		150	118.6-118.7	118.0-117.0	167.8-168.3
8 Jun	19,000	68.9	18	10	150	150	220	118.7-118.8	118.0-117.0	168.1-169.2
9 Jun	17,600	69.4	18	8 to 10	150	150	220	114.8-118.7	118.0	168.7-169.0
10 Jun	16,100	68.4	17	8	150	150	220	117.2-117.3	117.0-118.0	168.9-168.3
11 Jun	15,000	68.6	18	8 to 10	150	150	220	113.3-118.8	118.0	168.9-169.1
12 Jun	15,200	67.3	18	10	150	150	220	118.8-118.9	118.0	167.9-168.5

hfinal98.xls/Tb 2 - 1/14/99

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 1998.

Date:	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*
Observation Time - Start:	*1234*	*1022*	*1110*	*1023*	*1227*	*1130*	*1030*	*1137*	*1105*	*1040*
Observation Time - End:	*1830*	*1830*	*1830*	*1614*	*1816*	*1817*	*1818*	*1810*	*1809*	*1816*
Military Time (hours)										
0900 - 0959										
1000 - 1059		-		-			-			-
1100 - 1159		2		-		-	-	1	1	7
1200 - 1259	-	2		-	-	-	-	-	-	2
1300 - 1359	-	1		1	-	1	-	-	-	36
1400 - 1459	-	-		-	-	-	-	-	5	48
1500 - 1559	5	-		1	-	1	-	-	3	9
1600 - 1659	5	-		-	-	-	1	-	4	31
1700 - 1759	2	-			-	-	4	3	3	8
1800 - 1859	-	-			-	-	-	-	-	5
1900 - 1959										
Total Catch	***12***	***5***	***10[a]***	***2***	***0***	***2***	***5***	***4***	***16***	***146***

Date :	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*
Observation Time - Start :	*1030*	*1105*	*1131*	*1127*	*1135*					
Observation Time - End :	*1800*	*1745*	*1755*	*1735*	*1758*					
Military Time (hours)										
0900 - 0959										
1000 - 1059	6									
1100 - 1159	30	-	-	-	-					
1200 - 1259	53	-	1	-	-					
1300 - 1359	15	-	1	-	-					
1400 - 1459	3	-	1	-	-					
1500 - 1559	12	-	1	2	-					
1600 - 1659	47	-	-	-	-					
1700 - 1759	22	4	-	-	-					
1800 - 1859										
1900 - 1959										
Total Catch	***188***	***4***	***4***	***2***	***0***					

hfinal98.xls/Tb 3 - 1/14/99

Table 3

Continued.

Date:	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*
Observation Time - Start:		*1055*	*1120*	*1105*	*1052*	*909*	*911*	*930*	*910*	*1256*
Observation Time - End:		*1820*	*1827*	*1817*	*1830*	*1830*	*1826*	*1824*	*1825*	*1900*
Military Time (hours)										
0900 - 0959						1	5	-	-	
1000 - 1059		-			-	1	4	15	5	
1100 - 1159		-	1	25	7	2	1	11	8	
1200 - 1259		7	8	40	5	-	5	0	15	-
1300 - 1359		2	3	16	-	4	7	5	56	305
1400 - 1459		19	6	5	23	40	3	12	65	235
1500 - 1559		12	4	35	1	56	3	34	67	230
1600 - 1659		7	5	45	3	35	2	25	-	202
1700 - 1759		5	9	15	-	16	-	8	29	144
1800 - 1859		2	3	10	-	5	-	3	-	107
1900 - 1959										
Total Catch		***54***	***39***	***191***	***39***	***160***	***30***	***113***	***245***	***1,223***

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*
Observation Time - Start:	*918*	*1008*	*1020*	*830*	*918*	*920*	*1025*	*930*	*918*	*944*
Observation Time - End:	*1900*	*1831*	*1835*	*1830*	*1819*	*1905*	*1852*	*1832*	*1909*	*1821*
Military Time (hours)										
0900 - 0959	-			3	8	5		29	7	
1000 - 1059	200	16	2	-	7	261	-	110	65	100
1100 - 1159	160	30	128	15	8	400	270	36	20	50
1200 - 1259	120	36	25	13	9	120	116	87	70	-
1300 - 1359	155	5	33	2	2	-	100	61	65	50
1400 - 1459	170	14	31	3	16	150	190	-	-	20
1500 - 1559	95	25	10	-	3	291	75	10	48	40
1600 - 1659	95	29	32	1	19	170	67	52	-	-
1700 - 1759	17	9	15	1	6	178	100	27	16	40
1800 - 1859	8	4	3	3	2	154	65	30	25	
1900 - 1959						-			5	
Total Catch	***1,020***	***168***	***279***	***41***	***80***	***1,729***	***983***	***442***	***321***	***300***

Table 3

Continued.

Date :	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	
Observation Time - Start :	*910*	*921*	*941*	*923*	*850*	*931*	*900*	
Observation Time - End :	*1835*	*1808*	*1840*	*1824*	*1809*	*1725*	*1800*	*TOTAL*
Military Time (hours)								
0900 - 0959	-	7	-	-	1	-	1	*67*
1000 - 1059	19	3	-	1	-	-	4	*819*
1100 - 1159	20	28	10	7	4	-	-	*1,282*
1200 - 1259	25	-	15	4	1	1	1	*781*
1300 - 1359	28	44	-	-	-	-	2	*1,000*
1400 - 1459	-	6	10	5	4	2	1	*1,087*
1500 - 1559	14	3	5	8	1	2	1	*1,107*
1600 - 1659	33	-	-	3	-	2	-	*915*
1700 - 1759	21	7	6	4	-	-	-	*719*
1800 - 1859	4	-	9	-	1			*443*
1900 - 1959								*5*
Total Catch	*164*	*98*	*55*	*32*	*12*	*7*	*10*	*8,235*

* ScriptWriter malfunction; hourly data lost.

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 1998.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
27 Apr	12	12		100	
28 Apr	5	5		100	
29 Apr	10	10		100	
30 Apr	2	2		100	
1 May	0				
2 May	2	2		100	
3 May	5	5		100	
4 May	4	4		100	
5 May	16	12	4	75	25
6 May	146	88	58	60	40
7 May	188	168	20	90	10
8 May	4	4		100	
9 May	4	4		100	
10 May	2	2		100	
11 May	0				
12 May					
13 May					
14 May					
15 May					
16 May					
17 May					
18 May	54	49	5	90	10
19 May	39	35	4	90	10
20 May	191	172	19	90	10
21 May	39	39		100	
22 May	160	104	56	65	35
23 May	30	15	15	50	50
24 May	113	11	102	10	90
25 May	245	172	73	70	30
26 May	1,223	306	917	25	75
27 May	1,020	714	306	70	30
28 May	168	151	17	90	10
29 May	279	223	56	80	20
30 May	41	37	4	90	10
31 May	80	60	20	75	25
1 Jun	1,729	1,643	86	95	5
2 Jun	983	885	98	90	10
3 Jun	442	420	22	95	5
4 Jun	321	305	16	95	5
5 Jun	300	285	15	95	5
6 Jun	164	156	8	95	5
7 Jun	98	98		100	
8 Jun	55	55		100	
9 Jun	32	29	3	90	10
10 Jun	12	12		100	
11 Jun	7	7		100	
12 Jun	10	10		100	
Total	***8,235***	***6,311***	***1,924***	***76.6***	***23.4***

Table 5

Volume of flow (cfs) discharged over the spillway at Holtwood prior to installation of flash boards. Discharge volumes were calculated for the entire range of forebay elevation that coincided with spillway lift operation during the period 27 April to 25 May, 1998.

Head (ft)	Discharge (cfs) Over 2,028 ft of Spillway	Discharge (cfs) Over 300 ft Rubber Dam	Total Spillway Discharge
0.5	2,388	-	2,388
1.0	6,753	-	6,753
1.2[1]	8,877	-	8,877
1.5	12,406	-	12,406
2.0	19,101	-	19,101
2.5	26,695	-	26,695
3.0	35,091	-	35,091
3.5	44,220	-	44,220
4.0	54,026	-	54,026
4.5	64,466	-	64,466
4.75[2]	69,912	-	69,912
5.0	75,503	125	75,628
5.5	87,108	648	87,756
5.6[3]	89,104	783	90,277
6.0	99,252	1,396	100,648

1 Minimum head during 1998 operation.

2 Height of 4 ft rubber dam.

3 Maximum head during 1998 operation.

hfinal98.xls/Tb 5 - 1/14/99

Table 6

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 1998 Holtwood fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
20 May	20	1500 - 1559	35	35	0
22 May	24	1400 - 1459	40	40	0
25 May	20	1500 - 1559	67	65	-2 (3.9%)
29 May	24	1100 - 1159	128	126	-2 (1.6%)
1 Jun	26	1100 - 1159	400	394	-6 (1.5%)
2 Jun	22	1100 - 1159	270	266	-4 (1.5%)
3 Jun	24	1000 - 1059	110	109	-1 (0.9%)
4 Jun	24	1200 - 1259	70	70	0
5 Jun	18	1000 - 1059	100	101	+1

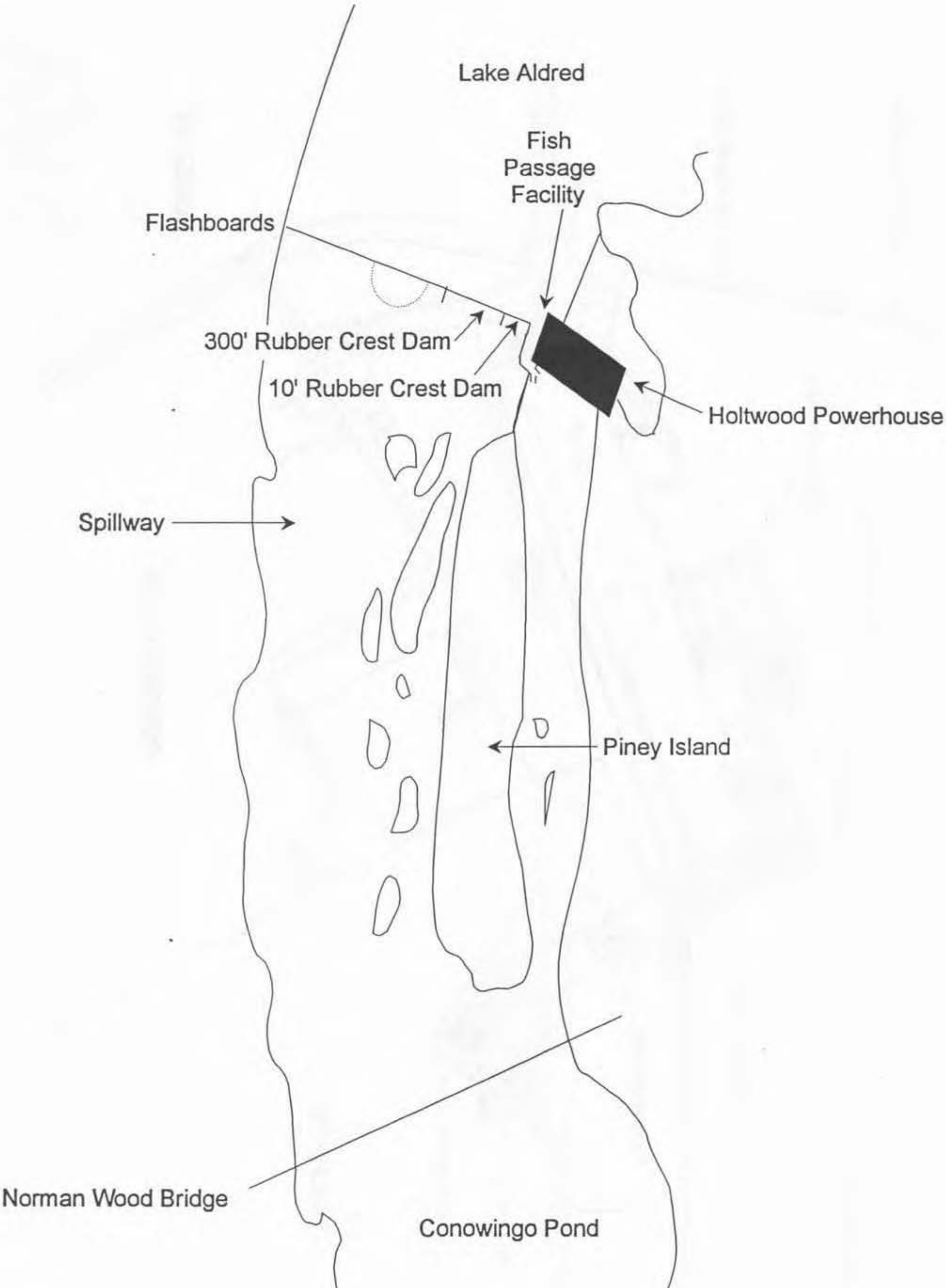


Figure 1

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

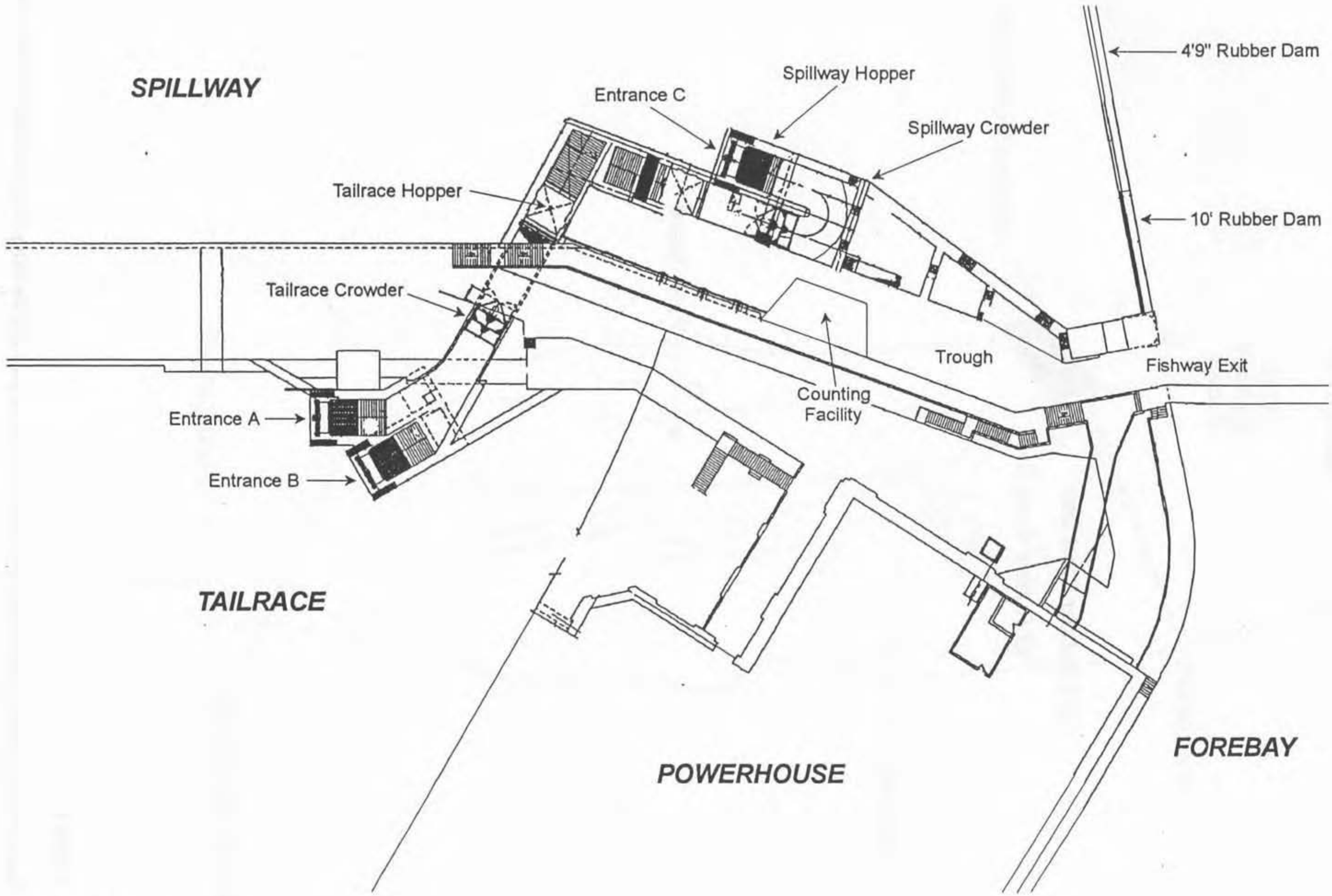


Figure 2

General layout of the Holtwood fish passage facility.

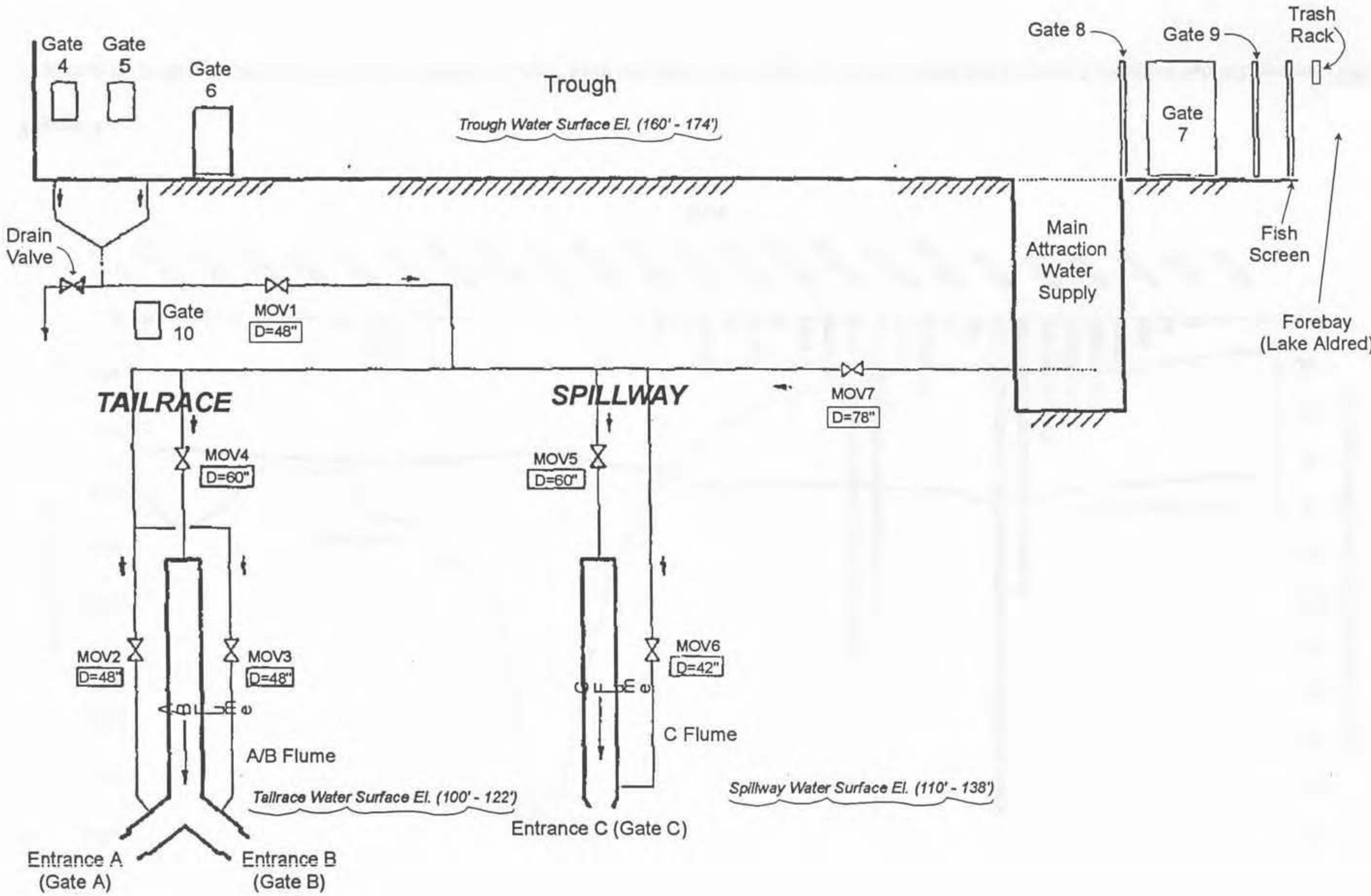


Figure 3

Simplified schematic of the Holtwood fish passage facility's fish attraction water system.

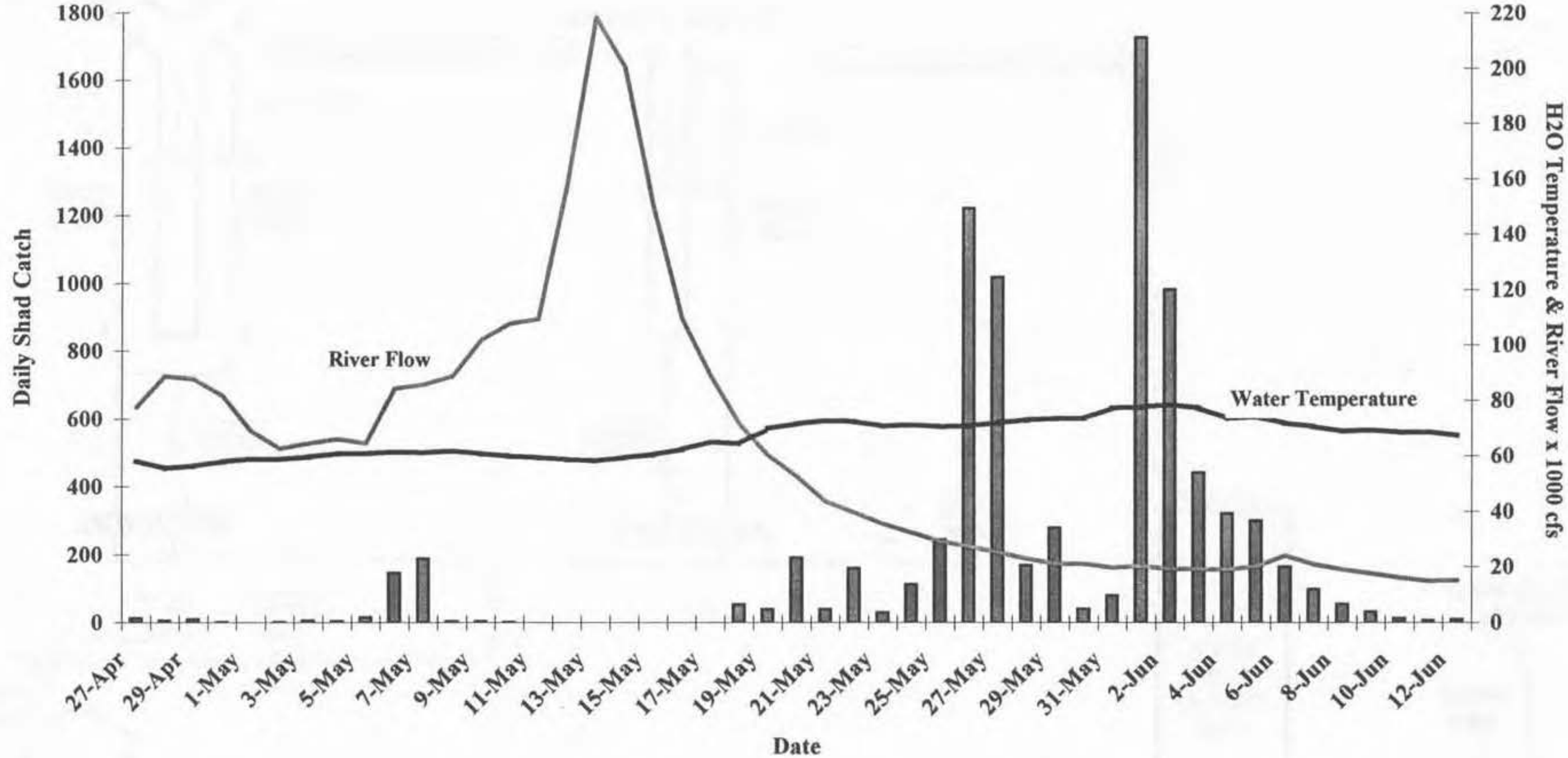


Figure 4

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 1998.

hfinal98.xls/Fg 4 - 2/1/99

Job I - Part 4
SUMMARY OF OPERATION AT THE SAFE HARBOR FISH PASSAGE FACILITY IN 1998

Normandeau Associates, Inc.
1921 River Road
Drumore, Pennsylvania 17518

1.0 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 23 March 1998, prior to the start of fishway operation, a meeting of the Safe Harbor Fish Passage Technical Advisory Committee (SHFPTAC) comprised of SHWPC, 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 1998 spring migration season. Objectives of 1998 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

2.0 SAFE HARBOR OPERATIONS

2.1 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.

2.2 Fishway Design and Operation

2.2.1 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. Fishway physical design parameters 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.

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; and (3) entrance A, B, and C individually. Based on experience from 1997 new software was developed which enabled automatic operation of entrance combination A and C. The majority of operation in 1998 utilized a combination of entrance A and C. Other combinations utilized included entrances A, B, and C and entrances B and C.

2.2.2 Fishway Operation

Preparation for the 1998 season began shortly after the end of the first year of operation. Based on experience gained in 1997 numerous improvements to enhance fishway operation were planned, developed, and installed. Improvements completed prior to the start of the 1998 season included: the repair of gate G, installation of a new 78" MOV-1; including vent and orifice, replacement of digital readouts for all motor operated valves and gates, installation of a closed circuit TV system for remote fishway operation, re-alignment of the 36" pipe downstream of MOV-2 to reduce vibration, replacement of pump room and hopper drive manual hoists with electric, and the development and installation of new software for the Programmable Logic Controller (PLC). In addition, improvements to the fish viewing area were undertaken and included: additional lighting, gate constrictions, and installation of a public viewing area building.

Although fishway operation was not scheduled to commence until 500 American shad were passed via the Holtwood fishway (20 May), operation began on 8 May and continued for three days (8, 9, and 11 May) before high river flow stopped operation. Operation resumed on 18 May at a river flow of 73,000 cfs. Excluding the cancellation of operation after the first lift on 20 May, caused by a hopper failure, the fishway operated daily through 12 June, when operation was terminated 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 and addressed mechanical and/or electrical problems as needed. Excluding problems encountered on 20 May with the hopper braking system and capacitors (an integral component of this system), the fishway was operational 100% of the time in 1998. A routine maintenance program that included periodic cleaning of the exit channel, daily inspections, cleaning of picket screens, and other routine maintenance activities contributed to this excellent operating performance.

Operation of the fishway's two main systems, the attraction water and fish handling systems, are controlled by a PLC. The fishway was successfully operated remotely from the hydro station control room late in the season. The attraction water system (two motor operated valves, three entrance gates, and three attraction water gates) can be operated in automatic, manual, or remote mode. The fish handling system, including the hopper, crowder, separation screen, and a telescoping trough gate, which is normally maintained 1 ft above forebay elevation to facilitate sluicing of fish into the trough, can be operated in the automatic or manual mode. The fish handling system mode of operation is based on equipment availability and fish abundance. Normally, both the attraction water system and the fish handling system were operated in the automatic mode during the season if the system's equipment was available.

Hydraulics in the lift were generally a function of forebay and tailwater elevation, position of valves, attraction pool elevation, position of attraction water gates, and depth of entrance gates. A schematic diagram of the Safe Harbor fishway attraction water system is provided in Figure 2. Two motor operated valves control the distribution, and volume of water in the fishway. Flow control in and from the fishway is accomplished by adjusting the position of the valves, three attraction water gates, and three entrance gates. Valves 1 and 2 control the total volume of water in the fishway's main attraction water pool. This year the elevation in the main attraction pool was increased to an elevation of 180 ft. Valve 2 controls the velocity of water in the trough. Control of hydraulics in the crowder channel is based on the operation/position of attraction water gate F. Gate E controls flow of water from the main attraction water pool into attraction pool 1, floor diffuser 1, and flow from entrance gate A. Gate D controlled flow of water from the main attraction water pool into attraction pool 2, floor diffuser 2, and flow to entrance gates B and C. Velocity from each entrance is controlled by the position of the entrance gates A, B, and C.

Completion of repairs to the attraction water conveyance system and new software improved control of and the hydraulics in and from the fishway. Volume of flow utilized in the fishway varied from 450 to 600 cfs and was adjusted as needed based on fish movement and total discharge from the power station.

Water velocity in the fishway is a function of the total volume of water utilized, project hydraulics (*i.e.*, tailwater and forebay elevation), valve, and gate position. Generally, velocities in the trough, crowder channel, and at the entrance were maintained at approximately 1.0, 1.0, and 6.0 ft/sec, respectively. Based on visual observations of fish movements, operating experience, and equipment availability, velocities were manipulated, as needed, throughout the spring to facilitate the collection and passage of clupeids. The velocities noted above appeared to be very effective in capturing and passing target species.

Fishing time and/or lift frequency was determined by fish abundance and/or fish handling system equipment availability. Normally, when all the equipment was available, the fish handling system was cycled in the automatic mode, otherwise the lift was operated manually. Prior to conducting a lift in the automatic mode, the equipment had to be set in the "fish position". Equipment was considered in the fish position when: (1) the crowder was parked and the doors were set in the trap position; (2) both the separation screen and the hopper were fully lowered; and (3) the trough gate was positioned 1 ft above forebay elevation. Once the equipment was positioned, operating personnel entered the desired fishing time into the PLC. When the fishing time ended, the equipment cycled. This included raising the separation screen, closing the crowder doors, crowding fish over the hopper, raising the hopper, and sluicing fish into the trough. Manual operation occurred when difficulties with crowder operation were encountered. Generally, manual cycling of the fish handling system included raising and lowering the separation screen, raising the hopper, and sluicing fish into the trough. Normally, the lift was cycled at least every half-hour in the automatic mode.

2.3 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.

In addition to the 1,500 watt halogen lamp that was mounted above the viewing window in 1997, several improvements were completed prior to the 1998 season to improve fish counts and the video record of fish passage. Improvements included installation of three adjustable 500 watt underwater pool lights. A light was installed mid-depth on either side of the viewing window and one was installed at the bottom of the viewing area in the middle of 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 video tape. In addition, an adjustable screen capable of reducing the channel width from 36 in down to 18 in at the counting window area was installed. Screen design enables this gate to be set at several intermediate positions between 18 in and 36 in; the adjustable screen was set at 18 in for most of the season.

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 hard copy 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 camera was mounted on the wall approximately 6 ft off the floor and 1.5 ft from the back wall of the counting room. The camera was aimed at the center of the fish viewing window. Fish passage was recorded in 12 hour time-lapse mode, on video tape with a setting that yields 3.3 video records per second. During recording, the recorder imprinted the time and date on each frame of video tape, providing a record of the time for all fish passed.

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 technician who counted the number of shad passing the window during the selected time period.

3.0 RESULTS

3.1 Relative Abundance

The relative abundance of fishes collected and passed by the Safe Harbor fishway is presented in Table 1. A total of 135,604 fish of 31 taxa passed upstream into Lake Clarke. Gizzard shad (102,702) was the dominant species passed and comprised over 75% of the catch. Some 6,054 American shad were collected and passed upstream through the fishway. Other predominant fishes passed included walleye (11,198), smallmouth bass (5,674), quillback (4,088), and channel catfish (1,860). Peak passage occurred on 21 May when 16,701 fish were passed.

3.2 American Shad Passage

The Safe Harbor fishway captured and passed 6,054 American shad in 1998 during 28 days of operation (Table 1). In the first four days of operation 110 shad were passed prior to a high flow event (river flow equaled 214,000 cfs) that cancelled operation. When operation resumed on 18 May collection and passage of shad varied daily with over 90% (5,507) of the shad captured and passed between 26 May and 8 June. During this period almost 60 % of the shad were passed in six days (1 to 6 June). Peak shad passage occurred on 2 June when 1,200 shad were captured and passed in approximately 12 hours of operation. Over 61% of the shad passage occurred in June.

American shad were collected and passed at water temperatures of 59.0°F to 78.8°F and river flows of 13,900 to 100,000 cfs (Table 2 and Figure 3). Water temperature and river flow from 26 May to 8 June, the period when most shad passage occurred, averaged 73.2°F (67.4°F to 78.8°F) and 21,864 cfs (18,800 cfs to 27,000 cfs), respectively.

The hourly passage of American shad in the Safe Harbor fishway is given in Table 3. Shad passage varied daily with most shad (4,952) passed between 0900 and 1659 hrs. Peak hourly passage (840) occurred between 1100 and 1159 hrs. Although no obvious trend was evident the catch declined after 1700 hrs.

3.3 Other Alosids

Passage of other alosids was limited to 16 blueback herring and 4 river herring (Table 1). No alewife or hickory shad were observed. Although numbers passed were small, the Safe Harbor fishway passed over 32% of the other alosids (62) that passed into Lake Aldred via the Holtwood fishway.

3.4 Video Record

Installation of underwater lights and adjustable screen installed prior to the season improved counting conditions and the video record of fish passage. A limited review of the video record showed that fish passage was usually adequately captured on the tape record. Data in Table 4 list by date and time, visually and taped derived counts of shad, and the difference between the two counts. Differences between the counts were negligible 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 reflect shad passage.

4.0 SUMMARY

The 1998 Safe Harbor fishway operating season was successful. Excluding cancellation of fishway operation caused by high river flow, just one day of fishway operation was lost due to mechanical problems. Modifications undertaken and completed this season improved the overall performance of the fishway.

Observations indicated that fish reaching the fishway were effectively captured and passed upstream. In 28 days, 6,054 American shad were passed into Lake Clarke, or over 73.5% of the American shad that were passed into Lake Aldred by the Holtwood fishway. Few other alosids (16 blueback herring, 4 river herring) 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.

The impact of high river flow and rapidly rising water temperatures on the upstream movement of shad in the river and through Lake Aldred is unknown, although these factors play a role in the reduced catch in 1998. The limited catch of shad early in the season at Conowingo and Holtwood Dams delayed the start of fishway operation until 8 May. In addition, just four days after operation began a high flow event resulted in the cancellation of fishway operation for six days. The majority of shad were captured and passed between 26 May and 8 June.

At the present level of American shad passage, based on the tape review, there is no reason to continue the expenditure of resources to verify visual counts of shad passage. Not only was the accuracy of visual counts high, these counts enabled nightly and weekly distribution of passage numbers in a timely fashion to all cooperators, where as, tape derived counts would occur months later and are very labor intensive. To review just one hour of 1998 taped passage up to seven hours was required to review and determine the number of shad passed, which depended on various factors including the number and type of fish passed and tape quality. In addition, if tape quality was poor, as occurred on some days in 1998, determination of shad passage numbers would not be possible. However, the video record of fish passage should be continued. It provides a backup, and the means to verify the accuracy of visual counts as the shad population grows and hourly passage of shad increases. In the future, when hourly passage of shad exceeds 1,000 fish per hour, a limited review of the passage record should be conducted to determine the accuracy of visual counts. Also, continued taping of fish passage could provide fishway operators flexibility to respond to other aspects of fishway operation for limited periods of time.

Although the shad catch was less than half the 1997 catch, modifications to the fishway coupled with this year's operating experience will be utilized as a basis of future operation.

5.0 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.

6.0 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.

Table 1

Number and disposition of fish passed by the Safe Harbor fish passage facility in 1998.

Date:	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Hours Of Operation:	*7.2*	*7.5*		*7.1*				
Start Time:	*11:20*	*11:30*		*11:37*				
End Time:	*18:30*	*18:30*		*18:31*				
Numbers Of Lifts:	*22*	*19*		*14*				
Water Temperature (F):	*60.0*	*60.0*		*59.0*				
American Shad	78	23		9				
Gizzard Shad	6,740	3,337		2,115				
Blueback Herring								
River Herring								
Striped Bass								
Brown Trout	2							
Rainbow Trout								
Northern Pike								
Muskellunge								
Esox Sp.								
Carp								
Goldfish								
Quillback	4	2		3				
White Sucker	5			1				
Shorthead Redhorse	46	33		31				
White Catfish								
Channel Catfish	115	49		113				
White Perch								
Rock Bass	14	1		10				
Redbreast Sunfish								
Green Sunfish								
Pumpkinseed								
Bluegill	2	1						
Smallmouth Bass	291	74		53				
Largemouth Bass								
White Crappie		1						
Black Crappie								
Yellow Perch								
Walleye	260	185		278				
Atlantic Needlefish								
Hybrid Striped Bass				1				
Total	**7,557**	**3,706**	*	**2,614**	**	**	**	**

Table 1

Continued.

Date:	16 May	17 May	18 May	19 May	20 May	21 May	22 May	23 May
Hours Of Operation:			7.2	7.7		5.5	7.7	7.2
Start Time:			10:50	10:18		12:30	10:45	10:07
End Time:			18:00	18:00		18:00	18:25	17:00
Numbers Of Lifts:			17	22		18	21	21
Water Temperature (F):			67.0	69.0		73.0	71.6	71.5
American Shad			8	14		25	21	68
Gizzard Shad			6,630	6,200		14,855	10,430	10,900
Blueback Herring								
River Herring								
Striped Bass								
Brown Trout			1	1			2	
Rainbow Trout			1			1	1	
Northern Pike			2					
Muskellunge				1				
Esox Sp.								
Carp			37	10		41	346	200
Goldfish				1				
Quillback			1,570	325			40	526
White Sucker			3				2	
Shorthead Redhorse			380	440		4	62	53
White Catfish							1	
Channel Catfish			268	250		39	125	78
White Perch								
Rock Bass			44	85		98	65	28
Redbreast Sunfish			6			8	25	6
Green Sunfish						12	1	
Pumpkinseed			1	3		7	4	
Bluegill			6	26		7	27	39
Smallmouth Bass			1,081	855		962	520	490
Largemouth Bass			9	3		4	33	7
White Crappie							2	5
Black Crappie				3		11	3	
Yellow Perch			1	2		8	8	8
Walleye			1,939	635		619	624	620
Atlantic Needlefish								
Hybrid Striped Bass								
Total	**	**	**11,987**	**8,854**	*	**16,701**	**12,342**	**13,028**

Table 1

Continued.

Date:	24 May	25 May	26 May	27 May	28 May	29 May	30 May	31 May
Hours Of Operation:	6.2	6.7	8.3	7.2	8.3	9.2	9.3	9.1
Start Time:	10:00	10:31	10:35	11:37	9:55	8:30	8:20	9:30
End Time:	16:08	17:21	18:55	18:50	18:30	18:40	18:40	18:40
Numbers Of Lifts:	16	14	18	22	21	20	30	18
Water Temperature (F):	71.0	71.0	70.0	71.0	72.0	73.0	73.5	73.0
American Shad	73	44	125	721	524	268	232	68
Gizzard Shad	4,250	1,186	2,945	5,390	4,620	2,140	2,260	3,660
Blueback Herring	1			1	1	4		
River Herring								
Striped Bass			1	1			1	
Brown Trout			1					1
Rainbow Trout				1	1	1		
Northern Pike								
Muskellunge								
Esox Sp.			1					
Carp	132	75	207	74	14	4	51	2
Goldfish								
Quillback	862	307	150	8	12	10	83	30
White Sucker								
Shorthead Redhorse	11	33	27	2	9	5	22	17
White Catfish								
Channel Catfish	11	19	43	22	23	17	31	14
White Perch					1			
Rock Bass	11	7	6	12	17	18	13	5
Redbreast Sunfish	9	8	16	16	15	22	10	3
Green Sunfish	7	4		2	4	12	5	
Pumpkinseed	2	2		3	2	4	4	
Bluegill	11	9	57	9	17	16	11	12
Smallmouth Bass	181	120	185	68	169	93	127	57
Largemouth Bass	5	3	10	3	5	4	7	3
White Crappie			3	1	1	4	5	
Black Crappie	2	2			3			
Yellow Perch	8		1	1	4	6	153	1
Walleye	572	509	288	238	576	450	365	384
Atlantic Needlefish								1
Hybrid Striped Bass								
Total	**6,148**	**2,328**	**4,066**	**6,573**	**6,018**	**3,078**	**3,380**	**4,258**

SHByp98.fnLxls/Tb 1 - 1/25/99

Table 1

Continued.

Date:	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*
Hours Of Operation:	*11.1*	*9.9*	*9.8*	*10.1*	*10.5*	*10.7*	*11.0*	*9.2*
Start Time:	*9:21*	*9:30*	*8:15*	*8:45*	*8:30*	*9:00*	*8:30*	*8:10*
End Time:	*20:25*	*19:25*	*18:00*	*18:50*	*19:00*	*19:43*	*19:30*	*18:00*
Numbers Of Lifts:	*21*	*22*	*19*	*21*	*21*	*16*	*20*	*20*
Water Temperature (F):	*78.8*	*77.0*	*77.4*	*73.6*	*72.7*	*73.0*	*73.0*	*67.4*
American Shad	343	1,200	630	379	343	349	193	132
Gizzard Shad	1,802	1,825	794	752	729	580	577	415
Blueback Herring				1	4		2	
River herring		2						1
Striped Bass			2	1	1	1		1
Brown Trout	1							
Rainbow Trout	1							
Northern Pike								
Muskellunge				1				
Esox Sp.								
Carp	6	36	8	36	16	10		5
Goldfish								
Quillback	76	1	49	3		8	5	7
White Sucker								
Shorthead Redhorse	6	12	3		5			
White Catfish								
Channel Catfish	111	280	31	30	14	19	2	9
White Perch					1			
Rock Bass	7	9	1	2		3	1	
Redbreast Sunfish	5	7	4	4	2	1	7	1
Green Sunfish	1		2	1				
Pumpkinseed	1						1	
Bluegill	8	17	1	11	3	2	1	3
Smallmouth Bass	57	115	49	70	20	13	5	5
Largemouth Bass	5	2	2	2	1		1	
White Crappie					1	1		2
Black Crappie	2		1	2	1		3	1
Yellow Perch		1	1		1	1		
Walleye	452	250	136	162	111	175	146	115
Atlantic Needlefish								
Hybrid Striped Bass								
Total	**2,884**	**3,757**	**1,714**	**1,457**	**1,253**	**1,163**	**944**	**697**

Table 1

Continued.

Date:	9 Jun	10 Jun	11 Jun	12 Jun	TOTAL
Hours Of Operation:	*10.2*	*7.6*	*11.0*	*10.0*	**242.5**
Start Time:	*8:50*	*10:40*	*7:30*	*8:30*	
End Time:	*19:00*	*18:15*	*18:30*	*18:30*	
Numbers Of Lifts:	*19*	*15*	*13*	*21*	**541**
Water Temperature (F):	*67.7*	*68.8*	*67.0*	*67.5*	
American Shad	89	53	21	21	**6,054**
Gizzard Shad	450	940	2,370	3,810	**102,702**
Blueback Herring				2	**16**
River Herring		1			**4**
Striped Bass	1	2			**12**
Brown Trout				1	**10**
Rainbow Trout					**7**
Northern Pike					**2**
Muskellunge					**2**
Esox Sp.					**1**
Carp	5	1	3	1	**1,320**
Goldfish					**1**
Quillback	1	2	2	2	**4,088**
White Sucker					**11**
Shorthead Redhorse			2	3	**1,206**
White Catfish					**1**
Channel Catfish	11	3	3	130	**1,860**
White Perch					**2**
Rock Bass	2		2	3	**464**
Redbreast Sunfish	4	1	1	2	**183**
Green Sunfish					**51**
Pumpkinseed					**34**
Bluegill	3	1	1	1	**302**
Smallmouth Bass	5	5	4		**5,674**
Largemouth Bass	3			9	**121**
White Crappie	3	2	1	4	**36**
Black Crappie		1			**35**
Yellow Perch					**205**
Walleye	170	206	228	505	**11,198**
Atlantic Needlefish					**1**
Hybrid Striped Bass					**1**
Total	**747**	**1,218**	**2,638**	**4,494**	**135,604**

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 1998.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
8 May	85,000	60.0	6	11	2 to 12	A & C	500	174.8-175.4	226.6-226.4
9 May	98,000	60.0	8	11	2 to 12	A & C	500	175.8-175.8	226.1-226.1
10 May	104,600	59.0							
11 May	100,000	59.0	20	11	2 to 12	A & C	500	176.0-176.2	226.9-227.0
12 May	152,000	59.0							
13 May	214,000	58.0							
14 May	197,200	59.0							
15 May	147,800	60.0							
16 May	107,500	62.0							
17 May	87,400	64.0							
18 May	73,000	67.0	20	12	1 to 12	A & C	500	175.0-174.5	226.4-224.9
19 May	64,000	69.0	16	10	3 to 12	A & C	500	173.4-172.4	226.1-224.1
20 May	50,300	70.0							
21 May	40,000	73.0	8	10	3 to 12	A & C	600	171.0-172.3	226.9-225.5
22 May	40,000	71.6	12	8	3 to 9,11	A & C,AB C	600	173.8-171.8	225.6-225.2
23 May	38,000	71.5	16	8	3 to 9,11	A & C	600	171.5-171.1	226.8-225.6
24 May	33,000	71.0	20	7	3 to 9	A & C	600	171.6-170.8	226.8-226.3
25 May	29,000	71.0	24	7	3 to 9	A & C	600	171.8-170.9	226.8-225.6
26 May	27,000	70.0	20	4	4,5,6,9	A & C	600	169.6-170.2	227.0-226.6
27 May	24,300	71.0	20	4	8,9,10,11	A & C	600	169.3-173.4	227.2-225.3
28 May	23,000	72.0	28	6	2,3,4,5,6,11,12	A & C	600	171.0-171.4	226.6-225.4
29 May	22,000	73.0	28	4	1,2,3,4,5,11,12	A & C	600	169.6-171.3	226.8-225.6
30 May	22,000	73.5	28	6	3,4,5,8,9,10,11	A & C	600	170.2-171.1	226.8-225.5
31 May	20,000	73.0	24	5	3,4,5,8,9,10	A & C	600	169.2170.5	227.0-225.6
1 Jun	22,000	78.8	20	5	2 to 5,11	A & C	600	169.8-170.2	226.9-225.2
2 Jun	20,000	77.0	20	5	2 to 5,9	A & C	600	169.9-170.8	226.8-225.1
3 Jun	20,000	77.4	20	6	2 to 5,8,9,10	A & C	600	171.0-170.4	227.0-225.3
4 Jun	18,800	73.6	20	6	2 to 5,7,9	A & C	600	169.3-170.3	227.1-225.6
5 Jun	20,000	72.7	20	6	2,4,5,7,9,10	A & C	600	169.7-170.6	227.2-225.8
6 Jun	24,000	73.0	12	6	3,4,5,6,7,9	B &C,A&C	600	170.1-170.3	226.9-225.3
7 Jun	23,000	73.0	12	6	4,5,7,8,9,10	A & C	600	170.3-171.3	226.9-225.5
8 Jun	20,000	67.4	12	6	1,5,7,8,9,10	A & C	600	170.1-169.9	226.9-225.3
9 Jun	18,100	67.7	14	6	1,3,5,7,8,9	B &C,A&C	600	169.1-169.7	226.2-224.9
10 Jun	15,000	68.8	16	4	3,4,7,9	A & C	450	169.7-169.2	226.8-169.2
11 Jun	16,000	67.0	20	3	2,7,9	A & C	450	168.9-168.9	226.9-225.8
12 Jun	13,900	67.5	16	5	3,4,5,7,9	A & C	450	169.2-169.4	227.0-225.3

SHByp98.fnl.xls/Tb 2 - 1/25/99

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 1998.

Date:	8 May	9 May	10 May	11 May	12 May	13 May	14 May	15 May	16 May	17 May
Observation Time (Start):	*11:35*	*11:10*		*11:30*						
Observation Time (End):	*18:40*	*18:40*		*18:35*						
MILITARY TIME (HRS)										
0800 to 0859										
0900 to 0959										
1000 to 1059										
1100 to 1159	-	5		-						
1200 to 1259	6	7		4						
1300 to 1359	16	2		-						
1400 to 1459	4	6		1						
1500 to 1559	13	2		2						
1600 to 1659	17	1		1						
1700 to 1759	18	-		-						
1800 to 1859	4	-		1						
1900 to 1959										
2000 to 2059										
TOTAL CATCH	**78**	**23**	**0**	**9**	**0**	**0**	**0**	**0**	**0**	**0**

SHByp98.fnl.xls/Tb 3 - 1/25/99

Table 3

Continued.

Date:	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Observation Time (Start):	*10:28*	*10:00*		*13:50*	*10:45*	*10:19*	*10:10*	*10:40*	*10:04*	*11:37*
Observation Time (End):	*18:20*	*18:14*		*18:03*	*18:30*	*17:07*	*16:15*	*17:20*	*19:03*	*18:50*
MILITARY TIME (HRS)										
0800 to 0859										
0900 to 0959										
1000 to 1059	-	-			2	5	15	1	-	
1100 to 1159	-	1			3	14	30	4	17	10
1200 to 1259	3	6			7	4	15	13	37	140
1300 to 1359	-	3		-	-	10	8	14	25	160
1400 to 1459	-	2		-	1	15	2	4	15	75
1500 to 1559	2	-		17	1	8	3	7	20	115
1600 to 1659	1	2		7	4	12		1	8	99
1700 to 1759	1			1	-				2	64
1800 to 1859	1				3				1	58
1900 to 1959										
2000 to 2059										
TOTAL	**8**	**14**	**0**	**25**	**21**	**68**	**73**	**44**	**125**	**721**

Table 3

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*
Observation Time (Start):	*9:55*	*9:30*	*8:30*	*10:10*	*10:00*	*8:57*	*8:17*	*9:06*	*8:30*	*8:45*
Observation Time (End):	*18:38*	*18:50*	*18:46*	*18:40*	*20:17*	*19:45*	*17:55*	*18:50*	*19:40*	*19:42*
MILITARY TIME (HRS)										
0800 to 0859			5			-	26		19	5
0900 to 0959	-	31	48			55	142	62	16	30
1000 to 1059	119	51	42	9	15	50	120	52	66	10
1100 to 1159	148	13	30	19	20	150	109	43	53	90
1200 to 1259	74	45	20	10	11	71	76	32	31	-
1300 to 1359	45	20	25	9	8	200	46	58	22	60
1400 to 1459	52	17	25	3	13	204	68	47	28	30
1500 to 1559	15	10	8	3	10	100	13	26	13	30
1600 to 1659	26	35	17	5	17	100	9	26	25	25
1700 to 1759	36	16	4	5	68	25	21	16	16	10
1800 to 1859	9	30	8	5	94	100		17	21	10
1900 to 1959					66	145			33	49
2000 to 2059					21					
TOTAL	**524**	**268**	**232**	**68**	**343**	**1,200**	**630**	**379**	**343**	**349**

Table 3

Continued.

Date:	*7 Jun*	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*TOTAL*
Observation Time (Start):	*8:55*	*8:49*	*9:00*	*9:57*	*9:10*	*9:25*	
Observation Time (End):	*19:30*	*18:03*	*19:00*	*18:33*	*18:53*	*18:42*	
MILITARY TIME (HRS)							
0800 to 0859	2	-					**57**
0900 to 0959	20	30	-	-	6	2	**442**
1000 to 1059	55	30	3	5	-	2	**652**
1100 to 1159	46	10	10	10	4	1	**840**
1200 to 1259	16	15	17	15	-	2	**677**
1300 to 1359	7	15	20	5	5	3	**786**
1400 to 1459	2	5	15	8	-	2	**644**
1500 to 1559	5	10	10	2	4	1	**450**
1600 to 1659	3	5	4	6	1	4	**461**
1700 to 1759	16	10	2	1	-	1	**333**
1800 to 1859	13	2	8	1	1	3	**390**
1900 to 1959	8						**301**
2000 to 2059							**21**
TOTAL	**193**	**132**	**89**	**53**	**21**	**21**	**6,054**

SHByp98.fnl.xls/Tb 3 - 1/25/99

Table 4

Comparison of American shad passage visual counts versus video based counts, during several discrete time periods of the 1998 Safe Harbor fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
28 May	28	1000 - 1059	119	117	-2 (1.7%)
28 May	28	1100 - 1159	148	151	0
29 May	28	1000 - 1059	51	51	0
1 Jun	20	1700 - 1759	68	69	1 (1.5%)
2 Jun	20	1100 - 1159	150	147	-3 (2.0%)
2 Jun	20	1200 - 1259	71	71	0
2 Jun	20	1300 - 1359	200	197	-3 (1.5%)
2 Jun	20	1500 - 1559	100	99	-1 (1.0%)
2 Jun	20	1600 - 1659	100	102	2 (2.0%)
4 Jun	20	1000 - 1059	62	62	0
4 Jun	20	1100 - 1159	52	52	0

SHByp98.fnl.xls/Tb 4 - 1/25/99

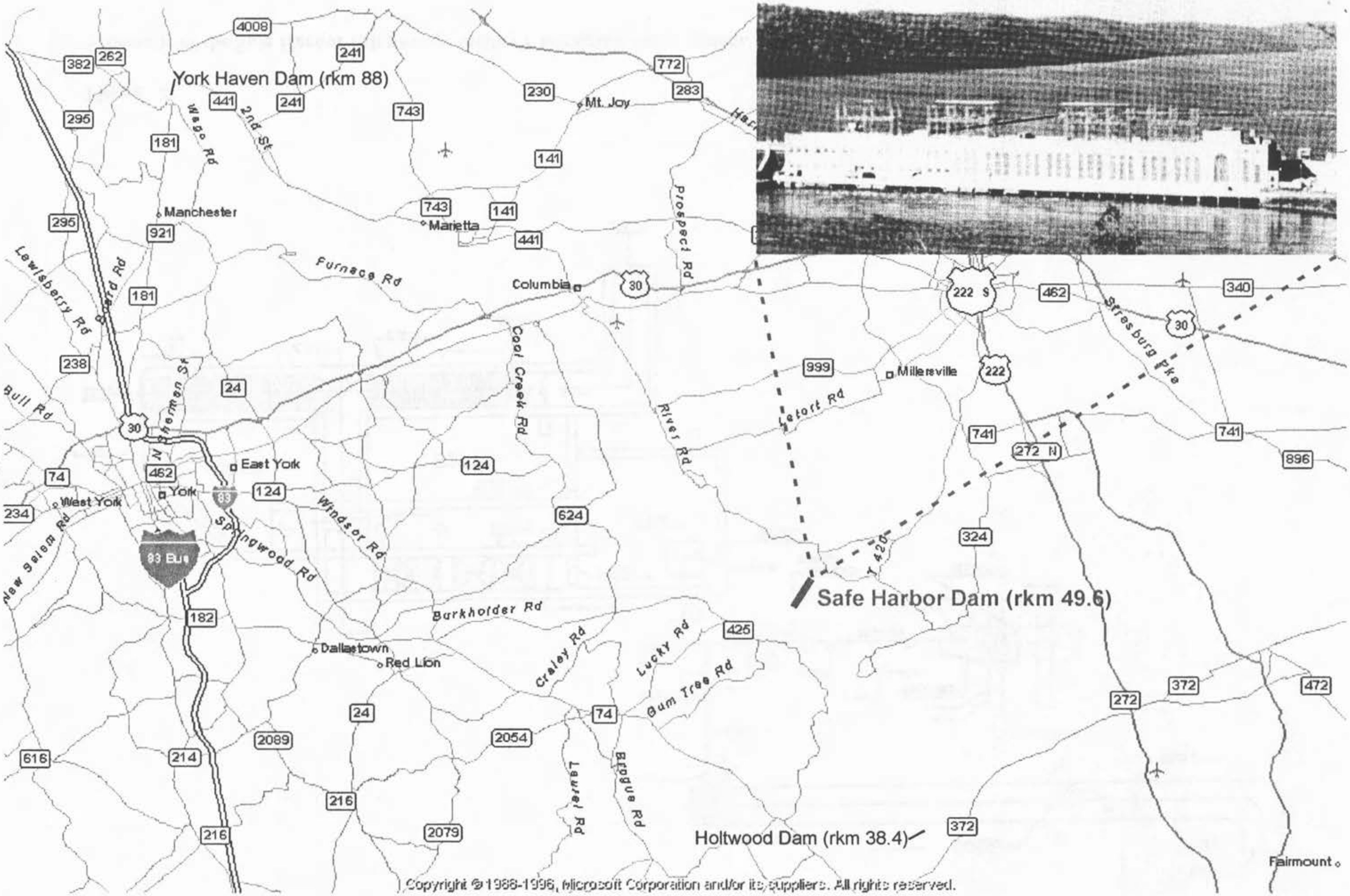


Figure 1

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

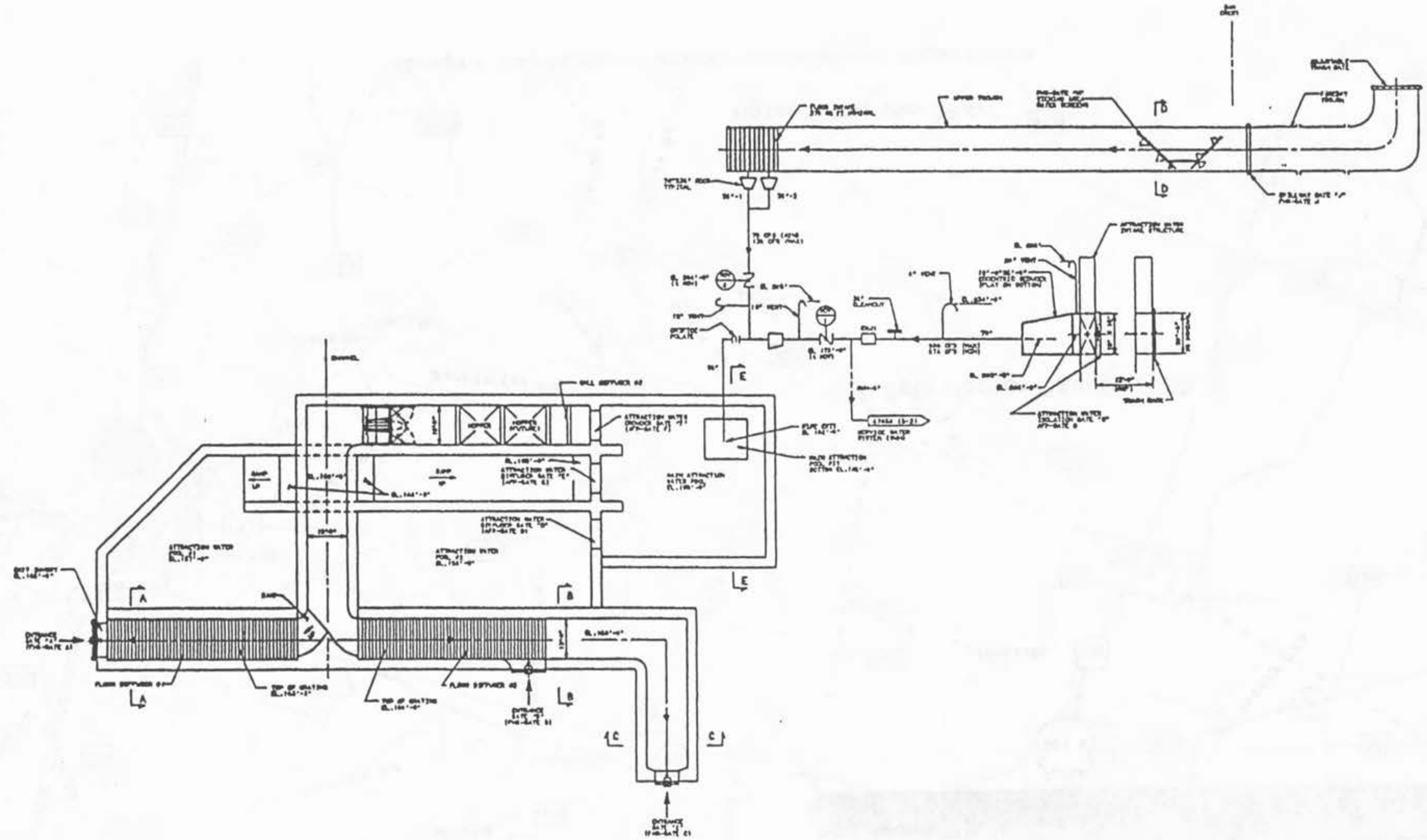


Figure 2

Schematic of the Safe Harbor fish passage facility's attraction water system.

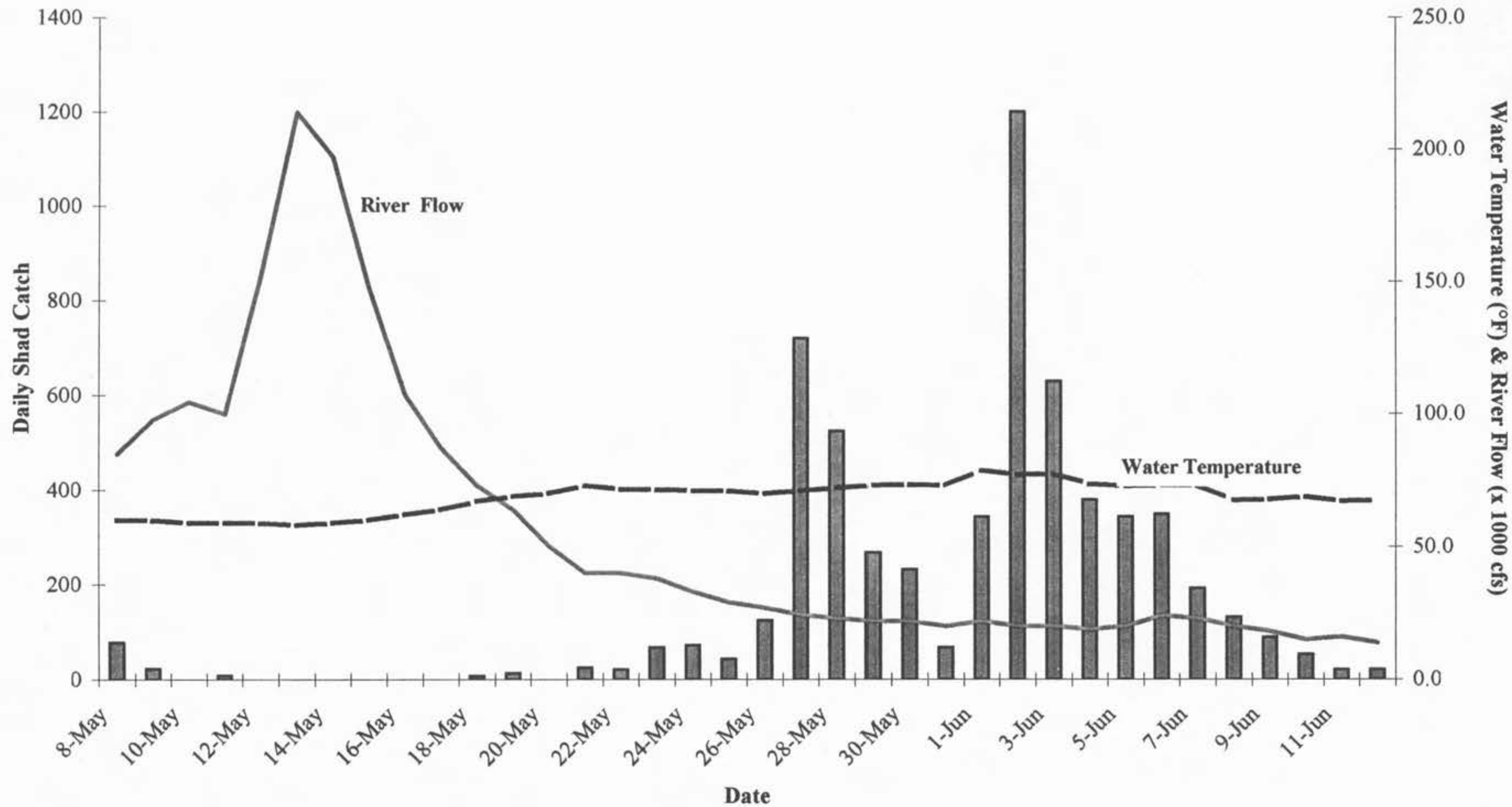


Figure 3

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Safe Harbor fish passage facility, spring 1998.

JOB II - Part 1

AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER IN 1997

The Wyatt Group, Inc.
1853 William Penn Way
P.O. Box 4423
Lancaster, PA 17604

INTRODUCTION

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

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. was contracted to capture ripe adult shad on the spawning grounds during spawning activity, artificially fertilize the eggs, and deliver them to the hatchery. The objective in 1998 was to deliver up to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Since 1980 more than 485 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 the 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 1 April. After this date, contact was made once a week until 15 April and then every two days until conditions showed that it was time to start the project. Persons contacted included: (a) Everett Nack, commercial fisherman, Clavarack, NY, (b) Tom Lake, commercial fisherman, Wappinger Falls, NY, and (c) Andy Kahnle and Kathy Hattala, New York Department of Environmental Conservation (NYDEC), New Paltz, NY.

Mssrs. Nack and Lake began gill netting for shad in the first week of April. They were initially contacted to obtain water temperature data. As the shad fishing season progressed, they were asked about the size of catches and spawning condition 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 Mssrs. Lake or Nack. Information obtained by The Wyatt Group was conveyed to the PFBC Project Officer to establish a start date for the project.

The project commenced when water temperature and local conditions on the Hudson River showed that ripe shad were available for capture. This occurred in the 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 water temperature reached 64°F, in the first week of June.

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 field work 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 1,000 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. Some 1,800 to 2,400 feet of net was set by each crew. Gill nets were mainly anchored at a site and tended regularly after being set, or occasionally drifted and tended after an approximately 30-45 minute drift.

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

During collection efforts in 1988-1995, The Wyatt Group fished for ripe adult American shad between Kingston (RM 95) and the Troy Dam at Albany, NY (RM 151). Within this reach ripe shad were concentrated and could be consistently captured in large numbers between Barrytown (RM 99) and Castleton-on-Hudson (RM 137). Primary collecting sites in 1998 included Cheviot (RM 106) and Coxsackie (RM 123). The haul seine fishery is located at Rogers Island (RM 114).

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

All netting is done in tidal areas. The impact of tidal conditions, although mostly affecting netting efficiency at certain sites, influences the availability of ripe shad. On the Hudson River spawning shad are especially vulnerable to gill netting on the flats and along the shore during the period when the tide changes from ebb to flood. Tide tables were used to decide when gill netting would be most effective at selected sites. At Cheviot and Glasco the depth at the shoreline prevents the setting of gill nets at ebb tide. At Castleton-on-Hudson 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 Rodgers 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 26 April. The second crew started gill netting on 2 May following the collection of more than one million eggs at Coxsackie on 30 April. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on 21 May when water temperature reached 67°F. Sampling occurred on 23 dates during this period including 39 boat-days of gill netting. Haul seining was unsuccessful in producing ripe shad.

A total of 15.6 million eggs was shipped to the Van Dyke Hatchery (Table 2). Hudson River egg collection in 1998 was only exceeded by that in 1991 when 17.6 million eggs were taken. Most eggs (13.4 million or 85.5%) came from the Coxsackie site. Cheviot produced 1.7 million eggs and Castleton 0.45 million. The goal of 60-70% viability was achieved. Egg viability averaged 75.8% (Table 3) and ranged from 51.1 to 86.7% in individual shipments.

Eggs were collected over a period of 23 days from 26 April to 21 May. Examination of daily results (Table 4) 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 first collected eggs on 29 April and Boat 2 collected eggs on its first night of operation, 2 May. The value of two crews operating is not restricted to egg production. Because spawning activity varies over the section of river sampled, the second crew is used to find new locations where eggs can be collected. Boat 2 took about one-third more eggs than Boat 1 because it fished consistently at Coxsackie while Boat 1 attempted to locate other productive sites.

Weather conditions did not hamper egg collection in 1998. Sampling was suspended for only one day (May 6) when thunderstorms forced cancellation of the effort. Water temperature increased gradually contributing in part to consistent collection of eggs.

SUMMARY

A total of 15.6 million American shad eggs was collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 1998. The number of eggs collected this year was exceeded only by that of 1991 when 17.6 million were taken. This success can be attributed in great part to favorable weather and water temperature conditions. Egg viability averaged 76.3%, exceeding the goal of 60-70% established by PFBC. The use of two boat crews provided flexibility needed on the Hudson River for obtaining maximum numbers of eggs available.

TABLE 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson Rivers and delivered to the Van Dyke Hatchery, 1983-1998.

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
Totals	125.16	101.10	226.26

TABLE 2 American shad egg totals by site, Hudson River, New York, 1998.

Site	Number of Shipments	Volume of Eggs (liters)	Number of Eggs Received	Number of Viable Eggs	Percent Viability
Cheviot	3	48.5	1,702,611	1,348,027	79.2
Castleton	1	13.3	447,675	366,366	81.8
Rogers Island	1	3.4	127,148	89,345	70.3
Glasco	0	0.0	0	0	0.0
Coxsackie	17	349.4	13,401,663	9,892,489	73.8
Total	22	414.6	15,679,097	11,696,227	76.3

TABLE 3. Summary of American shad egg collections, Hudson River, New York, 1998.

Site	Date	Water Temp (F)	Eggs Shipped Liters	Eggs Shipped Number	Eggs Shipped Viability(%)	Shad Collected Roe	Shad Collected Males	Shad Collected Ripe
Cheviot	26-Apr	54	-	-	-	2	6	0
Cheviot	4-May	58	24.5	824,664	78.0	75	17	53
Cheviot	5-May	59	17.4	604,707	78.2	37	8	25
Cheviot	6-May	55	-	-	-	15	3	7
Cheviot	12-May	60	-	-	-	12	2	3
Cheviot	13-May	61	-	-	-	24	0	7
Cheviot	16-May	62	6.6	273,240	84.7	14	3	16
Cheviot	17-May	63	-	-	-	9	4	1
Cheviot	18-May	64	-	-	-	17	2	2
Cheviot	20-May	65	-	-	-	12	1	3
Coxsackie	29-Apr	54	11.2	383,406	78.4	37	12	15
Coxsackie	30-Apr	55	24.6	978,243	69.3	48	33	8
Coxsackie	2-May	59	88.7	3,168,362	76.9	290	58	181
Coxsackie	3-May	56	69.3	2,357,701	72.2	208	67	169
Coxsackie	4-May	58	38.7	1,854,724	64.8	146	29	102
Coxsackie	5-May	58	27.5	1,060,650	73.9	103	35	73
Coxsackie	7-May	55	6.4	213,122	72.0	21	7	10
Coxsackie	11-May	60	7.0	240,703	81.4	16	5	12
Coxsackie	12-May	60	3.7	121,891	80.5	18	9	8
Coxsackie	13-May	62	14.8	530,880	83.4	36	16	23
Coxsackie	14-May	60	5.4	358,057	86.7	20	23	13
Coxsackie	16-May	62	9.2	412,170	70.4	22	14	17
Coxsackie	17-May	63	11.6	494,792	77.6	31	17	20
Coxsackie	18-May	63	10.1	470,351	77.5	35	7	20
Coxsackie	19-May	64	12	439,537	80.0	40	14	18

Table 3. Continued

Coxsackie	20-May	66	5.5	187,119	51.0	17	8	11
Coxsackie	21-May	67	3.7	129,955	79.1	10	11	9
Rogers Island	9-May	62	3.4	127,148	70.3	17	4	8
Castleton	9-May	63	13.3	447,675	81.8	32	8	19
Totals			414.6	15,679,097	76.3	1,110	365	721

TABLE 4. Numbers of eggs collected by date and location, Hudson River, New York, 1998.

Date	Castleton RM 137	Coxsackie RM 123	Cheviot RM 106	Rogers Island RM 112	
26-Apr	-	-	-	-	
27-Apr	-	-	-	-	
28-Apr	-	-	-	-	
29-Apr	-	383,406	-	-	
30-Apr	-	978,243	-	-	
1-May	-	LIFT DAY	-	-	
2-May	-	3,168,362	-	-	
3-May	-	2,357,701	-	-	
4-May	-	1,854,724	824,664	-	
5-May	-	1,060,650	604,707	-	
6-May	-	-	-	-	
7-May	-	213,122	-	-	
8-May	-	LIFT DAY	-	-	
9-May	447,675	-	-	127,148	
10-May	-	-	-	-	
11-May	-	240,703	-	-	
12-May	-	121,891	-	-	
13-May	-	530,880	-	-	
14-May	-	358,057	-	-	
15-May	-	LIFT DAY	-	-	
16-May	-	412,170	273,240	-	
17-May	-	494,792	-	-	
18-May	-	470,351	-	-	
19-May	-	439,537	-	-	
20-May	-	187,119	-	-	
21-May	-	129,955	-	-	
Totals	447,675	13,401,663	1,702,611	127,148	15,679,097

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 1998

Ecology III, Inc.
R. R. 1, Box 1795
Berwick, PA 18603

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

Introduction

The goal of this activity in 1998, 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 in the vicinity of 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 to be 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. Up to nineteen, 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 holding 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 lime.

Results and Discussion

Gill netting for shad began on 4 May when the river temperature was 15.2 C. This temperature was more seasonal than last year when it did not exceed 15.0 C until 20 May. All Delaware River shad egg collections in 1998 are shown in Table 1.

A total of 100 shad were caught during the first week from 4 May through 7 May. Most were green females that were not ready to spawn. Only a total of 10.8 liters of eggs were shipped on two of the four nights fished. The river level rose continuously each night causing turbid water conditions and floating debris, which tended to accumulate in the nets. Heavy rains over the weekend caused extremely high river flows that prevented gill netting throughout the second week. It was unfortunate to loose a week of egg collecting during a period that normally would have been a prime time for shad spawning.

On the third week, we resumed netting on 17 May and continued through 21 May. Shad catch increased nightly from 72 to 132 fish and an average of 14.0 liters of eggs was shipped each night. Percent viability of these eggs varied from 12.8% to 55.8%. On 18 May, assistance was provided by Richard Snyder, Chief, PFBC Division of Fisheries Management, and three of his student interns. On the same night, Kim Selmer-Larson, Lamar Laboratory, U.S. Fish and Wildlife Service, prepared bacteria cultures of pancreas, liver, kidney, and spleen tissue removed form 60 of the 87 shad caught that evening. On 19 May, Richard St. Pierre, Susquehanna River Fisheries Coordinator, helped along with Mai Jiabo, Deputy Director of the Dongguan Fisheries Bureau, and Wang Hanping, leader of the Chinese Shad Project, Yangtze River Fisheries Institute, P. R. China.

On the fourth week, netting resumed on Monday, 25 May, after the Memorial Day weekend. Catch averaged over 145 shad per night, the largest number of shad taken in any week this year. Subsequent egg shipments were also the highest in any week averaging over 1.4 million each night. On the fifth and final week, netting was attempted on 31 May, but wind, rain, and tornado warnings kept the crew off the water. Nets were set on 1 and 2 June, but too few fish were captured and spawned to make egg shipments.

Summary

Shad eggs were collected and shipped from the Delaware River on 11 of the 15 nights fished from 4 May through 2 June 1998. During this time, 1,237 adult shad were captured and 238 liters of eggs were shipped for a hatchery count of 10.4 million eggs. This was 34% fewer liters of eggs than were shipped in 1997, but only 11% fewer eggs because of the smaller average size of this year's eggs. Percent viability in 1998 was 42% compared to 39% in 1997. The egg-collection season was plagued by high river flows and stormy weather conditions that reduced netting effectiveness.

TABLE 1

Delaware River Shad Egg Collection Data
4 May - 2 Jun 1998

Date	Water Temp (C)	No. of Nets Set	No. of Shad Captured	Eggs Shipped (liters)		Eggs (million)	Percent Viability
				Field Count	Van Dyke Count		
04 May	15.2	11	40	10	7.2	0.237	63.5
05 May	14.4	15	3	NO SHIPMENT			
06 May	14.0	14	15	NO SHIPMENT			
07 May	15.1	15	42	5	3.6	0.098	59.3
10 May	NO NETS SET DUE TO HIGH RIVER LEVELS.						
11 May							
12 May							
13 May							
14 May							
17 May	19.1	15	72	18	11.8	0.598	55.1
18 May	19.9	16	87	20	14.4	0.947	21.1
19 May	19.8	17	99	20	16.0	0.827	55.8
20 May	21.0	17	130	17	13.3	1.228	12.8
21 May	20.3	17	132	15	14.8	0.696	32.3
25 May	19.1	17	161	28	26.6	1.520	52.6
26 May	19.6	17	171	38	30.0	1.397	34.5
27 May	20.7	17	145	40	30.2	1.225	21.3
28 May	21.2	19	110	27	19.6	1.610	53.8
31 May	23.7	NO NETS SET -- NO SHIPMENT					
01 Jun	22.4	19	20	NO SHIPMENT			
02 Jun	20.6	19	10	NO SHIPMENT			
TOTALS		245	1,237	238	187.5	10.383	42.01*

*Mean percent viability.

JOB II - Part 3

Development of an American Shad Tank Spawning System

U.S. Fish and Wildlife Service

John W. Fletcher
Northeast Fishery Center
P.O. Box 75
Lamar, PA 16848

Background

The U.S. Fish and Wildlife Service (Service) and 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, Manning Hatchery, and for the past several years at Waldoboro Shad Hatchery in Maine. In 1998, the Service's Northeast Fishery Center (NEFC) began a cooperative effort to conduct tank spawning and develop technology with the goal of establishing a spawning sub-population of American shad imprinted to the West Branch of the Susquehanna River. Annual production requirements of 5 to 10 million fertilized shad eggs for the Pennsylvania Fish and Boat Commission, 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.

American Shad Tank Spawning, Incubation and Fry Culture Systems

Tank spawning components

The tank spawning experiences of the Manning and Waldoboro Hatcheries were reviewed as a basis for fundamental design. Results from these operations suggested that : Production of 28,000 fertile eggs and 14,000 fry per female could reasonably be expected; carrying capacities of one shad per 4.5 ft^3 water with a flow consideration of 40 gpm to each of four tanks would be sufficient; and that a heated recirculating water supply would be required. The tempered supply was required to achieve an optimum 64 F, since ambient water varies from 46 to 54 F during the six week (April to May) spawning period. To process sufficient numbers of brood (750 males and 500 females), the NEFC developed a 13,500 gallon recirculating tank spawning unit (Figure 1) in the Intensive Culture Building. Culture units include four spawning tanks, three 12' circular (3000 gal) and one cross flow (15' x 5' x 4' - 2000 gal) rectangular, along with four egg settling tanks (10' x 2' x 2') equipped with submerged 300 u mesh polyester "filtration / collection" socks (10' L x 1.25' D). Initial charging of the system is accomplished with ambient spring water. Once filled, a recirculating flow of water is delivered by a 3 HP pump equipped with duplex controls (second pump on auto-backup with alarms). This primary culture pump supplies approximately 40 gpm to each culture unit via a 3" feed line. Used water then exits through the egg collection tank and enters a 6" manifold that drains to the 10' circular sump. The system employs two treatment loops at the sump to ensure adequate water quality. The tempering loop utilizes a 3 HP pump to pass 80 gpm culture water through a "shell in tube heat exchanger" where heat is recovered from thermostat regulated hot water propane boilers (399 & 150 K - BTU) . As the tempered water returns to the sump, it cascades through a packed column to preclude nitrogen gas super-saturation . In the second loop, a one HP pump sends 40 gpm through an ultraviolet (UV) disinfection treatment. The UV treated water then enters an oxygenation tube where 2 ½ *lpm* oxygen from a pressure-swing adsorption oxygen generator is injected into the flow which returns to the sump via the 6" manifold. Operation of the oxygen injection and the packed column effect an approximate increase of dissolved oxygen from a level of 5mg/l to 8 mg/l. Nitrogenous wastes are avoided by exchanging the entire supply over a 24 hour cycle by adding 10 gpm ambient water to the sump. Cleanup and recharge of the system requires a minimum of six hours.

Egg incubation and fry rearing components

An existing tempered water and degassing system, (sensors and alarms, boiler, digital controlled mixing valve, packed columns, head boxes, and manifolds) supplies the AMS egg incubation and fry rearing areas (Figure 2) in the Hatchery Building. The egg incubation system included forty 6.5 liter hatching jars supplied with water tempered to 64 F and degassed to approximately 102 % nitrogen gas saturation. Four 40 x 3 x 2 foot concrete rectangular tanks were demolished and replaced with eight fry culture tanks (6 ft diam.- 400 gallon). When stocked at a rate of 208 fry per liter, the projected rearing capacity of the eight tanks is approximately 2.4 million AMS. The fry rearing complex is equipped with two 200 liter brine shrimp rearing units. Bellow pumps which are energized for 3 minutes every half-hour inject harvested nauplii from 100 liter aerated tanks into the head box water delivery system.

American Shad Northeast Fishery Center Operations, 1998

Tank spawning

High water conditions at the Conowingo fish lift on the lower Susquehanna River precluded collection of potential brood during the productive early and middle portion of the run. From May 21 to June 4, 1998, a total of 221 female and 290 male AMS were captured and transported to the NEFC by Normandeau Associates of Drumore, Pennsylvania, under contract with the SRAFRC. American shad were collected at Conowingo Dam the day preceding transport. Upon arrival at the NEFC in mid-afternoon, shad were individually netted from the transport unit, sexed, carried by net to a treatment table where either an implant or injection was administered and then released into the spawning tank (Table 1). Under the guidelines of Service INAD (Investigational New Animal Drug) 8061, one of three different dorsal musculature applications of LH-RHa (luteinizing hormone - releasing hormone analogue) obtained from Syndel International, Inc. Vancouver, British Columbia, was employed to induce tank spawning: 15 ug/kg implant , Lot 4904A; 30 ug/kg implant, Lot 4904a; and 0.5 ml/fish injection of Ovaprim ®, Lot 4830A (combination LH-RHa and dopamine blocker). Mortality rates 24 hours post delivery were relatively low ($< 10\%$). Eggs were collected the morning following receipt of broodstock and thereafter for up to 4 days. Typically spawning was most successful during the second and third night after hormone treatment. No viable spawns were collected from AMS after the third night. Production of eggs per female (Figure 3) varied with both shipment group and with hormone application. American shad received on May 26 which produced the greatest return (ml egg/female) were in noticeably better condition than broodstock received on other dates. In broodstock received on May 26, LH-RHa implants utilized at 30 ug/kg produced greater volume (ml) of eggs per female when compared to 15ug/kg implants (244 ml vs. 164 ml).

Broodstock received on May 28 and treated with Ovaprim produced fewer eggs per female (95 ml) than those implanted with 30 ug/kg LH-RHa (138 ml). In accordance with INAD guidelines, spent broodstock were disposed of by burial at an approved hazardous waste landfill.

Egg collection and shipment

Eggs were removed from the filtration socks which were submerged in 10 foot rectangular collection tanks. Egg processing included gleaning of scales, mucous and fecal material prior to enumeration and loading into coolers with oxygen supplemented egg shipment bags at no more than 5 liters of eggs per 5 liters water. A total of 3.2 million eggs were collected. Of that number, 1.8 million were shipped to the Van Dyke Hatchery and the remainder were incubated at the NEFC. Eggs incubated at the NEFC received an initial 10 minute disinfection of 100 ppm active ingredient iodophore in the incubation jars and fifteen minute flow-through treatments of 1500 ppm formalin as needed during incubation for control of *Saprolegnia* sp..

Fry culture, marking and stocking

Fry culture tanks received a flow of approximately 3 gpm at 64 F. *Artemia* were offered as feed starting day three. Shad fry received oxytetracline otolith marks on days 3, 6, 9, and 15 by four hour immersion in 200 ppm active ingredient of sodium bicarbonate buffered solutions of Terramycin 343 under Service INAD 9033. A total of 56,000 thousand marked American shad fry age 15 days were released by NEFC staff on June 19 (17 k) and June 25 (39k) into the West Branch of the Susquehanna at McElhatten, Pennsylvania.

Figure 1. Northeast Fishery Center American shad tank spawning system

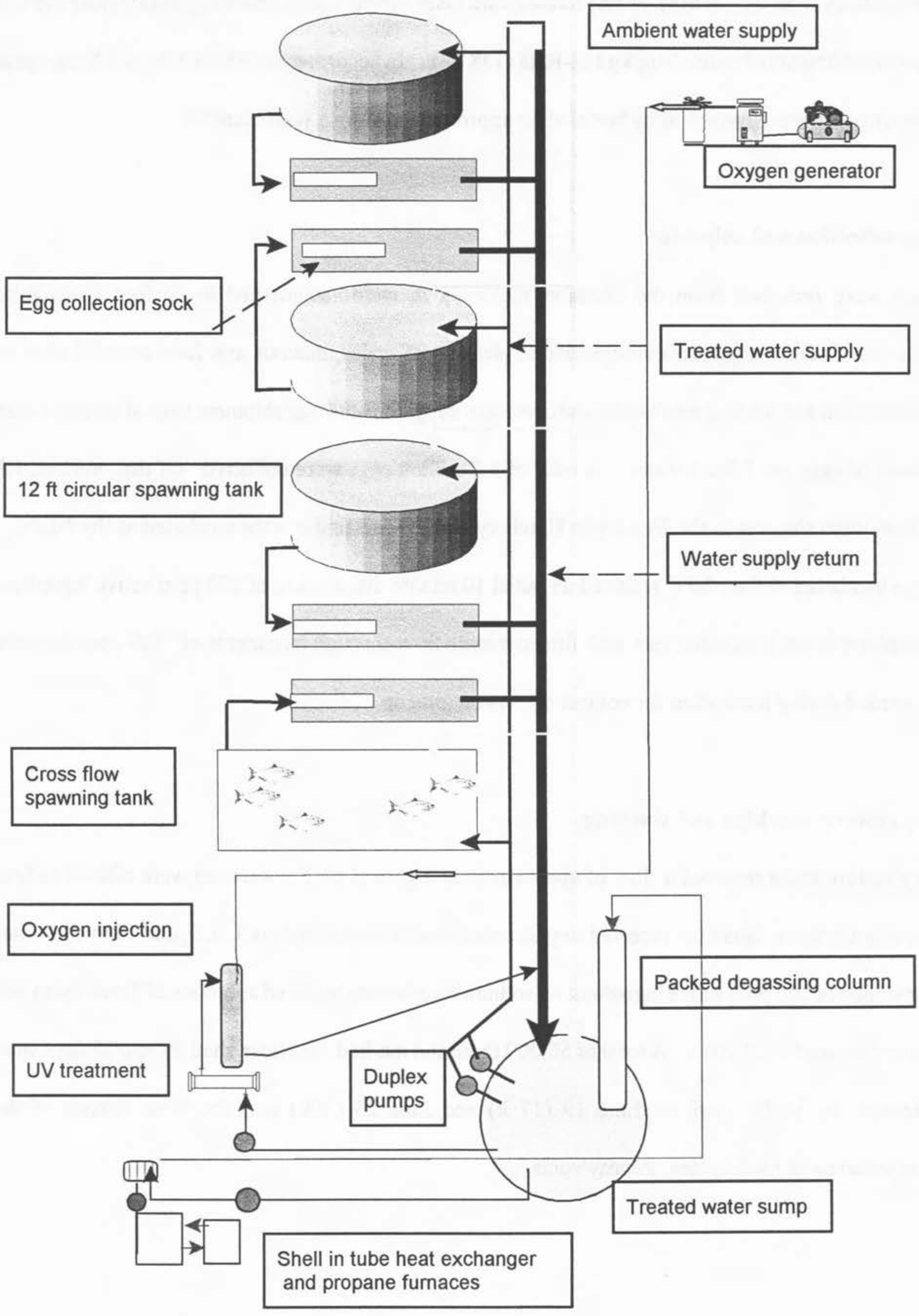


Figure 2. Northeast Fishery Center American shad incubation and fry culture system

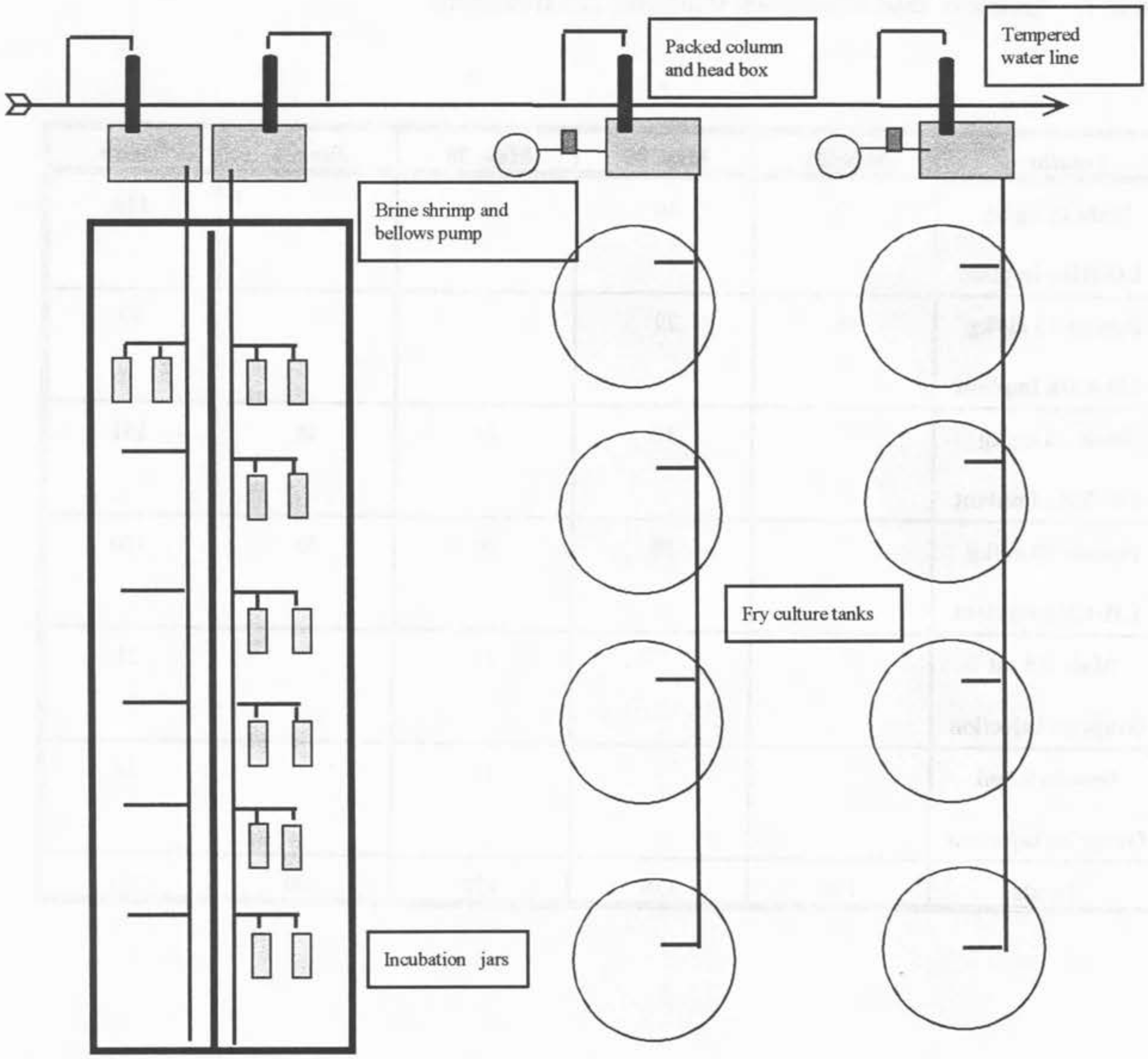
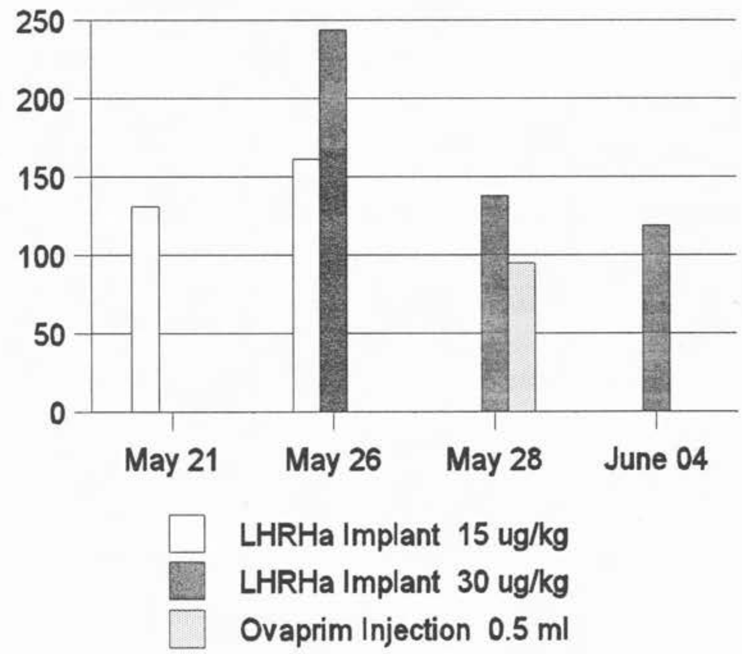


Table 1. American shad broodstock shipments and treatments.

Treatment	May 21	May 26	May 28	June 4	Totals
Male 15 ug/kg LH-RHa Implant	78	40			118
Female 15 ug/kg LH-RHa Implant	58	29			87
Male 30 ug/kg LH-RHa Implant		39	64	48	151
Female 30 ug/kg LH-RHa Implant		28	40	52	120
Male 0.5 ml Ovaprim Injection			21		21
Female 0.5ml Ovaprim Injection			14		14
Totals	136	136	139	100	511

Figure 3. Relative egg production - milliliters per female



JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1998

M. L. Hendricks
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, PA

INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous Fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River Basin. The objectives of the Van Dyke Station were to research culture techniques for American shad and to rear juveniles for release into the Juniata and Susquehanna Rivers. The program goal was to develop a stock of shad imprinted to the Susquehanna drainage, which will subsequently return to the river as spawning adults. 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 1998 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 27.8 million eggs (628 L) were received in 39 shipments in 1998 (Table 1). This represented the most eggs received since 1991 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 57.4%.

Egg collection efforts on the Delaware River were hampered by high water. Initial shipments were received on May 5 and 8, but high water delayed further shipments until May 18. A total of eleven shipments of eggs were received from the Delaware River (10.4 million eggs) with a viability of 32.6%. The lower viability for the Delaware River shipments, compared to previous years was due to use of a new method to enumerate dead eggs. Due to the high number of small eggs which do not layer out and cannot be siphoned, we estimated viability by taking samples and counting live and dead eggs. Three samples of at least 100 eggs each were taken 4 to 5 days after fertilization. The percentage of live eggs in the samples was recorded as the viability. This assumes there is no egg mortality after 4 to 5 days of incubation. Years of experience suggests that this is a reasonable assumption. Very few developed embryos have been noted in samples of dead eggs taken over the years. This method was used for 5 of the eleven Delaware shipments. Mean viability for these shipments was 28% compared to 42% for the other six 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.

Four different sites were fished on the Hudson River, producing a total of 22 shipments (15.7 million eggs) with an overall viability of 74.6%. This is the second most eggs received from the Hudson River since we began collecting eggs there in 1989.

The U. S. Fish and Wildlife Service, Northeast Fishery Center, in Lamar, PA began tank-spawning operations in 1998. 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. The Van Dyke hatchery received 6 shipments totalling 25.4 liters and 1.6 million eggs from this source. Egg viability in the first two shipments received was low (4.2% and 23.8%) but viability in the last four shipments ranged from 37.4% to 77.7%. Overall egg viability for the Susquehanna River source was 50.9%. Egg diameter for tank-spawned eggs was small (89,000 eggs per liter vs. 35,000 to 50,000 eggs per liter for a typical Hudson River shipment) but the eggs hatched, fed and cultured well, producing vigorous larvae.

SURVIVAL

Overall survival of fry was 79.5% compared to a range of 41% to 94% for the period 1984 through 1997. 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 two patterns (Figure 1). Forty-two tanks exhibited 19d survival averaging 85%. Five tanks exhibited high mortality within the first two days after hatch due to fry laying on top of each other. Nineteen-day survival for these tanks was 72%. This has been an ongoing problem (Hendricks, 1996, 1997). All the mortality problems noted in 1995- 1997 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 1997 and 1998, and, when possible, attempted to maintain water temperatures at 65 or 66F. Unfortunately, cool weather prevented us from reaching 65 or 66F for most of the 1998 rearing season. Fry laying on the bottom were fed immediately, regardless of age and forced off the bottom using a squeegee. These strategies appeared to eliminate the problems temporarily, but in 1998, fry in problem tanks tended to remain swimming during the day, but would again be on the bottom the morning after hatch, despite feeding on hatch day. 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 12.7 million. A total of 7.7 million was released in the Juniata River and 1.8 million in the Susquehanna River at Montgomery Ferry. American shad fry were also stocked in other main stem areas and in tributaries: 305 thousand in Conodoguinet Creek, 229 thousand in the Conestoga River, 230 thousand in Swatara Creek, 321 thousand in West Conewago Creek, and 1.1 million in the North Branch Susquehanna River. The West Branch Susquehanna River was stocked by the Northeast Fishery Center. In addition, 948 thousand fry were stocked in the Lehigh River to support restoration efforts there. Some sixteen thousand were transferred to raceways at Benner Spring for mark retention analysis.

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 and in the Susquehanna River at Montgomery Ferry were marked at 3 days of age. Fry from the Susquehanna River egg source and stocked in the Juniata River were marked at 3, 6, and 9 days of age. Fry stocked in the Conodoguinet Creek were given a triple mark at 9, 12, and 15 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 triple mark at 3, 9, and 12 days of age. Fry stocked in the North Branch Susquehanna River were given a quadruple mark at 3, 6, 9, and 12 days of age. Fry stocked in the West Branch Susquehanna River by the USFWS 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 3, 9, and 12 days of age.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways and examining otolith samples collected later. Retention of tetracycline marks for American shad was 100% for all groups analyzed. Analysis of survival of each uniquely marked group is discussed in Appendix A.

FINGERLING CULTURE

American shad marked as larvae and reared in raceways for mark retention studies were sampled for mark retention, then combined into two raceways and given two 3 day feed marks, 6 days apart, using 40g OTC per pound of food. A sample of fish from each raceway was marked with Bismark Brown dye and a mark-recapture population estimate was conducted resulting in an estimate of 4,200 fingerlings. Approximately 2,200 of these were stocked in Standing Stone Creek on Sept. 9, 1998. This group included numbers of fish with each of the eight unique immersion mark combinations, however, the double feed mark distinguishes them from all other groups released in 1997 and 1998.

SUMMARY

A total of 39 shipments (27.7 million eggs) was received at Van Dyke in 1998. Total egg viability was 57% and survival to stocking was 80%, resulting in production of 12.7 million fry. The majority of the fry were stocked in the Juniata River (7.7 million) and Susquehanna River at Montgomery Ferry (1.8 million). Fry were also released in Conodoguinet Cr. (305 thousand), Conestoga River (229 thousand), Swatara Creek (230 thousand), West Conewago Creek (321 thousand), the North Branch Susquehanna River (1.2 million), and the Lehigh River (948 thousand). Some 56,000 fry were released in the West Branch Susquehanna River by the USFWS.

Overall survival of fry was 79.5%. 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, with a unique mark for Susquehanna River source eggs. Retention of tetracycline marks was 100% for all production marks.

RECOMMENDATIONS FOR 1999

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. Estimate viability of egg shipments from the Delaware River by sampling 4 or 5 days after fertilization.

LITERATURE CITED

Hendricks, M. L. and T. R. Bender, Jr. 1993. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1992. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender, Jr. 1994. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1993. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender, Jr. 1995. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1996. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1997. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1996. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1998. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1997. Susquehanna River Anadromous Fish Restoration Committee.

Figure 1. Survival of American shad fry, Van Dyke, 1998.

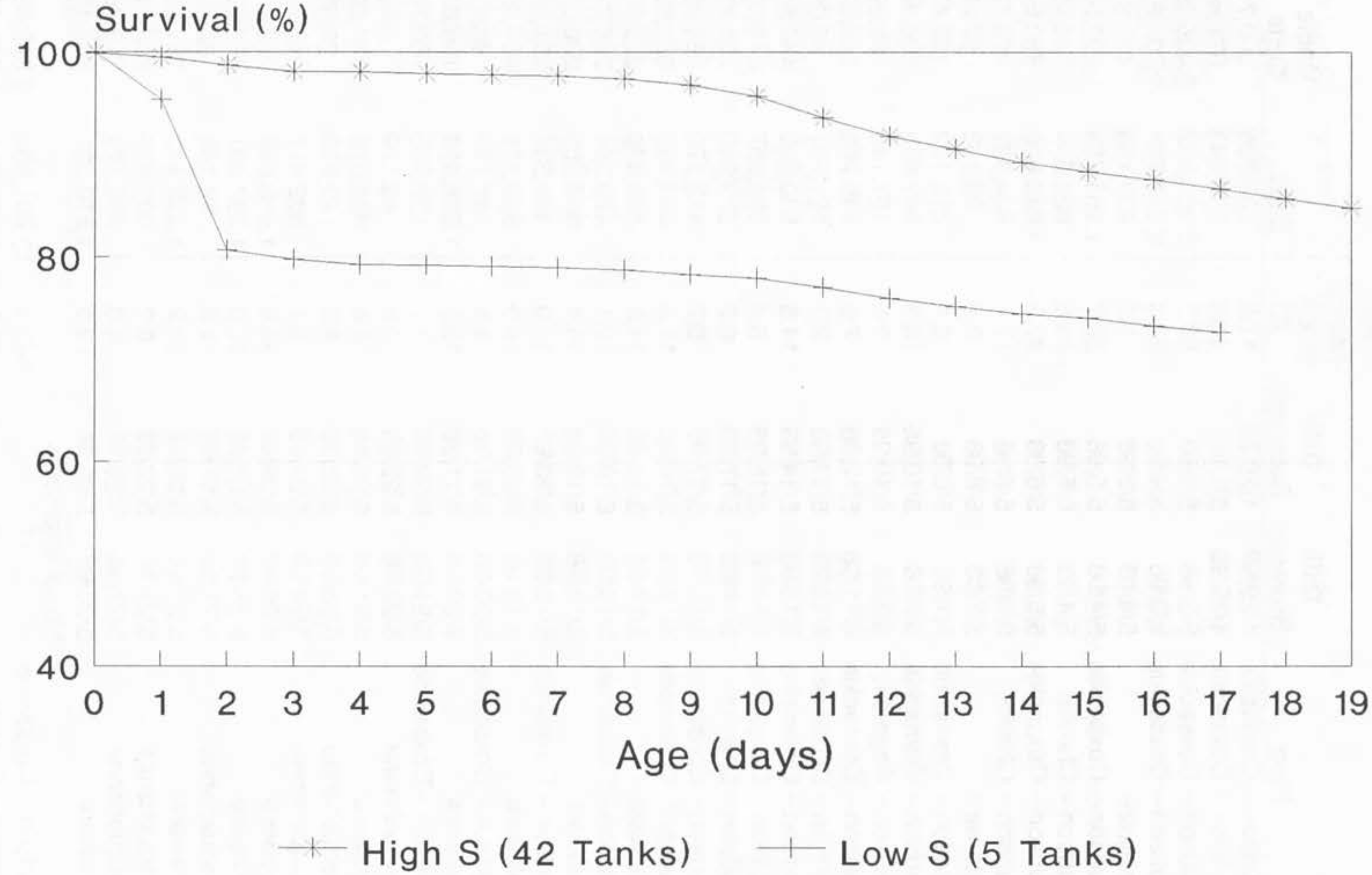


Table 1. American shad egg shipments recieved at Van Dyke, 1998.

Ship-ment No.	River	Date Spawned	Date Recieved	Vol. Rec-ieved (L)	Eggs	Viable Eggs	Percent Viable
1	Hudson- Coxsackie	4/29/98	4/30/98	11.2	383,406	300,715	78.4%
2	Hudson- Coxsackie	4/30/98	5/1/98	24.6	978,243	677,842	69.3%
3	Hudson- Coxsackie	5/2/98	5/3/98	88.7	3,168,362	2,435,384	76.9%
4	Hudson- Coxsackie	5/3/98	5/4/98	69.3	2,357,701	1,702,816	72.2%
5	Delaware	5/4/98	5/5/98	7.2	237,194	150,599	63.5%
6	Hudson- Coxsackie	5/4/98	5/5/98	38.7	1,854,724	1,202,031	64.8%
7	Hudson- Cheviot	5/4/98	5/5/98	24.5	824,664	643,457	78.0%
8	Hudson- Coxsackie	5/5/98	5/6/98	27.5	1,060,650	783,694	73.9%
9	Hudson- Cheviot	5/5/98	5/6/98	17.4	604,707	473,100	78.2%
10	Delaware	5/7/98	5/8/98	3.6	98,143	58,207	59.3%
11	Hudson- Coxsackie	5/7/98	5/8/98	6.4	213,122	153,458	72.0%
12	Hudson- Vlomankill	5/9/98	5/10/98	13.3	447,675	366,366	81.8%
13	Hudson- Rogers I.	5/9/98	5/10/98	3.4	127,148	89,345	70.3%
14	Hudson- Coxsackie	5/11/98	5/12/98	7.0	240,703	195,971	81.4%
15	Hudson- Coxsackie	5/12/98	5/13/98	3.7	121,891	98,091	80.5%
16	Hudson- Coxsackie	5/13/98	5/14/98	14.8	530,880	442,927	83.4%
17	Hudson- Coxsackie	5/14/98	5/15/98	5.4	358,057	310,600	86.7%
18	Hudson- Cheviot	5/16/98	5/17/98	6.6	273,240	231,470	84.7%
19	Hudson- Coxsackie	5/16/98	5/17/98	9.2	412,170	290,318	70.4%
20	Hudson- Coxsackie	5/17/98	5/18/98	11.6	494,792	383,878	77.6%
21	Delaware	5/17/98	5/18/98	11.8	598,458	329,516	55.1%
22	Hudson- Coxsackie	5/18/98	5/19/98	10.1	470,351	364,745	77.5%
23	Delaware	5/18/98	5/19/98	14.4	946,680	200,000	21.1%
24	Hudson- Coxsackie	5/19/98	5/20/98	12.0	439,537	351,838	80.0%
25	Delaware	5/19/98	5/20/98	16.0	826,731	461,252	55.8%
26	Hudson- Coxsackie	5/20/98	5/21/98	5.5	187,119	95,422	51.0%
27	Delaware	5/20/98	5/21/98	13.3	1,228,419	156,668	12.8%
28	Hudson- Coxsackie	5/21/98	5/22/98	3.7	129,955	102,758	79.1%
29	Susquehanna	5/22/98	5/22/98	0.6	48,719	2,062	4.2%
30	Delaware	5/21/98	5/22/98	14.8	695,875	224,661	32.3%
31	Susquehanna	5/23/98	5/23/98	1.8	120,049	28,539	23.8%
32	Susquehanna	5/24/98	5/24/98	5.1	332,417	202,572	60.9%
33	Delaware	5/25/98	5/26/98	26.6	1,519,699	799,476	52.6%
34	Delaware	5/26/98	5/27/98	30.0	1,397,081	482,062	34.5%
35	Susquehanna	5/27/98	5/27/98	1.8	88,755	68,957	77.7%
36	Delaware	5/27/98	5/28/98	30.2	1,225,441	261,098	21.3%
37	Susquehanna	5/27/98	5/28/98	8.2	601,410	225,014	37.4%
38	Susquehanna	5/27/98	5/28/98	8.0	469,479	318,767	67.9%
39	Delaware	5/28/98	5/29/98	19.6	1,610,337	259,426	16.1%
Totals		No. of shipments					
	Hudson- Coxsackie	17		349.4	13,401,664	9,892,489	73.8%
	Hudson- Cheviot	3		48.5	1,702,611	1,348,027	79.2%
	Hudson- Vlomankill	1		13.3	447,675	366,366	81.8%
	Hudson- Rogers I.	1		3.4	127,148	89,345	70.3%
	Hudson (Subtotal)	22		415	15,679,097	11,696,227	74.6%
	Delaware	11		187.5	10,384,059	3,382,965	32.6%
	Susquehanna	6		25.4	1,660,829	845,912	50.9%
	Grand Total	39		627.5	27,723,985	15,925,104	57.4%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1998.

					No. of shad stocked (all rivers)				
Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via–bility (%)	No. of Viable Eggs (exp.6)	Fry (exp.3)	Fing–erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.194	0.373
1977	146	6.4	46.7	2.9	969	35	1,003	0.159	0.342
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.104	0.330
1979	165	6.4	41.4	2.6	629	34	664	0.104	0.251
1980	348	12.6	65.6	8.2	3,526	5	3,531	0.283	0.431
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.177	0.393
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.196	0.548
1983	939	34.5	55.6	19.2	4,048	98	4,146	0.120	0.216
1984	1,157	41.1	45.2	18.6	11,996	30	12,026	–	0.728
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.279	0.682
1986	1,536	52.7	40.7	21.4	15,876	61	15,928	0.302	0.744
1987	974	33.0	47.9	15.8	10,274	81	10,355	0.314	0.655
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.331	0.855
1989	1,221	42.7	60.1	25.7	22,267	60	22,327	0.523	0.869
1990	897	28.6	56.7	16.2	12,034	253	12,287	0.430	0.758
1991	903	29.8	60.7	18.1	12,963	233	13,196	0.443	0.729
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.253	0.371
1993	558	21.5	58.3	12.8	7,870	79.4	7,949	0.370	0.621
1994	551	21.2	45.9	9.7	7,720 *	139.5	7,860	0.309	0.676
1995	768	22.6	53.9	12.2	10,930 *	–	10,930	0.426	0.789
1996	460	14.4	62.7	9.0	8,466 *	–	8,466	0.588	0.941
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.353	0.759
1998	628	27.7	57.4	15.9	11,757	2.2	11,759	0.425	0.740

*Includes fry reared at Manning.

Total	182,766
Total since 1985 (OTC marked)	151,369

Table 3. American shad stocking and transfer activities.

Date	Tank	Number	OTC Mark (days)	Location	Origin	Age	Size
5/19/98	B11	326,000	3	Montgomery Ferry	Hudson	9	Fry
5/19/98	B21	306,000	3	Montgomery Ferry	Hudson	9	Fry
5/20/98	B31	319,000	3	Montgomery Ferry	Hudson	10	Fry
5/20/98	B41	302,000	3	Montgomery Ferry	Hudson	10	Fry
5/21/98	C11	305,000	3	Montgomery Ferry	Hudson	11	Fry
5/21/98	C21	229,000	3	Montgomery Ferry	Hudson	11	Fry
5/22/98	C31	217,000	3	Millerstown (Greenwood)	Hudson	12	Fry
5/22/98	C41	296,000	3	Millerstown (Greenwood)	Hudson	11	Fry
5/23/98	D11	289,000	3	Thompsontown	Hudson	12	Fry
5/23/98	D21	271,000	3	Thompsontown	Hudson	12	Fry
5/24/98	D31	222,000	3	Thompsontown	Hudson	13	Fry
5/25/98	D41	151,000	3	Muskrat Springs	Hudson	14	Fry
5/26/98	E11	166,000	3	Mexico	Hudson	15	Fry
5/26/98	E21	125,000	3	Mexico	Delaware	14	Fry
5/27/98	A11	258,000	3,6,9,12	N. Branch Susq. R.	Hudson	20	Fry
5/27/98	A21	220,000	3,6,9,12	N. Branch Susq. R.	Hudson	19	Fry
5/27/98	A31	344,000	3,6,9,12	N. Branch Susq. R.	Hudson	19	Fry
5/27/98	A41	304,000	3,6,9,12	N. Branch Susq. R.	Hudson	17	Fry
5/27/98	A41	2,000	3,6,9,12	Benner Spring Raceway F1	Hudson	17	Fry
5/27/98	E11	2,000	3	Benner Spring Raceway F2	Hudson	15	Fry
5/28/98	E31	338,000	3	Muskrat Springs	Hudson	16	Fry
5/29/98	F41	305,000	9,12,15	Conodoguinet Cr.	Hudson	16	Fry
5/29/98	G11	321,000	3,9,12	West Conewago Cr.	Hudson	16	Fry
5/29/98	F41	2,000	9,12,15	Benner Spring Raceway F3	Hudson	16	Fry
5/29/98	G11	2,000	3,9,12	Benner Spring Raceway F4	Hudson	16	Fry
5/30/98	E41	368,000	3	Mifflin	Hudson	18	Fry
5/31/98	F11	394,000	3	Arch Rock	Hudson	19	Fry
6/1/98	F21	230,000	3,6,9,15,18	Swatara Cr.	Hudson	20	Fry
6/1/98	F31	229,000	3,9,12,15	Conestoga R.	Hudson	20	Fry
6/1/98	F21	2,000	3,6,9,15,18	Benner Spring Raceway E1	Hudson	20	Fry
6/1/98	F31	2,000	3,9,12,15	Benner Spring Raceway E2	Hudson	20	Fry
6/2/98	G21	312,000	3	Millerstown (Rt. 17 bridge)	Hudson	20	Fry
6/2/98	G31	146,000	3	Millerstown (Rt. 17 bridge)	Hudson	18	Fry
6/3/98	G41	286,000	3	Miller's Canoe Rental	Hudson	17	Fry
6/3/98	H11	242,000	3	Miller's Canoe Rental	Hudson	15	Fry
6/4/98	H21	384,000	3	Treaster's Exxon	Hudson	14	Fry
6/4/98	H31	298,000	3	Treaster's Exxon	Hudson	13	Fry
6/5/98	H41	265,000	3	Muskrat Springs	Hudson	13	Fry
6/5/98	I11	344,000	3	Muskrat Springs	Hudson	11	Fry
6/6/98	I21	317,000	3	Millerstown (Greenwood)	Delaware	12	Fry
6/7/98	I31	329,000	3	Thompsontown	Hudson	12	Fry
6/8/98	I41	307,000	3	Millerstown (Rt. 17 bridge)	Hudson	12	Fry
6/8/98	B12	420,000	3	Millerstown (Rt. 17 bridge)	Delaware	12	Fry
6/9/98	B22	183,000	3	Miller's Canoe Rental	Hudson	11	Fry
6/9/98	B42	213,000	3	Miller's Canoe Rental	Delaware	11	Fry
6/11/98	B32	226,000	3,6,9	Mexico	Susquehanna	11	Fry
6/11/98	D32	255,000	3	Mexico	Delaware	6	Fry
6/15/98	C32	59,000	3,6,9	Mifflin	Susquehanna	12	Fry
6/16/98	D12	133,000	3,6,9	Treaster's Exxon	Susquehanna	12	Fry
6/16/98	D22	147,000	3,6,9	Treaster's Exxon	Susquehanna	12	Fry
6/16/98	D22	2,000	3,6,9	Benner Spring Raceway E3	Susquehanna	12	Fry
6/17/98	C12	412,000	3,9,12	Lehigh River	Delaware	15	Fry
6/17/98	C22	250,000	3,9,12	Lehigh River	Delaware	14	Fry
6/17/98	C42	286,000	3,9,12	Lehigh River	Delaware	13	Fry
6/17/98	C22	2,000	3,9,12	Benner Spring Raceway E4	Delaware	14	Fry
9/9/98	Race ways	2,200	various/ double feed	Standing Stone Cr.	Various	?	Fing.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1998.

	Site	Fry
Releases	Millerstown (Greenwood)	830,000
	Millerstown (Rt. 17 bridge)	1,185,000
	Miller's Canoe Rental	924,000
	Thompsontown	1,111,000
	Muskrat Springs	1,098,000
	Mexico	772,000
	Mifflin	427,000
	Arch Rock	394,000
	Treaster's Exxon	962,000
	Juniata River Sub-total	**7,703,000**
	Montgomery Ferry	1,787,000
	Conodoguinet Cr.	305,000
	Conestoga R.	229,000
	Swatara Cr.	230,000
	West Conewago Cr.	321,000
	N. Branch Susq. R.	1,126,000
	W. Branch Susq. R.	56,000 *
	Susquehanna River Basin Sub-total	**11,757,000**
	Lehigh River	948,000
	Total	**12,705,000**
Transfers	Benner Spring Raceways	16,000
Fingerling Releases	Standing Stone Cr.	2,200
	Total Fry Production	12,721,000
	Viable eggs	15,925,104
	Survival of fry (%)	**79.5%**

*Reared and stocked by USFWS, Lamar.

Table 5. Tetracycline marking regime for American shad stocked in the Chesapeake Bay watershed, 1998.

Year	Number	Size	Mark Immersion (days)	Mark Feed	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers.	Mark Retention (%) Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source
1998– American shad												
	8,925,000	Fry	3	–	256ppm OTC	–	100	–	Van Dyke	–	Jun. & Susq. R.	Hud./Del.
	321,000	Fry	3,9,12	–	256ppm OTC	–	100	–	Van Dyke	–	W. Conewago Cr.	Hudson
	948,000	Fry	3,9,12	–	256ppm OTC	–	100	–	Van Dyke	–	Lehigh R.	Delaware
	565,000	Fry	3,6,9	–	256ppm OTC	–	100	–	Van Dyke	–	Juniata R.	Susq.
	305,000	Fry	9,12,15	–	256ppm OTC	–	100	–	Van Dyke	–	Conodoguinet Cr.	Hudson
	1,126,000	Fry	3,6,9,12	–	256ppm OTC	–	100	–	Van Dyke	–	North Br. Susq. R.	Hudson
	229,000	Fry	3,9,12,15	–	256ppm OTC	–	100	–	Van Dyke	–	Conestoga R.	Hudson
	230,000	Fry	3,6,9,15,18	–	256ppm OTC	–	100	–	Van Dyke	–	Swatara Cr.	Hudson
	12,649,000	Fry	Subtotal									
	2,200	Fing.	various	double	256ppm OTC	40g OTC/# food	–	100	Van Dyke	Benner Spring	Standing Stone Cr.	Various
	56,000	Fry	3,6,9,15	–	256ppm OTC	–		–	Lamar	–	West Br. Susq. R.	Susq.
	61,500	Fry	9,12	–	200ppm OTC	–		–	Manning	–	Patuxent R.	Susq.
	135,750	Fry	Egg	–	1000ppm OTC	–		–	Manning	–	Choptank R.	Susq.
	197,250	Fry	Subtotal									
	16,726	Fing.	–	single*	–	500mg/kg live wt		–	Manning	PEPCO Ponds	Patuxent R.	Susq.
	16,885	Fing.	–	single*	–	500mg/kg live wt		–	Manning	PEPCO Ponds	Choptank R.	Susq.
	33,611	Fing.	Subtotal									
	2,367,000	Fry	9	–	200ppm OTC	–	100	–	Harrison L.	–	James R.	York R.
	1,589,000	Fry	3,9	–	200ppm OTC	–	100	–	Harrison L.	–	Potomac R.	Potomac R.
	7,657,031	Fry	9	–	200ppm OTC	–	100	–	King & Queen	–	James R.	York R.
	4,057,739	Fry	3,6,12,15	–	200ppm OTC	–	100	–	King & Queen	–	York R.	York R.
	5,760,000	Fry	3,15	–	200ppm OTC	–		–	Pamunkey Trit	–	York R.	York R.
	471,000	Fry	5	–	200ppm OTC	–	–	–	Edenton	–	Meherrin R.	Roanoke R.
Hickory Shad												
	1,124,210	Fry	3	–	200ppm OTC	–		–	Manning	–	Tukahoe R.	Susq.
	2,792,019	Fry	2	–	200ppm OTC	–		–	Manning	–	Patuxent R.	Susq.
	3,683,351	Fry	Egg	–	1000ppm OTC	–		–	Manning	–	Patuxent R.	Susq.
	1,402,441	Fry	2	–	200ppm OTC	–		–	Manning	–	Choptank R.	Susq.
	2,464,813	Fry	Egg	–	1000ppm OTC	–		–	Manning	–	Choptank R.	Susq.
	11,466,834	Fry	Subtotal									
	31,979	Fing.	Egg	single*	1000ppm OTC	500mg/kg live wt		100	Manning	PEPCO Ponds	Patuxent R.	Susq.

*Also recieved coded wire tags

Table 6. Tetracycline mark retention for American shad reared in 1998.

Tank/ Raceway	Attempted Mark (days)	Observed Mark (days)	Number Exhibiting Mark	Projected Number Stocked	Disposition
Race E1	3,6,9,15,18	3,6,9,15,18	20/20(100%)	230,000	Stocked Swatara Cr.
Race E2	3,9,12,15	3,9,12,15	20/20(100%)	229,000	Stocked Conestoga R.
Race E3	3,6,9	3,6,9	20/20(100%)	565,000	Stocked– Juniata R. Susq. R. egg source
Race E4	3,9,12	3,9,12	20/20(100%)	948,000	Stocked Lehigh River
Race F1	3,6,9,12	3,6,9,12	20/20(100%)	1,126,000	Stocked North Br. Susq. R.
Race F2	3	3	20/20(100%)	8,925,000	Stocked Juniata River + Montgomery Ferry
Race F3	9,12,15	9,12,15	19/19(100%)	305,000	Stocked Conodoguinet Cr.
Race F4	3,9,12	3,9,12	20/20(100%)	321,000	Stocked West Conewago Cr.
All Raceways	double feed	double feed	27/27(100%)	2,200	Stocked Standing Stone Cr.

Appendix A

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 1998.

Michael L. Hendricks
Pennsylvania Fish and Boat Commission
Division of Research
Benner Spring Fish Research Station
1225 Shiloh Rd.
State College, Pa. 16801

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 1998, 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 1998 and summarizes results from 1995 to 1998.

Materials and Methods

The majority (81%) of production larvae stocked in 1998 was marked at three days of age and stocked at various sites in the Juniata River and the Susquehanna River at Montgomery Ferry. With the exception of the first three releases at Montgomery Ferry on May 19, 20, and 21, 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. The only fingerlings stocked consisted of a small number of uniquely marked fingerlings released in Standing Stone Cr.

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 1998 are tabulated in tables A1-1 through A1-4, respectively. In 1998, larvae stocked in the North Branch and Conewago Cr. exhibited the best survival (relative survival set to 1.00, Table A1-4). Larvae stocked in Swatara Cr. and at various sites in the Juniata R. and the Susq. R. at Montgomery Ferry also survived well (relative survival 0.93 and 0.71, respectively). Larvae stocked in the Juniata River from the Susquehanna River egg source exhibited a disappointing relative survival of 0.47. Larvae stocked in Conodoguinet Cr. also did poorly with a relative survival of 0.18. No shad from stockings in the West Branch, Conestoga R. or Standing Stone Creek were recovered.

Recovery rates for 1998 varied from 0.0 to 0.19. The overall recovery rate for 1998 (0.13) was only slightly better than 1996 (0.09) and well below 1995 (0.35) and 1997 (0.57).

A summary of the results of four years of uniquely marking larvae according to stocking site is provided in Table A1-5. Although the data are not definitive, spreading larvae out to reduce predation appears to promote increased survival. Larvae stocked in this manner for the last two years (Juniata R., various sites) survived well (relative survival 0.89 and 0.71). Larvae stocked by multiple stockings at the same site (Juniata R./ Susq. R. at Mont. 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 have done extremely well, exhibiting the highest survival in 1996 and 1998 and good survival (relative survival 0.68) in 1997. Larvae stocked in the West Branch have not done well, exhibiting relative survival of 0.38, 0.35, and 0.00 in 1996 to 1998, respectively, although releases in 1998 were perhaps too small to detect (56,000).

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, poor relative survival in 1997 (0.35) and were not detected in 1996 and 1998. This may relate to stocking site since the 1995 release was at the Rt. 322 bridge near

Ephrata (river mile 38) while subsequent releases were at Conestoga Pines Park in Lancaster (river mile 22). Larvae stocked in Conodoguinet Creek exhibited 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 for the first time in 1998, and did well (relative survival 1.00 and 0.93, respectively).

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. To reduce predation, 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 be moved back upriver to Rt. 322, near Ephrata.
3. Continue marking fish stocked in different tributaries with unique marks.

Literature Cited

Crecco, V. A. and T. F. Savoy. 1985. Effects of biotic and abiotic factors on growth and relative survival of young American shad, *Alosa sapidissima*, in the Connecticut River. Canadian Journal of Fisheries and Aquatic Sciences 42: 1640-1648.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management 11:212-219.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1992. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1991. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. and T. R. Bender. 1993. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1992. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1995. Relative survival of Hudson River American shad larvae released at 7 days of age vs. those released at 19 days of age. Appendix 4, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1998. Survival of American shad larvae released via multiple releases at a single site vs. single releases at multiple sites. Appendix A, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1997. Susquehanna River Anadromous Fish Restoration Committee.

Li, S. and J. A. Mathias. 1987. The critical period of high mortality of larvae fish- A discussion based on current research. Chinese Journal of Oceanology and Limnology (5)1: 80-96.

St. Pierre, R. 1994. Job IV. Evaluation of movements, abundance, growth and stock origin of juvenile American shad in the Susquehanna River. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1993. Susquehanna River Anadromous Fish Restoration Committee.

Wiggins, T. A., T. R. Bender, Jr., V. A. Mudrak, and J. A. Coll. 1985. The development, feeding, growth, and survival of cultured American shad larvae through the transition from endogenous to exogenous nutrition. Progressive Fish-Culturist 47(2): 87-93.

Table A1-1. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 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 A1-2. 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	

Table A1–3. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1997.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	8–14	6/2–6/25	3,037,000	41%	211	46	0.69	1.00
Juniata R./ various sites	18–20	6/9–7/1	2,270,000	30%	140	31	0.62	0.89
Conodoguinet Cr.	18	6/24	174,000	2%	3	1	0.17	0.25
Conestoga R.	25	7/1	231,000	3%	6	1	0.26	0.37
Huntingdon	10	5/31	486,000	7%	26	6	0.53	0.77
W. Br. Susq. R.	23	6/30	622,000	8%	15	3	0.24	0.35
N. Br. Susq. R.	17–19	6/23	1,199,000	16%	57	12	0.48	0.68
		Total	8,019,000		458		0.57	

Table A1–4. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1998.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	9–20	5/19–6/9	8,925,000	76%	119	26	0.13	0.71
Juniata R./ Susq. egg source	11–12	6/11–6/15	565,000	5%	5	1	0.09	0.47
Conodoguinet Cr.	16	5/29	305,000	3%	1	0	0.03	0.18
Conestoga R.	20	6/1	229,000	2%	0	0	0.00	0.00
Conewago Cr.	16	5/29	321000	3%	6	1	0.19	1.00
Swatara Cr.	20	6/1	230000	2%	4	1	0.17	0.93
W. Br. Susq. R.	15	6/19–6/25	56,000	0%	0	0	0.00	0.00
N. Br. Susq. R.	17–20	5/27	1,126,000	10%	21	5	0.19	1.00
Standing Stone Cr.	fing.	9/9	2,200	0%	0	0	0.00	0.00
		Total	11,759,200		156		0.13	

Table A1–5. 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, 1995–1998.

Stocking	Recovery Rate				Relative Survival			
Site	1995	1996	1997	1998	1995	1996	1997	1998
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			0.89	0.71
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	0.18	0.50	0.25	0.18
mouth of Conodiguinet Cr.	0.39				0.31			
Conestoga R.	1.26	0.00	0.26	0.00	1.00	0.00	0.37	0.00
mouth of Conestoga Cr.	0.42				0.33			
Muddy Cr.	0.00				0.00			
Conewago Cr.				0.19				1.00
Swatara Cr.				0.17				0.93
W. Br. Susq. R.		0.09	0.24	0.00		0.38	0.35	0.00
N. Br. Susq. R.		0.23	0.48	0.19		1.00	0.68	1.00
Overall	0.35	0.09	0.57	0.13				

*Includes several releases in the Susquehanna R. at Mont. Ferry.

JOB IV.

ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER

R. S. Carney
Pennsylvania Fish and Boat Commission
State College, Pennsylvania

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 1998, 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 39,904 American shad while lifts at Holtwood and Safe Harbor passed 8,235 and 6,054, respectively. These fish had the opportunity to spawn naturally in the river reach above York Haven Dam.

Of the 6,577 adult shad collected at Conowingo West Lift in 1998, 4,593 were transported and stocked at the Tri-County Marina and Columbia Borough boat launch during the period 30 April through 9 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. Five-hundred and seven shad were transported to the USFWS Hatchery in Lamar, PA for live tank spawning and culture. Observed transport and delayed mortalities amounted to 75 fish (1.5%). Overall sex ratio (SR) in these transfers was about 0.9:1.0 males:females. Numbers of adults transported and stocked compares with about 10,145 live shad in 1997(SR 2:1); 37,500 in 1996 (SR 1.1:1); 55,000 in 1995 (SR 1.1:1); 28,100 in 1994 (SR 1.8:1); 11,200 in 1993 (SR 1.3:1); 14,500 in 1992 (SR 1:1), and 22,000 in 1991 (SR 1.6:1). The sex ratio favoring females in 1998 transfers reflects the fact that high river flows thwarted efforts to capture shad early in the season when males are dominant. Approximately 4,755 blueback herring were stocked at the Tri-County Marina (1,102) and in Little Conestoga Creek (3,653) during 1998. This compares with approximately 28,600 blueback herring captured and stocked at the Tri-County Marina (18,600) and in three tributaries; Conestoga River (2,500), Little Conestoga River (2,500), and Conodoguinet Creek (5,000) during 1997. High flows also impacted efforts to capture herring in 1998.

During the 1998 shad production season, the PFBC released 11.8 million shad larvae in the Susquehanna watershed (includes 56,000 cultured and released in the W. Br. Susquehanna R. by USFWS Hatchery, Lamar, PA). This stocking level compares with 3 to 10 million fry stocked each year in 1990 - 1997. Most larvae were released between 19 May to 17 June in the following locations, numbers, days(d) of age (tetracycline marks by days of age in parentheses):

Juniata R.(various sites)	7,703,000	age 9-20d (3)and(3,6,9)
Susq. R.@ Montgomery Ferry	1,787,000	age 9-11d (3)
W. Br. Susq. R.	56,000	age 15d (5,9,13,21)
N. Br. Susq. R.	1,199,000	age 17-20d (3,6,9,12)
Conodoguinet Ck.	305,000	age 16d (9,12,15)
Conestoga R.	229,000	age 20d (3,9,12,15)
W. Conewago Ck.	321,000	age 16d (3,9,12)
Swatara Ck.	230,000	age 20d (3,6,9,15,18)
Standing Stone Ck.	2,200	fingerlings (double feed)

Juvenile American shad were collected at several locations in the Susquehanna River Basin during the summer and fall of 1998 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.

Methods

Juvenile American shad occurrence and distribution in the river above Conowingo Dam was assessed at several locations during the summer and fall of 1998.

<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 16 July through 21 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 evenings with a net measuring 400-ft x 6-ft with 3/8 in stretch mesh.

<u>Haul Seining - Tributaries</u>

The Conestoga River, Little Conestoga Creek (Lancaster County), W. Conewago Creek (York County), Swatara Creek (Dauphin/Lebanon County), and Conodoguinet Creek (Cumberland County) were sampled by seine on a weekly basis from 27 July through 27 August. A total of 300 hauls were conducted at 30 stations (Table 1) in the 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 (Figure 1) in the upper portion of Conowingo Pond between 12 June and 20 July, 1998 for a total of 12 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

Electrofishing was conducted by RMC/Normandaeu Assoc., Inc. At four sites, two on the Susquehanna River at Clemson Island and Columbia, and two on the Juniata River at Mifflintown and Greenwood, using a jon-boat and variable voltage pulsator electrofisher with anode mounted on bow. Sampling consisted of six 3 to 10 minute electrofishing runs per date at each site beginning at sunset and ending after dark. The Clemson Island site was sampled on three dates. Columbia, Mifflintown, and Greenwood were each sampled on two dates. All sampling was conducted during the month of August.

In an attempt to document the occurrence and distribution of adult alosids utilizing the fish lifts or being transported and released upriver, 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. - Conowingo Pond, Dock Street Dam (Harrisburg), and 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.

Ichthyoplankton Sampling

In an attempt to evaluate the reproductive success of transported river herring, icthyoplankton sampling was conducted on Conestoga Ck., Lancaster Co.

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 in mid-September and continuing every three days through mid-December. Sampling began at sunset and consisted of 10 lifts with 10 minute intervals between lift cycles.

At Conowingo Dam, RMC/Normandeau Assoc., Inc. checked cooling water strainers for impinged shad bi-weekly from October through December. Unlike past years, intake screen washes at Peach Bottom Atomic Power Station were not checked for impinged alosids.

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.

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 230 juveniles American shad were collected in 94 hauls for an overall Catch-Per-Unit-Effort (CPUE) of 2.45 shad per haul. Of the total 230 juveniles captured, 140 (60.9%) were taken on 29 July; 136 were captured in a single haul. Daily CPUE ranged from zero (11 August, 30 September, 14 October, 21 October) to 24.00 shad per haul (29 July). Table 2 shows juvenile shad catch and effort by date for in-river seine collections at Columbia in 1998.

Haul Seining - Tributaries

The only juvenile alosids captured during this study were eight American shad taken from W. Conewago Creek. Shad were collected at Stations 1, 3, 4, and 5 on W. Conewago Creek on three separate sampling occasions on 28 July, 4 August, and 20 August (Table 3). CPUE was not calculated due to small catches. Few gizzard shad were captured in 1998 seine collections. Observations of juvenile shad during float trips (Table 4) occurred on 9 September in W. Conewago Creek (approximately 24 observed at Stations 3 to 6) and on 15 September in Swatara Creek (approximately 7 observed at Stations 2 to 5). No juveniles were captured by cast-net.

Push-netting

A total of nine juvenile American shad were collected in approximately 600 min of push-netting. The majority (67%; n=6) were collected from the west shore of Lower Bear Island (Table 5) The remaining shad were collected from the west shore of Henry Island (n=2) and the east shore of Lower Bear Island (n=1). CPUE ranged from zero to 0.04. A total of 13 additional species were also collected (Table 5). Push-net sampling in Conowingo Pond during 1997 resulted in the capture of three juvenile blueback herring and no American shad. Few gizzard shad were captured in 1998 push-net collections.

Electrofishing

Four sites were sampled for a total of 634 minutes of shock time producing 18 juvenile American shad (Table 6). The Columbia site yielded 0.4 shad per hour of shock time. No juvenile shad were captured at the Clemson Island and Mifflintown in 1998. The Greenwood site yielded 7.0 shad per hour of shock time.

Boat electrofishing was conducted at the base of Dock Street Dam, Susquehanna River; Fabri Dam, Susquehanna River; Warrior Ridge Dam, Frankstown Branch of the Juniata River; and Raystown Dam, Raystown Branch of the Juniata River during 1998 spring migratory season (Table 7 and 8). Six adult American shad were captured in Conowingo Pond on 2 and 8 June. Seven adult American shad and one alewife were captured at the base of Dock Street Dam on 8 June 1998; others were observed but avoided capture. One adult American shad was captured at the base of the Fabri Dam in Sunbury on 8 June 1998. No alosids were captured or observed at the base of Warrior Ridge and Raystown dams.

As in 1997, no adult American shad or river herring were captured in any of the tributaries sampled by electrofishing during 1998.

<u>Ichthyoplankton Sampling</u>

Ichthyoplankton sampling in Little Conestoga Creek yielded no alosids. One clupeid larvae was captured but was too damaged for species identification.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam Inner Forebay was conducted from 14 September and continued every three days until 10 December. A total of 180 juvenile American shad were captured in 230 lifts for an overall CPUE of 0.78 shad per lift (Table 9). Highest daily catch occurred on 29 October resulting in a CPUE of 4.9 fish per lift. Two adult American shad were also captured by lift-net in 1998; no blueback herring were captured. Few gizzard shad were observed in the 1998 lift-net collections.

Cooling water strainers and intake screens at the Conowingo and Holtwood hydroelectric projects were examined for impinged fish twice per week from October through December. No alosids were present.

Susquehanna River Mouth and Flats

As part of a fin fish survey, Maryland DNR researchers collected 113 juvenile American shad in the upper Chesapeake Bay during August through October.

Otolith Mark Analysis

Otoliths from 434 juvenile American shad taken in the summer and fall collections were analyzed for hatchery marks. A total of

155 juvenile shad otoliths from seine and electrofishing collections above Holtwood Dam was successfully processed (Table 10). Overall, 149 (96%) of the fish were marked and the remaining 6 (4%) fish were wild. All but one of the 24 juveniles collected by electrofishing were hatchery produced with the single wild fish collected at Greenwood on 24 August. Seine collections from Columbia included 119(96%) hatchery fish and 5(4%) wild fish. Of the 8 juvenile shad captured with seines on W. Conewago Creek, all were hatchery produced and stocked in W. Conewago Creek prior to sampling.

Otoliths from a total of 166 juvenile American shad collected at Holtwood Dam and Conowingo Pond were successfully processed. Overall, 155 (93%) of the fish were marked and the remaining 11 fish (7%) were wild. Three of the nine juvenile American shad captured by push-net in Conowingo Pond were wild fish. 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 113 juvenile American shad processed from DNR collections in the upper Bay, only 2 (1%) were hatchery marked with the remaining 111 fish (99%) being wild. Maryland DNR did not stock shad larvae in the Susquehanna River during 1998.

Discussion

In-Stream Movements and Outmigration Timing

River conditions during 1998 could be characterized by abnormally high spring flows followed by drought conditions and elevated water temperatures in the summer and fall. Despite lower than anticipated seine and lift-net catches for the 1998 juvenile sampling season, the general pattern of in-stream movement and timing of outmigration was similar to those observed in previous years. The pattern of occurrence of juveniles, present in July and moving downstream in mid-October, remained essentially the same. The 1998 seine collections are best characterized by highest catches in July (CPUE 8.8) through August(CPUE 1.8) and lowest catches in September (CPUE 0.3) through October (CPUE 0.5). Approximately 94% of this year's juvenile shad collected by seine occurred in the months of July and August. During July and August, juvenile shad utilize the Columbia area as nursery water and their abundance is higher than in September and October when decreasing water temperatures and increasing river flows trigger outmigration. In addition, lower than normal river flows and high water clarity in late summer and fall may have also contributed to low seine catches during the second half of the 1998 seining season.

The first marked fish collected at Columbia by seine occurred on 16 July. These included ten shad stocked in the Juniata River (various sites) and/or Montgomery Ferry on the Susquehanna. Fish stocked in the N. Branch of the Susquehanna at Berwick were first captured by seine at Columbia on 21 July suggesting a movement of approximately 120 miles in no more than 56 days. Fish stocked in Swatara Creek near Union Deposit were first appeared in the Columbia collections on 29 July suggesting a movement of approximately 30 miles within 59 days or less. All stockings sites with the exception of the W. Branch of the Susquehanna River, Conestoga River, and Standing Stone Creek were represented in the Columbia collections. Five juvenile shad stocked in the W. Conewago Creek near Detter's Mill were collected approximately 16 miles downstream near the intersection of Interstate 83.

Based on lift-net catches at Holtwood Dam, peak outmigration of juvenile American shad occurred from 11 October through 10 November with 93% of the juveniles captured in that time period. This pattern is consistent with previous years. The CPUE during peak outmigration period ranged from zero to 4.9 shad per lift. Generally, outmigration of juvenile American shad is episodic in nature. Typically it occurs when water temperature falls below 50 F and river flow increase, with the majority of the outmigration occurring in a one to three week period. This years sampling effort occurred during a historic low flow period. The drought conditions experienced this fall resulted in above normal water temperatures for most of the season. In addition, it was the first year since 1985 that all emigrating juvenile American shad would have to pass through the powerhouse at Holtwood Dam; no spill occurred during the sampling period in 1998. Although the 1998 hatchery production of American was one of the best on record, results of lift-netting indicate that the number shad emigrating this year was well below the 14-year average. The impact of the 1998 drought had on this year's outmigration is unknown, it is possible that flow and temperature may have influenced the timing of emigration. The collection of six juvenile American shad by lift-net on the 10 December (final sampling date) appeared to indicate that lower than normal river flows and above normal river temperatures during late summer and fall may have protracted this year's outmigration. In 1991, low catches at Holtwood was attributed to gear avoidance brought about by similar drought conditions. All stockings sites with the exception of the W. Branch of the Susquehanna River, Conestoga River, and Standing Stone Creek were represented in the Holtwood collections. The table below list CPUE by lift-net since 1985:

Year	Dates	Effort (lifts)	Shad Catch	CPUE
1997	10/18-12/2	160	1,372	8.60
1996	Lift netting did not occur due to flood damage of net platform			
1995	10/06-11/08	100	2,100	21.00
1994	09/08-11/17	210	206	0.98
1993	09/28-11/22	170	1,093	6.43
1992	09/17-10/29	130	39	0.30
1991	10/14-12/16	210	208	0.99
1990	09/26-11/16	200	3,980	19.90
1989	09/22-10/26	116	556	4.79
1988	10/26-12/07	154	929	6.03
1987	09/10-11/20	358	832	2.32
1986	10/06-12/02	393	2,928	7.45
1985	10/16-12/19	378	3,625	9.59
	Average	**215**	**1,489**	**7.36**

Juvenile shad stocked in the Juniata and/or Susquehanna River at Montgomery Ferry were collected by push-net in Conowingo Pond on 15 June and Maryland DNR in the Upper Bay on 20 July. This suggests early outmigration may have occurred as a result of high spring river flows which could have effectively flushed large numbers of young shad out of the system. Flushing could also explain poor catches of juvenile American shad by all gear types on the main stem above Holtwood Dam. Low catches of juvenile shad were also observed in the fall of 1992 after higher than normal river flows in late summer and early fall. In 1998, Maryland DNR observed high catches of juvenile shad in the Upper Bay; a percentage of these individuals may have been spawned in the Susquehanna River.

Location of catches and abundance of adult American shad was similar to those observed in 1997. Transported adult American shad released at Tri-Counry Marina migrated a distance of approximately 60 miles to the base of the Fabri dam at Sunbury. In past years, adult American shad have been observed in the Juniata River near Lewistown. However, sampling at the base Warrior Ridge and Raystown have yet to document the presence of adults American shad in the Frankstown and Raystown branches of the Susquehanna.

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. Monthly CPUE for 1998 seining at Columbia was highest in July (8.8) and lowest in September (0.3). Overall CPUE (all months combined) of 2.45 per haul is the third lowest on record since 1992. Over approximately the same time period in 1997, 1996, 1995, 1994, 1993, and 1992, CPUE in the Columbia vicinity averaged 9.77, 2.70, 4.79, 3.24, 1.76, and 1.99, respectively. A single haul produced 136 juvenile shad and more than 50% of the years total catch during the 1998 sampling season.

Tributary seining efforts resulted in the capture of few shad. However, it remains the best method to evaluate juvenile abundance in tributaries. Tributary seining was first initiated in 1997 on the Conestoga River, Little Conestoga Creek, and W. Conewago Creek. Catches for 1997 included 17 juvenile American shad from the Conestoga River.

Since 1996, efforts to use electrofishing to overcome difficulties in net sampling to catch juveniles have experienced marginal success. 1998 Catches of juvenile shad at Columbia, Clemson Island, and Mifflintown were below those observed in previous years. Electrofishing CPUE (fish per hour) at Columbia was 0.4 during the 1998 sampling season. This is well below the CPUE of 8.5 and 11.5 in observed 1996 and 1997, respectively. No juvenile shad were captured at Clemson Island in 1998. This compares to 5.2 and 2.2 during approximately the same time period in 1997 and 1996, respectively. No juvenile shad were captured at Mifflintown in 1998. This compares to 12.6 and 0.3 during approximately the same time period in 1997 and 1996, respectively. The inability to catch fish at Clemson Island and Mifflintown coupled with the lack of dimpling observed suggests that the juvenile shad were not present at these sites in any abundance. This is supported by the fact that juveniles were successfully captured at Greenwood during approximately the same time period; the Greenwood site yielded 7.0 shad per hour of shock time. 1998 was the first year that Greenwood was sampled. Unlike previous years, little if any dimpling was observed prior to electrofishing offering further support that juvenile shad abundance may have been low in the river sections sampled. Extreme low flows in conjunction with clear water conditions may have also influenced juvenile distribution and catchability. Despite some drawbacks, electrofishing remains one of the few sampling methods for collecting juveniles in areas where haul seining is impractical. Electrofishing may 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. Total CPUE for juvenile shad by electrofishing in 1998 (all sites combined) was 2.0 fish per hour, 1/4 of that observed in 1997.

Push-netting has been demonstrated to be successful at catching juvenile alosids. 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 were not at levels anticipated. It is unclear if lower than anticipated catches were the result of net design and techniques, low alosid abundance, gear avoidance due to water clarity, or some other undetermined factor(s). Push-netting remains the most effective method of sampling juveniles in the lower Susquehanna River impoundments.

Lift-netting at Holtwood Dam is considered historically the best indicator of juvenile stock abundance. CPUE for lift-netting in 1998 was 0.78 fish per lift, the second lowest on record since 1985. This compares to 1,372 juveniles in 160 lifts (CPUE 8.6) during 1997, and 2100 juveniles in 100 lifts (CPUE 21.0) during 1995. Lift-netting was not conducted in 1996. Catches for 1998 are considerably lower than the long-term average CPUE of 7.36 from 1985 to 1997. Low CPUE by lift-net does not necessarily represent a poor juvenile year-class or predict adult recruitment. The lowest recorded CPUE (0.30) for juvenile shad by lift-net occurred in 1992. Total recruitment of adults from this cohort to the Conowingo lifts is presently within the range of previous year-classes even though it will not fully recruited until 1999 or possible 2000 (Table 11). Likewise, the ratio of adults transported in 1992 to their progeny recruited as adults is the second lowest on record since 1986 (Table 13). The number of larvae stocked in 1992 to recruit a single adult fish to Conowingo was also the second lowest since 1986 (Table 11). During each of its first two operating seasons, the fish lift at Holtwood Dam has lifted less than 30% of the American shad passed at Conowingo Dam. Reproductive success of these adults spawning below Holtwood Dam is not known and may be substantial. Failure to capture juvenile blueback herring by lift-net in 1998 reflects that fact that few pre-spawn adults were released upriver and, as a result, reproduction was most likely low. In 1997, twenty-six blueback herring were captured by lift-net with approximately six times as many adults transported than in 1998. The concurrent low numbers of gizzard shad collected during sampling and no shad collected from strainers and intake screens at Holtwood and Conowingo dams may suggest that environmental conditions were not conducive for survival of young clupeids.

Growth

Juvenile American shad collected with seines at Columbia averaged approximately 76 mm total length (TL) from 21 July to 29 July (range 56-88 mm) and grew to an average 117 mm (range 109-122 mm) by 16 September to 22 September. Growth of wild fish was difficult to assess due to few individuals captured. Total length of wild juveniles captured by seine and lift net was 68 mm on 4 August to 170 mm on 20 October. Growth of hatchery and wild fish appeared to be similar. Average length of juvenile shad captured by lift net on 10 December, the last sampling event during 1998, was 158mm (range 140-169 mm). Growth was similar to that observed in past years.

Stock Composition and Mark Analysis

Of the 321 juvenile shad otoliths analyzed from collections above Conowingo Dam, 17 (5%) were unmarked. This compares to 11% wild fish in 1997 collections, and 21-58% in 1991-1996. The high percentage of hatchery juveniles observed in 1998 may be due, in part, to changes in stocking procedures. 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, as well as low passage effectiveness and unstable river conditions during the spawn may have reduced natural reproduction. The presence of Susquehanna basin marked juveniles in Upper Bay collections in July suggest that at least a small percentage of juveniles used the Upper Bay as nursery waters. These fish may have been flushed out of the system during high river flows that occurred in early spring. It is reasonable to assume that progeny of spawned between Conowingo and Holtwood dams may have also experienced a similar fate. However, since these juveniles would be of wild origin and undistinguishable, this assumption is only speculation. Survival of the 1998 year-class will not be determined until they are fully recruited as adults. Relative survival of larval shad from the various stocking locations, in terms of their recovery rates above and below Holtwood Dam, is discussed in Job III.

Summary

- Juvenile American shad were successfully collected by haul seine, electrofisher, push-net and lift-net.
- Haul seining CPUE of 2.45 was the third lowest ever recorded for that gear since sampling at Columbia was standardized in 1992.
- Electrofishing CPUE for juvenile shad (all sites combined) was 2.0 fish per hour, the lowest recorded since sampling began in 1996.
- Lift-netting at Holtwood resulted in a CPUE of 0.78 fish per lift, the second lowest on record since 1985.
- Push-netting catches in Conowingo Pond were up slightly compared to 1997.
- Peak out-migration based on lift-net collections occurred during October/November.
- Low river flows and slowly decreasing water temperatures may have partially delayed and/or protracted the juvenile outmigration period.
- Otolith analysis determined that only 5% of the juveniles collected above Conowingo Dam were of wild origin.
- Despite having excellent hatchery production, the abundance

of juvenile American shad in the Susqhehanna River Basin based on catch returns was poor compared to prior years.

- Several factors may have attributed to low catches of juveniles in 1998 including: 1) poor reproductive success of transported adults; 2) high juvenile mortality; 3) ineffective sampling methods due to low river flows and high water clarity; 4) low juvenile abundance in the drainage because young shad were flushed out of the system from high spring river flows.
- The survival and composition (hatchery verses wild) of the 1998 year-class can not be completely assessed until the cohort is fully recruited as adults.

Acknowledgments

RMC/Normandeau and Associates (Drumore, PA) and The Wyatt Group, Inc. (Lancaster, 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 (RMC), Timothy Robbins (Wyatt), and Mike Hendricks, Mike Kaufmann, Larry Jackson (PFBC). Gina Russo and Kevin Walters processed most of the otoliths and Ted Jacobsen (Ecology III) administered the otolith contract.

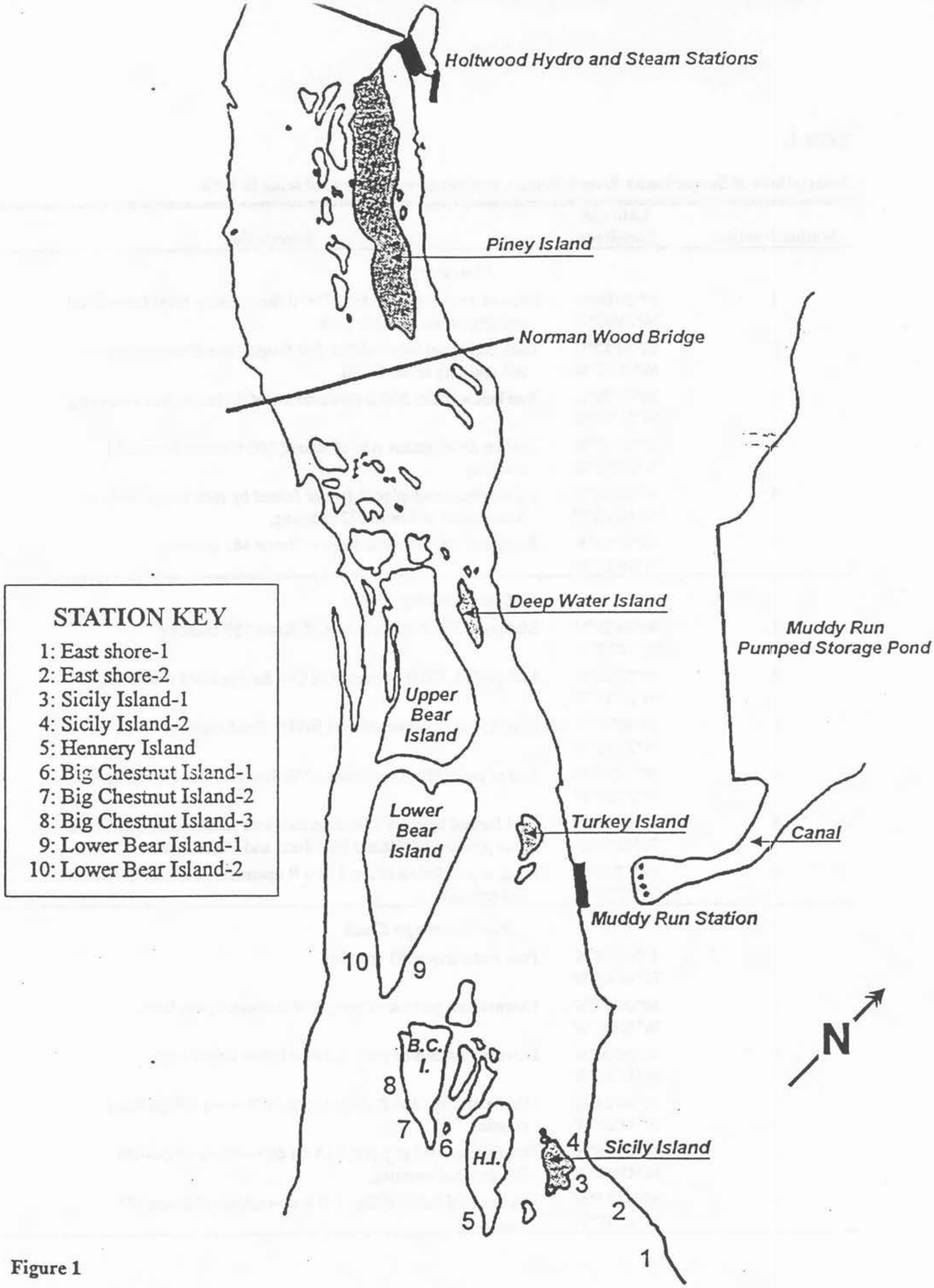


Figure 1

Map of Conowingo Pond showing location of spring 1998 push-net stations.

Table 1.

Descriptions of Susquehanna River tributary stations sampled by haul seine in 1998.

Station Number	Latitude Longitude	Description
		Conestoga River
1	39°56'04"N 76°23'05"W	Head of pool below riffle; 1,700 ft downstream from River Road crossing at Safe Harbor park.
2	39°57'42"N 76°21'57"W	Back eddy/pool below riffle; 200 ft upstream of township road 561 crossing at Rock Hill.
3	39°57'59"N 76°21'28"W	Run below riffle; 300 ft downstream of Steinman Road crossing.
4	39°59'47"N 76°18'38"W	Pool on downstream side of island; 300 ft above Route 324 crossing.
5	40°00'40"N 76°18'16"W	Downstream end of pool (water funnel by rock ledge); 0.72 mi downstream of Route 222 crossing.
6	40°02'13"N 76°16'15"W	Run/pool; 300 ft downstream of Route 462 crossing.
		Little Conestoga River
1	40°00'19"N 76°22'27"W	Mid pool; 300 ft downstream of Route 999 crossing.
2	39°59'15"N 76°22'52"W	Mid pool; 1,700 ft upstream of Owl Bridge Road crossing.
3	39°59'02"N 76°22'42"W	Run; 150 ft upstream of Owl Bridge Road crossing.
4	39°58'20"N 76°22'32"W	End of pool; 450 ft upstream of Walnut Hill Road crossing.
5	39°57'59"N 76°22'26W	Pool formed by entry of Indian Run into Little Conestoga Creek, near junction of Walnut Hill Road and Creek Road.
6	39°57'39"N 76°22'20"W	Head of pool below riffle; 1,200 ft upstream of township road 561 crossing.
		West Conewago Creek
1	40°06'09"N 76°46'43"W	Pool under Route 83 crossing.
2	40°06'07"N 76°46'06"W	Downstream portion of pool; 250 ft above Hykes Dam.
3	40°06'00"N 76°45'48"W	Downstream end of pool; 1,350 ft below Hykes Dam.
4	40°06'24"N 76°44'28"W	Middle of pool; 300 ft downstream of Bowers Bridge Road crossing.
5	40°05'39"N 76°43'46"W	Downstream end of pool; 1.13 mi downstream of Bowers Bridge Road crossing.
6	40°04'55"N 76°42'57"W	Head of pool below riffle; 750 ft downstram of Route 181 crossing.

Table 1.

Continued.

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

Table 2.

Juvenile American shad catch per effort (CPUE), standard deviation, variance, and confidence for haul seining at Columbia on the lower Susquehanna River, 1998.

Date	Number of Hauls	Number of American Shad	CPUE	Standard Deviation	Variance	Confidence Interval
16 Jul	7	10	1.43	1.99	3.95	1.47
21 Jul	6	14	2.33	3.83	14.67	3.06
29 Jul	6	144	24.00	54.90	3014.00	43.93
04 Aug	6	30	5.00	6.69	44.80	5.36
11 Aug	7	0	0.00	0.00	0.00	0.00
19 Aug	7	9	1.29	1.70	2.90	1.26
26 Aug	7	10	1.43	3.36	11.29	2.49
02 Sep	6	3	0.50	1.22	1.50	0.98
09 Sep	6	3	0.50	1.22	1.50	0.98
16 Sep	6	3	0.50	1.22	1.50	0.98
22 Sep	6	1	0.17	0.41	0.17	0.33
30 Sep	6	0	0.00	0.00	0.00	0.00
07 Oct	6	3	0.50	1.22	1.50	0.98
14 Oct	6	0	0.00	0.00	0.00	0.00
21 Oct	6	0	0.00	0.00	0.00	0.00

Table 3.

Summary of fishes collected by haul seine in west Conewago Creek, 1998.

Location	Sample Number	River Flow (cfs)	Water Temp. (°C)	Secchi (in)	Start Time	Finish Time	Number of Shad	Other Species
					28-Jul			
1	1	75	24.5	>15	0845	0855	1	CS, SFS
	2	75	24.5	>15	0905	0915	2	SMB, CS, SFS
2	1	75	26.0	12	0955	1010	0	GZS, SMB, CS, SFS, STS, PS, RH, BNM
	2	75	26.0	12	1025	1035	0	SMB, CS, SFS, STS, PS, NHS, BNM
3	1	75	25.5	12	1050	1058	0	SMB, SFS, STS, NHS, RB
	2	75	25.5	12	1100	1110	1	SMB, SFS, STS, NHS
4	1	75	25.5	15	1125	1135	0	CS, SFS, STS, PS, NHS
	2	75	25.5	15	1146	1156	1	CS, SFS, TD
5	1	75	27.0	18	1215	1224	0	SMB, CS, SFS
	2	75	27.0	18	1226	1238	0	SFS, WE, CCF
6	1	75	26.0	15	1254	1305	0	SFS
	2	75	26.0	15	1315	1325	0	CS, SFS, CC
					4-Aug			
1	1	91	23.0	12	0825	0830	1	SMB, CC, STS, TD, RH
	2	91	23.0	12	0833	0840	0	SMB, CC, SWT, TD
2	1	91	23.2	15	0910	0916	0	GZS, SMB, STS
	2	91	23.2	15	0925	0935	0	SMB, STS, PS, BG, NHS, CS, GS
3	1	91	24.0	15	0943	0946	0	STS
	2	91	24.0	15	0949	0955	0	SMB, STS, GS, RB, SFS
4	1	91	24.0	12	1010	1015	0	STS, SFS
	2	91	24.0	12	1020	1025	0	STS, SFS
5	1	91	24.0	15	1033	1037	0	STS, SFS
	2	91	24.0	15	1045	1050	1	SMB, STS, SFS, WE
6	1	91	24.0	12	1106	1112	0	STS, SFS
	2	91	24.0	12	1120	1126	0	BG, SFS
					11-Aug			
1	1	960	22.0	0	0850	0856	0	STS, SFS, CS, PS, BG, SMB, RB
	2	960	22.0	0	0900	0906	0	STS, SFS, CS, SMB, TD
2	1	960	Water very high, too much flow to sample					
	2	960	Water very high, too much flow to sample					
3	1	960	22.0	0	0935	0940	0	STS, SFS
	2	960	22.0	0	0942	0947	0	STS, SFS, BNM
4	1	960	22.5	0	1016	1022	0	STS, SFS, RB, BNM
	2	960	22.5	0	1024	1030	0	STS, SFS, PS, SMB, TD, BNM, CCF
5	1	960	23.5	0	1048	1055	0	
	2	960	23.5	0	-	-	0	
6	1	960	23.5	0	1050	1105	0	STS, SFS, RB, TD
	2	960	23.5	0	1105	1120	0	GZS, STS, SFS, TD

Table 3.

Continued.

Location	Sample Number	River Flow (cfs)	Water Temp. (°C)	Secchi (in)	Start Time	Finish Time	Number of Shad	Other Species
					20-Aug			
1	1	168	21.0	8	0956	1003	0	SFS
	2	168	21.0	8	1006	1009	0	SFS, PS, CS
2	1	168	20.5	6	0928	0930	0	SFS, FF
	2	168	20.5	6	-	-	0	
3	1	168	20.5	5	0855	0900	0	SFS, PS
	2	168	20.5	5	0901	0907	0	SFS, TD, FF, WS, NHS, CS
4	1	168	20.0	8	0835	0840	1	SFS, SMB
	2	168	20.0	8	0841	0846	0	SFS, SMB, TD, FF
5	1	168	20.0	8	0815	0822	0	SFS, CMS, SMB
	2	168	20.0	8	0823	0830	0	SFS, CMS, SMB, TD, PS
6	1	168	20.5	6	0735	0740	0	SFS, CMS
	2	168	20.5	6	0745	0755	0	CMS
					27-Aug			
1	1	74	27.5	>8	1230	1235	0	SFS, STS
	2	74	27.5	>8	1237	1240	0	SMB, SFS, STS, TD
2	1	74	25.8	6	1147	1151	0	GZS, SMB, SFS, STS, CS, LMB, BG, SWT
	2	74	25.8	6	1205	1206	0	SFS, STS, CS, MS, BG, SWT, UN, WC
3	1	74	26.0	6	1120	1123	0	SFS, STS, CS, MS, CC
	2	74	26.0	6	1130	1134	0	SMB, SFS, NHS, CS, MS, LMB, CC
4	1	74	25.5	8	1058	1101	0	SFS, STS, CS, MS
	2	74	25.5	8	1103	1106	0	SFS, CS, MS
5	1	74	26.0	10	1037	1040	0	SFS
	2	74	26.0	10	1047	1051	0	SFS, NHS, STS, CS
6	1	74	25.5	3	1018	1020	0	SMB, SFS
	2	74	25.5	3	1021	1023	0	SMB, SFS

BD =banded darter
BG =bluegill
BNM =bluntnose minnow
CC =creek chub
CCF =channel catfish
CLM =cutlips minnow
CMS =common shiner
CS =comely shiner
D =dace
FF =fallfish
GS =golden shiner
GSD =greenside darter
GZS =gizzard shad
HS =hogsucker
KF =killifish
LMB =largemouth bass
LND =longnose dace
LP =logperch
MMT =margined madtom
MS =mimic shiner
NHS =northern hogsucker
PS =pumpkinseed
RB =rock bass
RBS =redbreast sunfish
RH =redhorse
SD =shield darter
SFS =spotfin shiner
SMB =smallmouth bass
STS =spottail shiner
SWT =swallotail
TD =tesselated darter
UN =unknown
WC =white crappie
WE =walleye
WS =white sucker

Table 4.

Summary of reconnaissance surveys in the Conewago, Conodoguinet, and Swatara creeks and Conestoga River, 1998.

	Conewago Creek	Conodoguinet Creek	Swatara Creek	Conestoga River
Date	9-Sep	10-Sep	15-Sep	16-Sep
Water temperature (°C)	20	19.5	25	28
Secchi (in)	9	36	30	28
Flow (cfs)	54	162	130	180
Miles covered	3 to 4	5 to 6	7	8
Station	Stations 3 to 6	Stations 4 to 1	Stations 5 to 2	Stations 5 to 3
Observation of juvenile American shad	approximately 24	0	approximately 7	0

Table 5.

Summary of Conowingo Pond push-net sampling, spring/summer 1998.

Date	Location	Water Temperature (°C)	Average Daily River Flow (cfs)	Start Time	End Time	Number of American Shad	CPUE (#/50 min)	Other Species*
12 Jun	East Shore (1)	20.5	15,200	1953	1958	0	-	-
12 Jun	East Shore (2)	20.5	15,200	2001	2005	0	-	-
12 Jun	Sicily Island (1)	20.5	15,200	2014	2017	0	-	-
12 Jun	Sicliy Island (2)	20.5	15,200	2025	2030	0	-	GS
12 Jun	Hennery Island	20.5	15,200	2049	2054	0	-	GS
12 Jun	Big Chestnut Island (1)	20.5	15,200	2102	2107	0	-	YP
12 Jun	Big Chestnut Island (2)	20.5	15,200	2125	2130	0	-	SMB
12 Jun	Big Chestnut Island (3)	20.5	15,200	2218	2222	0	-	SMB
12 Jun	Lower Bear Island (1)	20.5	15,200	2228	2233	0	-	-
12 Jun	Lower Bear Island (2)	20.5	15,200	2240	2245	0	-	SMB
					Subtotal	*0*	*0*	
15 Jun	East Shore (1)	20.0	29,100	1953	1958	0	-	-
15 Jun	East Shore (2)	20.0	29,100	2002	2007	0	-	SMB, YP
15 Jun	Sicily Island (1)	20.0	29,100	2015	2020	0	-	QB
15 Jun	Sicliy Island (2)	20.0	29,100	2028	2033	0	-	SMB
15 Jun	Hennery Island	20.0	29,100	2045	2050	1	-	SMB, CS
15 Jun	Big Chestnut Island (1)	20.0	29,100	2108	2113	0	-	SMB, CS
15 Jun	Big Chestnut Island (2)	20.0	29,100	2120	2125	0	-	SMB
15 Jun	Big Chestnut Island (3)	20.0	29,100	2132	2136	0	-	SMB, QB, HS
15 Jun	Lower Bear Island (1)	20.0	29,100	2155	2200	0	-	SMB, RB, ST, TD, BB
15 Jun	Lower Bear Island (2)	20.0	29,100	2209	2214	1	-	SMB
					Subtotal	*2*	*0.04*	
18 Jun	East Shore (1)	22.5	39,200	1945	1950	0	-	-
18 Jun	East Shore (2)	22.5	39,200	1957	2002	0	-	-
18 Jun	Sicily Island (1)	22.5	39,200	2012	2017	0	-	-
18 Jun	Sicliy Island (2)	22.5	39,200	2026	2031	0	-	-
18 Jun	Hennery Island	22.5	39,200	2045	2050	0	-	-
18 Jun	Big Chestnut Island (1)	22.5	39,200	2052	2057	0	-	-

Table 5.

Continued.

Date	Location	Water Temperature (°C)	Average Daily River Flow (cfs)	Start Time	End Time	Number of American Shad	CPUE (#/50 min)	Other Species*
18 Jun	Big Chestnut Island (2)	22.5	39,200	2116	2121	0	-	LMB, CS, CC
18 Jun	Big Chestnut Island (3)	22.5	39,200	2131	2136	0	-	LMB, CS, CC
18 Jun	Lower Bear Island (1)	22.5	39,200	2144	2149	0	-	SMB, CS, WS, CC, TD
18 Jun	Lower Bear Island (2)	22.5	39,200	2158	2203	1	-	CS
					Subtotal	*1*	*0.02*	
21 Jun	East Shore (1)	24.5	35,800	1948	1953	0	-	-
21 Jun	East Shore (2)	24.5	35,800	1958	2003	0	-	-
21 Jun	Sicily Island (1)	24.5	35,800	2011	2016	0	-	-
21 Jun	Sicliy Island (2)	24.5	35,800	2031	2036	0	-	-
21 Jun	Hennery Island	24.5	35,800	2046	2051	0	-	CS, WS
21 Jun	Big Chestnut Island (1)	24.5	35,800	2056	2103	0	-	CS
21 Jun	Big Chestnut Island (2)	24.5	35,800	2109	2114	0	-	CS
21 Jun	Big Chestnut Island (3)	24.5	35,800	2120	2125	0	-	CS, SMB, CC
21 Jun	Lower Bear Island (1)	24.5	35,800	2212	2217	0	-	YP, SMB, CC
21 Jun	Lower Bear Island (2)	24.5	35,800	2222	2227	2	-	CC
					Subtotal	*2*	*0.04*	
24 Jun	East Shore (1)	26.5	32,000	2011	2016	0	-	GS
24 Jun	East Shore (2)	26.5	32,000	2023	2028	0	-	GS
24 Jun	Sicily Island (1)	26.5	32,000	2033	2037	0	-	
24 Jun	Sicliy Island (2)	26.5	32,000	2043	2048	0	-	
24 Jun	Hennery Island	26.5	32,000	2059	2104	0	-	GS
24 Jun	Big Chestnut Island (1)	26.5	32,000	2111	2116	0	-	GS, CS
24 Jun	Big Chestnut Island (2)	26.5	32,000	2126	2131	0	-	CS, SMB, ST
24 Jun	Big Chestnut Island (3)	26.5	32,000	2138	2143	0	-	MS, CC
24 Jun	Lower Bear Island (1)	26.5	32,000	2152	2157	0	-	SMB, CC, BD
24 Jun	Lower Bear Island (2)	26.5	32,000	2206	2217	0	-	CS, ST, CC
					Subtotal	*0*	*0*	

Table 5.

Continued.

Date	Location	Water Temperature (°C)	Average Daily River Flow (cfs)	Start Time	End Time	Number of American Shad	CPUE (#/50 min)	Other Species*
27 Jun	East Shore (1)	28.0	28,300	1949	1954	0	-	
27 Jun	East Shore (2)	28.0	28,300	2001	2006	0	-	SMB, CC
27 Jun	Sicily Island (1)	28.0	28,300	2013	2018	0	-	YP
27 Jun	Sicliy Island (2)	28.0	28,300	2024	2029	0	-	WS
27 Jun	Hennery Island	28.0	28,300	2041	2046	1	-	CS, LMB
27 Jun	Big Chestnut Island (1)	28.0	28,300	2056	2106	0	-	CS, GS
27 Jun	Big Chestnut Island (2)	28.0	28,300	2112	2117	0	-	CS
27 Jun	Big Chestnut Island (3)	28.0	28,300	2122	2127	0	-	CS
27 Jun	Lower Bear Island (1)	28.0	28,300	2135	2140	0	-	CS
27 Jun	Lower Bear Island (2)	28.0	28,300	2147	2153	1	-	CS,GS
					Subtotal	*2*	*0.04*	
1 Jul	East Shore (1)	26.5	22,500	1959	2004	0	-	GS
1 Jul	East Shore (2)	26.5	22,500	2010	2015	0	-	GS
1 Jul	Sicily Island (1)	26.5	22,500	2023	2028	0	-	GS
1 Jul	Sicliy Island (2)	26.5	22,500	2036	2041	0	-	GS
1 Jul	Hennery Island	26.5	22,500	2048	2053	0	-	GS
1 Jul	Big Chestnut Island (1)	26.5	22,500	2103	2108	0	-	GS
1 Jul	Big Chestnut Island (2)	26.5	22,500	2115	2120	0	-	CS, GS
1 Jul	Big Chestnut Island (3)	26.5	22,500	2126	2131	0	-	GS
1 Jul	Lower Bear Island (1)	26.5	22,500	2139	2144	0	-	CS, GS
1 Jul	Lower Bear Island (2)	26.5	22,500	2152	2156	0	-	GS
					Subtotal	*0*	*0*	
6 Jul	East Shore (1)	25.8	26,900	2000	2005	0	-	
6 Jul	East Shore (2)	25.8	26,900	2010	2015	0	-	
6 Jul	Sicily Island (1)	25.8	26,900	2020	2025	0	-	
6 Jul	Sicliy Island (2)	25.8	26,900	2030	2035	0	-	
6 Jul	Hennery Island	25.8	26,900	2045	2050	0	-	GS, CS
6 Jul	Big Chestnut Island (1)	25.8	26,900	2100	2105	0	-	
6 Jul	Big Chestnut Island (2)	25.8	26,900	2114	2119	0	-	CS

Table 5.

Continued.

Date	Location	Water Temperature (°C)	Average Daily River Flow (cfs)	Start Time	End Time	Number of American Shad	CPUE (#/50 min)	Other Species*
6 Jul	Big Chestnut Island (3)	25.8	26,900	2122	2122	0	-	CS
6 Jul	Lower Bear Island (1)	25.8	26,900	2133	2138	0	-	CC
6 Jul	Lower Bear Island (2)	25.8	26,900	2146	2151	0	-	GS, CS, CC, ST
					Subtotal	***0***	***0***	
9 Jul	East Shore (1)	25.0	32,100	1956	1959	0	-	GS, ST
9 Jul	East Shore (2)	25.0	32,100	2006	2011	0	-	GS, ST
9 Jul	Sicily Island (1)	25.0	32,100	2016	2021	0	-	
9 Jul	Sicliy Island (2)	25.0	32,100	2026	2031	0	-	
9 Jul	Hennery Island	25.0	32,100	2040	2045	0	-	GS
9 Jul	Big Chestnut Island (1)	25.0	32,100	2051	2056	0	-	
9 Jul	Big Chestnut Island (2)	25.0	32,100	2103	2108	0	-	
9 Jul	Big Chestnut Island (3)	25.0	32,100	2113	2118	0	-	GS, CS, CC
9 Jul	Lower Bear Island (1)	25.0	32,100	2125	2130	0	-	CC
9 Jul	Lower Bear Island (2)	25.0	32,100	2138	2143	1	-	GS, CS
					Subtotal	***1***	***0.02***	
12 Jul	East Shore (1)	24.5	49,100	1950	1955	0	-	GS,
12 Jul	East Shore (2)	24.5	49,100	1959	2004	0	-	CS
12 Jul	Sicily Island (1)	24.5	49,100	2010	2015	0	-	CS
12 Jul	Sicliy Island (2)	24.5	49,100	2021	2026	0	-	
12 Jul	Hennery Island	24.5	49,100	2034	2039	0	-	WC
12 Jul	Big Chestnut Island (1)	24.5	49,100	2045	2050	0	-	GS
12 Jul	Big Chestnut Island (2)	24.5	49,100	2054	2059	0	-	GS, CS
12 Jul	Big Chestnut Island (3)	24.5	49,100	2103	2108	0	-	CS
12 Jul	Lower Bear Island (1)	24.5	49,100	2115	2120	0	-	GS, CS
12 Jul	Lower Bear Island (2)	24.5	49,100	2125	2130	0	-	GS
					Subtotal	***0***	***0***	

Table 5.

Continued.

Date	Location	Water Temperature (°C)	Average Daily River Flow (cfs)	Start Time	End Time	Number of American Shad	CPUE (#/50 min)	Other Species*
15 Jul	East Shore (1)	26.0	23,800	1947	1952	0	-	CS
15 Jul	East Shore (2)	26.0	23,800	1957	2003	0	-	GS
15 Jul	Sicily Island (1)	26.0	23,800	2009	2014	0	-	CS
15 Jul	Sicliy Island (2)	26.0	23,800	2018	2023	0	-	-
15 Jul	Hennery Island	26.0	23,800	2031	2036	0	-	-
15 Jul	Big Chestnut Island (1)	26.0	23,800	2042	2047	0	-	CS
15 Jul	Big Chestnut Island (2)	26.0	23,800	2053	2055	0	-	CS
15 Jul	Big Chestnut Island (3)	26.0	23,800	2105	2110	0	-	CS
15 Jul	Lower Bear Island (1)	26.0	23,800	2115	2120	1	-	GS
15 Jul	Lower Bear Island (2)	26.0	23,800	2130	2135	0	-	CS
					Subtotal	***1***	***0.02***	
20 Jul	East Shore (1)	27.0	13,300	2013	2018	0	-	CS
20 Jul	East Shore (2)	27.0	13,300	2023	2028	0	-	GS
20 Jul	Sicily Island (1)	27.0	13,300	2034	2039	0	-	-
20 Jul	Sicliy Island (2)	27.0	13,300	2043	2048	0	-	-
20 Jul	Hennery Island	27.0	13,300	2057	2102	0	-	CS, CC
20 Jul	Big Chestnut Island (1)	27.0	13,300	2109	2114	0	-	CC
20 Jul	Big Chestnut Island (2)	27.0	13,300	2115	2020	0	-	CC
20 Jul	Big Chestnut Island (3)	27.0	13,300	2130	2035	0	-	CS, CC
20 Jul	Lower Bear Island (1)	27.0	13,300	2143	2048	0	-	CS, CC
20 Jul	Lower Bear Island (2)	27.0	13,300	2158	2203	0	-	GS, CC
					Subtotal	***0***	***0***	
					Total	***9***	***0.001***	

* "Other Species" codes:

BB=Brown bullhead
BD=Banded darter
CC=Channel catfish
CS=Comely shiner
GS=Gizzard shad
LMB=Largemouth bass
QB=Quillback
RB=Rock bass
SMB=Smallmouth bass
ST=Spottail shiner
TD=Tessellated darter
WC=White catfish
WS=White sucker
YP=Yellow perch

Table 6.

Summary of two sampling events for juvenile American shad with boat mounted electroshocker in the Juniata River at Greenwood, 1998.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi (m)	Run	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Shad Captured (#, mm)	Shad Observed
24 Aug	795	27.9	1.5	1	10	350	9.0	Yes	2 (83, 123)	0
				2	10	350	9.0	Yes	0	0
				3	10	350	9.0	No	2 (78, 96)	0
				1*	13	200	2.0	Yes	0	0
				2*	10	200	2.0	Yes	3 (104, 97, 113)	0
				3*	10	200	2.0	No	2 (87, 111)	0
31 Aug	766	28.5	1.2	1	11	370	9.0	No	0	0
				2	14	370	9.0	Yes	6 (92, 105, 113, 120, 121, 121)	2
				3	15	370	9.0	Yes	1 (108)	1
				4	11	370	9.0	Yes	1 (124)	0
				5	10	370	9.0	No	0	0
				6	10	370	9.0	No	0	0

* PA Fish and Boat Commission.

Table 6.

Summary of two sampling events for juvenile American shad with boat mounted electroshocker in the Juniata River at Mifflintown, 1998.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi (m)	Run	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Shad Captured (#, mm)	Shad Observed
6 Aug	736	28.0	1.25	1	10	150	4.0	Yes	0	0
				2	12	150	4.0	Yes	0	0
				3	10	150	4.0	No	0	0
				4	12	150	4.0	No	0	0
				5	10	150	4.0	No	0	0
				6	10	150	4.0	No	0	0
13 Aug	970	26.5	1.1	1	10	235	7.0	No	0	0
				2	10	235	7.0	No	0	0
				3	10	245	7.5	No	0	0
				4	10	245	7.5	No	0	0
				5	10	270	7.5	No	0	0
				6	10	270	7.5	No	0	0

Table 6.

Summary of two sampling events for juvenile American shad with boat mounted electroshocker in the Susquehanna River at Columbia, 1998.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi (m)	Run	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Shad Captured (#, mm)	Shad Observed
17 Aug	8,710	26.5	1.1	1	13	270	7.0	No	0	0
				2	12	270	7.0	No	0	0
				3	13	230	7.0	No	0	0
				4	12	230	7.0	No	0	0
				5	20	100	5.0	No	0	0
				6	26	250	7.5	No	0	0
20 Aug	8,580	25.5	1.2	1	10	400	9.5	No	0	0
				2	10	400	9.5	No	0	0
				3	12	400	9.5	No	0	1
				4	13	400	9.5	No	1 (82 mm)	1
				5	12	400	9.5	No	0	1
				6	10	400	9.5	No	0	2

Table 6.

Summary of three sampling events for juvenile American shad with boat mounted electroshocker in the Susquehanna River at Clemson Island, 1998.

Date	River Flow (cfs)	Water Temperature (°C)	Secchi (m)	Run	Duration (min)	Volts Pulsed (DC)	Amps	Dimpling?	Shad Captured (#, mm)	Shad Observed
3 Aug	6,750	28.0	1.5	1	10	180	5.0	No	0	0
				2	10	180	5.0	No	0	0
				3	10	180	5.0	No	0	0
				4	13	180	5.0	No	0	0
				5	14	180	5.0	No	0	0
				6	12	180	5.0	No	0	0
11 Aug	6,600	28.0	2	1	10	210	6.0	No	0	0
				2	9	210	6.0	No	0	0
				3	10	230	7.0	No	0	0
				4	13	220	7.0	No	0	0
				5	10	220	7.0	No	0	0
				6	10	220	7.0	No	0	0
27 Aug	5,550	27.5	1.5	1	10	350	9.5	No	0	0
				2	13	350	9.5	No	0	0
				3	11	350	9.5	No	0	0
				4	13	350	9.5	No	0	0
				5	14	350	9.5	No	0	0
				6	10	350	9.5	No	0	0

Table 7.

Summary of PFBC electrofishing surveys conducted during late spring, 1998.

Date	Location	Water Temperature (°C)	Start Time	End Time	Number of American Shad	CPUE (#/time)	Other Species*
					Stream Surveys		
26 May	Fishing Creek	17.0	1143	1153	0	0	LMB,SMB,WS,MIN,RBA,TD,YB,BT
26 May	Fishing Creek	17.0	1158	1208	0	0	LMB,SMB,WS,MIN,BT,GS,LND
26 May	Fishing Creek	17.0	1211	1221	0	0	WS,HS,MIN,YB,BT,BRT
26 May	Fishing Creek	17.0	1227	1237	0	0	SMB,WS,MIN,RBA,YB,BT,BRT,LP,HS
26 May	Fishing Creek	17.0	1240	1250	0	0	SMB,WS,MIN,RBA,HS,LP,BT
26 May	Fishing Creek	17.0	1304	1314	0	0	SMB,WS,MIN,LP,BT
				Subtotal	***0***	***0***	
27 May	Peters Creek	16.0	920	930	0	0	LMB,SMB,WS,MIN,RBA,TD,YB,RBT,BG
27 May	Peters Creek	16.0	937	947	0	0	LMB,WS,MIN,HS,LP,LND,BT
27 May	Peters Creek	16.0	950	1000	0	0	LMB,WS,MIN,RBA,TD,YB,BT,HS,GS,BG
27 May	Peters Creek	16.0	1005	1015	0	0	SMB,WS,MIN,RBA,TD,YB,BT,HS,GS,LP
27 May	Peters Creek	16.0	1017	1031	0	0	LMB,SMB,WS,MIN,RBA,BT,YB,BB,WC,CC,FF,LP,GS,BG,PS
				Subtotal	***0***	***0***	
28 May	Michael's Run	16.0	1100	1115	0	0	LMB,SMB,WS,MIN,RBA,BT,LP,HS,BG
				Subtotal	***0***	***0***	
29 May	Muddy Creek	17.5	940	950	0	0	SMB,BG,GS
29 May	Muddy Creek	17.5	958	1008	0	0	SMB,GS,RH
29 May	Muddy Creek	17.5	1025	1035	0	0	SMB,GS,WA,CC,RH
29 May	Muddy Creek	17.5	1045	1055	0	0	GS,WS,HS
				Subtotal	***0***	***0***	
				Stream Surveys Total	***0***	***0***	

Continued.

Table 7.

Continued.

Date	Location	Water Temperature (°C)	Start Time	End Time	Number of American Shad	CPUE (#/time)	Other Species*
					Pond Surveys		
01 Jun	Conowingo Pond	25.0	1041	1051	0	0	RH,GS,CP,QB
01 Jun	Conowingo Pond	25.0	1052	1102	0	0	RH,GS,CP,QB
01 Jun	Conowingo Pond	25.0	1115	1125	0	0	RH,GS,CP,WS
01 Jun	Conowingo Pond	25.0	1126	1136	0	0	RH,GS,CP,WS
01 Jun	Conowingo Pond	25.0	1139	1149	0	0	RH,GS,SMB
01 Jun	Conowingo Pond	25.0	1151	1201	0	0	RH,GS
				Subtotal	***0***	***0***	
02 Jun	Conowingo Pond	26.5	928	938	0	0	GS,SMB,CC
02 Jun	Conowingo Pond	26.5	941	951	0	0	GS,SMB,CC
02 Jun	Conowingo Pond	26.5	955	1005	0	0	GS,SMB,RH,BG
02 Jun	Conowingo Pond	26.5	1006	1016	2	0	GS,SMB,RH
02 Jun	Conowingo Pond	26.5	1019	1031	1	0	GS
02 Jun	Conowingo Pond	26.5	1035	1045	0	0	GS,SMB,RH,WS
				Subtotal	***3***	***0.05***	
03 Jun	Conowingo Pond	26.0	950	1000	0	0	0
03 Jun	Conowingo Pond	26.0	1001	1011	0	0	0
03 Jun	Conowingo Pond	26.0	1016	1026	0	0	GS,SMB,RH,QB
03 Jun	Conowingo Pond	26.0	1027	1037	0	0	GS,RH,QB
03 Jun	Conowingo Pond	26.0	1045	1055	0	0	GS,RH,QB
03 Jun	Conowingo Pond	26.0	1056	1107	0	0	GS,RH,QB
				Subtotal	***0***	***0***	
04 Jun	Conowingo Pond	26.0	1415	1425	0	0	GS,CP,SMB
04 Jun	Conowingo Pond	26.0	1431	1441	0	0	GS,SMB,YP,WS
04 Jun	Conowingo Pond	26.0	1449	1459	0	0	GS,SMB,WS
04 Jun	Conowingo Pond	26.0	1507	1517	0	0	GS,SMB,RH
04 Jun	Conowingo Pond	26.0	1522	1532	0	0	GS,SMB,WS,RH,BG
04 Jun	Conowingo Pond	26.0	1544	1554	0	0	GS,CP,SMB,YP,WS,BB
				Subtotal	***0***	***0***	

Continued.

Table 7.

Continued.

Date	Location	Water Temperature (°C)	Start Time	End Time	Number of American Shad	CPUE (#/time)	Other Species*
08 Jun	Conowingo Pond	22.0	922	932	0	0	GS,CP
08 Jun	Conowingo Pond	22.0	933	944	0	0	GS,CP
08 Jun	Conowingo Pond	22.0	950	1000	0	0	GS,CP,SMB,RH,QB,LMB
08 Jun	Conowingo Pond	22.0	1001	1011	0	0	GS,CP,SMB,RH,QB
08 Jun	Conowingo Pond	22.0	1015	1025	0	0	GS,SMB
08 Jun	Conowingo Pond	22.0	1026	1036	0	0	WS
08 Jun	Conowingo Pond	22.0	1050	1100	6	0	GS,SMB,WA
08 Jun	Conowingo Pond	22.0	1101	1110	0	0	SMB
08 Jun	Conowingo Pond	22.0	1118	1128	0	0	GS,SMB,RH,WS
08 Jun	Conowingo Pond	22.0	1129	1139	0	0	GS,SMB,RH,QB
08 Jun	Conowingo Pond	22.0	1143	1153	0	0	GS,SMB,RH,CA
08 Jun	Conowingo Pond	22.0	1154	1204	0	0	GS,SMB,RH,WS
				Subtotal	*6*	*0.05*	
				Pond Surveys Total	*9*	*0.025*	

* Species abbreviations:

BB= Brown bullhead
BG= Bluegill
BRT= Brook trout
BT= Brown trout
CC= Channel catfish
CP= Common carp
GS= Green sunfish
HS= Northern hog sucker
LMB= Largemouth bass
LP= Log perch
MIN= Minnows
PS= Pumpkinseed
QB= Quillback
RBA= Rock bass
RT= Rainbow trout
SMB= Smallmouth bass
TD= Tessellated darter
WA= Walleye
WC= White catfish
WS= White sucker
YB= Yellow bullhead

TABLE 8. AMERICAN SHAD, (*Alosa sapidissima*), ADULT SAMPLING BY BOAT ELECTROFISHING DURING THE WEEKS OF JUNE 8 AND JUNE 22, 1998.

	DOCK ST. DM		FABRI DM		WARRIOR RIDGE DM		RAYSTOWN DM	
DATE	6/8/98	6/24/98	6/9/98	6/22/98	6/10/98	6/25/98	6/11/98	6/23/98
EF START	2100	2058	2100	2040	2048	2048	RAINOUT	2110
EF STOP	2354	2306	2301	2234	2251	2225		2324
ACTUAL EF TIME	1.83 HRS	1.77 HRS	1.5 HRS	1.63 HRS	1.1 HRS	58 MIN		1.05 HRS
VOLTS	250-300 VDC	250-300 VDC	300 VDC	300 VDC	250 VDC	250 VDC		250 VDC
AMPS	2	2	2	2	3	2		-
WATER TEMP.	18 C	26 C	18 C	-	15 C	23 C		-
RIVER STAGE HT.	4.0' (15,000 CFS)	4.5' (23,600CFS)	7.7'	8.9	-	-		-
SHAD CAPT.	7	0	1	0	0	0		0
LENGTH (mm). SEX	515 GRAVID FEMALE 501 GRAVID FEMALE 545 GRAVID FEMALE 504 GRAVID FEMALE 455 FEMALE 520 FEMALE 565 FEMALE		531 FEMALE					
ADDITIONAL SHAD OBS.	8	0	0	0	0	0		0
BLUEBACK HERRING CAPT.	0	0	0	0	0	0		0
ALEWIFE CAPT.	137mm	0	0	0	0	0		0

Table 9.

Catch per unit effort (CPUE), standard deviation, variance, and confidence for juvenile American shad collected by 8 ft x 8 ft lift net at the Holtwood Power Station, 5 October to 10 December 1998.

Date	Number of Shad	CPUE	Standard Deviation	Variance	Confidence
5 Oct	1	0.10	0.32	0.10	0.20
8 Oct	2	0.20	0.42	0.18	0.26
11 Oct	17	1.70	1.95	3.79	1.21
14 Oct	5	0.50	1.58	2.50	0.98
17 Oct	10	1.00	2.00	4.00	1.24
20 Oct	27	2.70	3.83	14.68	2.37
23 Oct	25	2.50	6.22	38.72	3.86
26 Oct	0	0.00	0.00	0.00	NA
29 Oct	49	4.90	6.85	46.99	4.25
1 Nov	3	0.30	0.48	0.23	0.30
4 Nov	0	0.00	0.00	0.00	NA
7 Nov	29	2.90	3.35	11.21	2.08
10 Nov	2	0.20	0.63	0.40	0.39
13 Nov	0	0.00	0.00	0.00	NA
16 Nov	1	0.10	0.32	0.10	0.20
19 Nov	1	0.10	0.32	0.10	0.20
22 Nov	1	0.10	0.32	0.10	0.20
25 Nov	1	0.10	0.32	0.10	0.20
28 Nov	0	0.00	0.00	0.00	NA
1 Dec	0	0.00	0.00	0.00	NA
4 Dec	0	0.00	0.00	0.00	NA
7 Dec	0	0.00	0.00	0.00	NA
10 Dec	6	0.60	1.58	2.49	0.98

Table 10. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1998.

		Immersion marks									Feed Marks			
Collection Site	Coll. Date	Day 3	Days 3,6,9	Days 3,9,12	Days 9, 12,15	Days 3,6, 9,12	Days 3,6, 9,15	Days 3,9, 12,15	Days 3,6,9, 15,18	Days 3,6	double	Hatchery Total	Wild	Total
Juniata R.	8/6/98	1	5									6	0	6
at Greenwood	8/24/98	5	3									8	1	9
	8/31/98	6	2									8		8
W. Conewago Cr	7/28/98			5 *								5		5
	8/4/98			2								2		2
	8/20/98			1								1		1
Columbia	7/16/98	10										10		10
	7/21/98	9				5						14		14
	7/29/98	19	1	9		7			1			37		37
	8/4/98	14		6	4	4			1			29	1	30
	8/19/98	4		1	1	2			1			9		9
	8/20/98	1										1		1
	8/26/98	7							1			8	2	10
	9/2/98	1										1	2	3
	9/9/98	2		1								3		3
	9/16/98	3										3		3
	9/22/98					1						1		1
	10/7/98	2		1								3		3
Above Holtwood		84	11	26	5	19		0	4	0	0	149	6	155
Percent		54%	7%	17%	3%	12%		0%	3%	0%	0%	96%	4%	

Table 10. (continued).

Collection Site	Coll. Date	Immersion marks: Day 3	Days 3,6,9	Days 3,9,12	Days 9, 12,15	Days 3,6, 9,12	Days 3,6, 9,15	Days 3,9, 12,15	Days 3,6,9, 15,18	Days 3,6	Feed Marks: double	Hatchery Total	Wild	Total
Holtwood	10/5/98											0	1	1
	10/8/98	2										2		2
	10/11/98	13 **				2						15	1	16
	10/14/98	4										4	1	5
	10/17/98	7				2			1			10		10
	10/20/98	19	1			3			1			24	2	26
	10/23/98	22		1		2						25		25
	10/29/98	22	1		1	4			1			29	1	30
	11/1/98	3										3		3
	11/7/98	14	1	5		7			1			28	2	30
	11/10/98	1	1									2		2
	11/16/98	1										1		1
	11/19/98	1										1		1
	11/22/98					1						1		1
	11/25/98	1										1		1
	12/10/98	4	1									5		5
Conowingo Pond	6/15/98	2										2		2
	6/18/98											0	1	1
	6/21/98											0	1	1
	6/27/98	1										1	1	2
	7/9/98	1										1		1
	7/15/98	1												
Holt./P. Bot./Con.		119	5	6	1	21	0	0	4	0	0	155	11	166
Percent		72%	3%	4%	1%	13%	0%	0%	2%	0%	0%	93%	7%	
Total (above Con.)		203	16	32	6	40	0	0	8	0	0	304	17	321
Percent		63%	5%	10%	2%	12%	0%	0%	2%	0%	0%	95%	5%	

Table 10. (continued).

Collection Site	Coll. Date	Immersion marks: Day 3	Days 3,6,9	Days 3,9,12	Days 9, 12,15	Days 3,6, 9,12	Days 3,6, 9,15	Days 3,9, 12,15	Days 3,6,9, 15,18	Days 3,6	Feed Marks: double	Hatchery Total	Wild	Total
Below Conowingo:														
Upper Bay	7/20/98	2										2	17	19
Ordinary Point	7/20/98											0	9	9
Elk Neck Park	7/21/98											0	15	15
Plum Point	7/22/98											0	9	9
Poplar point	7/22/98											0	5	5
Tydings Park	7/22/98											0	2	2
Spoil Island	7/22/98											0	1	1
Carpenter Point	7/22/98											0	2	2
Howell Point	8/17/98											0	2	2
Parlor Point	8/18/98											0	17	17
Elk Neck Park	8/18/98											0	1	1
Carpenter Point	8/18/98											0	1	1
Carpenter Point	8/19/98											0	1	1
Plum Point Flats	8/19/98											0	2	2
Howell Point	9/14/98											0	9	9
Hyland Point	9/15/98											0	4	4
Upper Bay	9/16/98											0	6	6
Plum Point	9/16/98											0	5	5
Cell #7	9/30/98											0	2	2
Cell # 17	9/30/98											0	1	1
Total (below Con.)		2	0	0	0	0	0	0	0	0	0	2	111	113
Percent		2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	98%	

*One specimen marked only on days 3 and 9.

**Includes one specimen which appears to be marked on days 1 and 2.

Stocking sites for immersion marks:
Day 3: Juniata R. (various sites) or Susquehanna R. at Montgomery Ferry
Days 3,9,12: West Conewago Cr.
Days 3,6,9: Juniata R. (Susq. R. egg source)
Days 9,12,15: Conodoguinet Cr.
Days 3,9,12,15: Conestoga R.
Days 3,6,9,15: W. Br. Susquehanna R.
Days 3,6,9,12: N. Br. Susquehanna R.
Days 3,6,9,15,18: Swatara Cr.
Days 3,6: Below Conowingo Dam
Double Feed Mark: Standing Stone Cr.

Table 11. Recruitment of American shad to the Conowingo Dam Fish Lifts from larvae stocked in the Susquehanna River above dams.

Year	Fish lift catch	% Age composition 8	7	6	5	4	3	2	Hatchery larvae %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		13 *								
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%	373	16							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%	1,706	166	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	6,956	2,250	307	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	6,652	6,870	2,181	545	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	277	1,867	4,563	1,867	69	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	0	859	5,918	14,318	5,059	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	77%		0	1,954	10,522	29,313	5,561	301	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%			0	152	2,881	7,430	6,015	1,365	51
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%				0	0	3,676	6,363	15,695	9,191
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%					0	80	1,125	4,983	3,858
Total recruits to lifts:										15,977	12,028	14,924	27,404	37,322	16,748	13,804	22,043	13,099
Larval releases (millions):										9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42
Number of larvae to return 1 adult:										620	431	432	491	151	431	220	297	490
Mean number of larvae to return 1 adult (1986–1993):										358								

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

Table 12. Recruitment of American shad to the Conowingo Dam Fish Lifts from fingerlings stocked in the Susquehanna River above dams.

Year	Fish Lift Catch	% Age Composition 8	7	6	5	4	3	2	Fingerling Contribution %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2		0	0							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0		0	0	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	2%	188	61	8	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	1%	83	85	27	7	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	2%	7	50	122	50	2	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	1%	0	12	80	195	69	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	1%		0	30	163	455	86	5	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	1%			0	3	66	171	139	31	1
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	1%				0	0	132	228	563	330
1998	46481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	2%					0	6	78	344	266
Total Recruits to Lifts:										278	208	268	418	592	395	449	938	597
Fingerlings stocked/10,000:										7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95
No. of fingerlings to return 1 adult:										261	392	239	144	152	138	49	85	234
Mean No. of fingerlings to return 1 adult (1986–1993):										148								

Table 13. Stock/recruitment for naturally reproduced American shad collected in the Conowingo Dam Fish Lifts.

Year	Fish Lift Catch	% Age Composition 8	7	6	5	4	3	2	Naturally Reproduced %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		4 *								
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	18%	83	4							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	26%	612	59	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	27%	2814	910	124	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	23%	2092	2161	686	171	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	17%	73	494	1209	494	18	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	10%	0	104	717	1734	613	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	16%		0	397	2137	5954	1130	61	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	45%			0	144	2742	7072	5725	1299	48
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	60%				0	0	6538	11317	27914	16346
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	71%						255	3570	15810	12240
									Total Recruits to Lifts:	5,678	3,732	3,133	4,682	9,327	14,995	20,673	45,023	28,634
									Adults transported/1000:	4.2	7.2	4.7	6.5	15.1	24.7	15.7	11.7	28.7
									No. of adults transported to return 1 adult:	0.73	1.93	1.51	1.38	1.62	1.64	0.76	0.26	1.00

Mean No. of adults transported to return 1 adult (1986–1994): 0.87

*No estimate of contribution of naturally reproduced fish available, used mean 1989–1996.

Job V. Analysis of adult American shad otoliths, 1998

M.L. Hendricks
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, Pa.

Abstract

A total of 132 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam fish lifts in 1998. Based on tetracycline marking and otolith microstructure, 71% of the 130 readable otoliths were identified as wild and 29% hatchery. Wild fish represented a higher proportion of the catch in samples collected in Upper Chesapeake Bay pound nets (86%) than that found in Conowingo (71%) or Safe Harbor (71%) Fish Lifts, but the difference was not statistically significant. Double marked fish (releases below Conowingo Dam) represented 4.5% of the marked fish in the pound net samples and 5.3% of the fish in the Conowingo 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 1986-1993 year classes, stocking of approximately 358 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 148 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.87 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1993 year class is not

fully recruited. Actual survival is even higher since not all surviving adults enter the lifts. Evidence is presented which suggests that fish lift performance in 1998 was poor relative to previous years, probably due to high river flows.

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 1998.

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad to enter the West lift. Some 70 adult shad were collected from the Safe Harbor Dam Fish Lift during clean-out on May 2, 3, and 4, 1998. Adult American shad collected in pound nets in the upper Chesapeake Bay as well as the Nanticoke River were also sacrificed for otolith analysis. Net mortalities and moribund fish were used for the Upper Bay pound net sample.

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 15 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 Upper Bay, 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 1998, 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 132 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 1998. No samples were collected from the East lift since it was operated in fish passage mode. For 2 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 130 readable otoliths (Table 1). A total of 92 (71%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 29% of the specimens was identified as hatchery in origin. Thirty-eight otoliths exhibited tetracycline marks including single, double, triple, and quadruple immersion marks. Two specimens (2%) 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 steadily since 1993 (Figure 2).

Analysis of otoliths of adult American shad collected in Upper Chesapeake Bay pound nets suggests that the pound nets and fish lifts are sampling intermixed stocks. Wild fish contribution to the pound nets exceeded that in the lift catches in each year sampled (Table 3). In 1998, however, wild fish contribution was not significantly different between the lifts and the pound nets (Chi-square = 4.47, df =2, 1998 data). In the period 1993 through 1997, results were statistically significant, suggesting that there are two distinct stocks, an upper bay stock and a Susquehanna River stock (Hendricks, 1998). The Upper Bay stock may not have a strong urge to move upstream and do not typically enter the lifts with the same frequency as do fish which originated upstream (Susquehanna River stock). The lack of a statistically significant difference in 1998 does not mean that there is no difference. We simply could not demonstrate it, given the sample size.

Otoliths were extracted and analyzed from adult shad collected by MDNR in the Nanticoke River (Table 4). Thirty-five (90%) of the otoliths analyzed from the Nanticoke River were wild. Four otoliths exhibited marks including three with a single day 7 mark and single feed mark and one with a double immersion mark (days 3,17) and a single feed mark. Based on their mark, these fish originated from releases in the Patuxent River in 1994. Otolith macrostructure from the other otolith confirmed that these fish were 4 year olds except for one which appears to be age 3. This age must be incorrect, since no such marked fish were released in 1995.

In 1996 and 1997, all otoliths examined from the Nanticoke were wild (1996 n=36, 1997 n=42), while in 1995, 5 of 20 (25%) of the otoliths exhibited marks. These included 2 double marked fish, stocked in the upper Bay and three triple marked fish, stocked in the Susquehanna River above Conowingo Dam. Straying into the Nanticoke of marked fish, stocked in other rivers has thus been documented in both 1995 and 1998.

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 5). Overall mean age was 4.3 years for males and 5.1 years for females. For wild fish, mean ages were 4.4 for males and 5.1 for females (Table 6). For hatchery fish, mean age was 4.3 for males and 5.1 for females. Overall sex ratio was 1.1 to 1, males to females. Length frequencies and mean length at age are tabulated in Tables 7 to 10. As expected, females were larger than males. No consistent difference in length at age is apparent between wild and hatchery fish.

Adult shad collected at the lifts were partitioned into their respective year classes using scale or otolith age data and corrected for hatchery contribution (Table 11). 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 (Table 11). Year classes after 1992 are not fully recruited, however, recruitment from the 1993 year class was above the long term average, and is included in the analysis. For the period 1986-1993, the number of hatchery larvae required to produce one returning adult ranged from 151 to 620, with a mean of 358. This is a maximum estimate since the 1993 year class is 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 12). For the period 1986-1993, the number of hatchery fingerlings required to produce one returning adult ranged from 49 to 392, with a mean of 148. Again, this is a maximum estimate since the 1993 year class is not fully recruited. At first glance, it would appear that stocking fingerlings is advantageous over stocking larvae, however, on average, one must stock 100,000 larvae in a pond to harvest 10,000 to 20,000 fingerlings. Therefore, it would take 840 to 1,690 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 13). For the period 1986 to 1994, transport of an average of 0.87 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 in 1998 (46,481) were substantially below those of 1997 (103,945). It has been speculated that this was due to high river flows which reduced lift efficiency, rather than simply a smaller number of fish returning to the river. Evidence for this can be found in the stock-recruitment data. Shad maturity schedules dictate that, for any cohort, more fish return as four year olds than three year olds. This is true for hatchery larvae, fingerlings and wild fish (Tables 11, 12, 13). For the cohorts from 1986 to 1993, total returns of age 4 hatchery larvae, fingerlings, and wild fish combined (79,413) were 15.9 times more than those of age 3 fish (4,995). In contrast, for the 1994 cohort, total returns of age 4 larvae, fingerlings, and wild fish combined (16,364) were 0.63 times less than those of age 3 (25,867). Clearly, something impacted returns of four year olds in 1998, most likely high river flows which reduced lift efficiency.

Literature Cited

Hendricks, M.L. 1996. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1995. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. 1997. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1996. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1996. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L. 1998. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1997. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1997. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.W.H. Backman, and D.L. Torsello. 1991. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad in the Susquehanna River. In

Restoration of American shad to the Susquehanna River, Annual Progress Report, 1990. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1986. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1987. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management. 11: 212-219.

Hendricks, M.L., D. L. Torsello, and T.W.H. Backman. 1994. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad (Alosa sapidissima) in the Susquehanna River. North American Journal of Fisheries Management.

Lorson, R.D. and V.D. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. N. Am. J. Fish. Mgmt. 7:453-455.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxberry Press, Belmont, California 730 p.

Young, L.M. 1987. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1998.

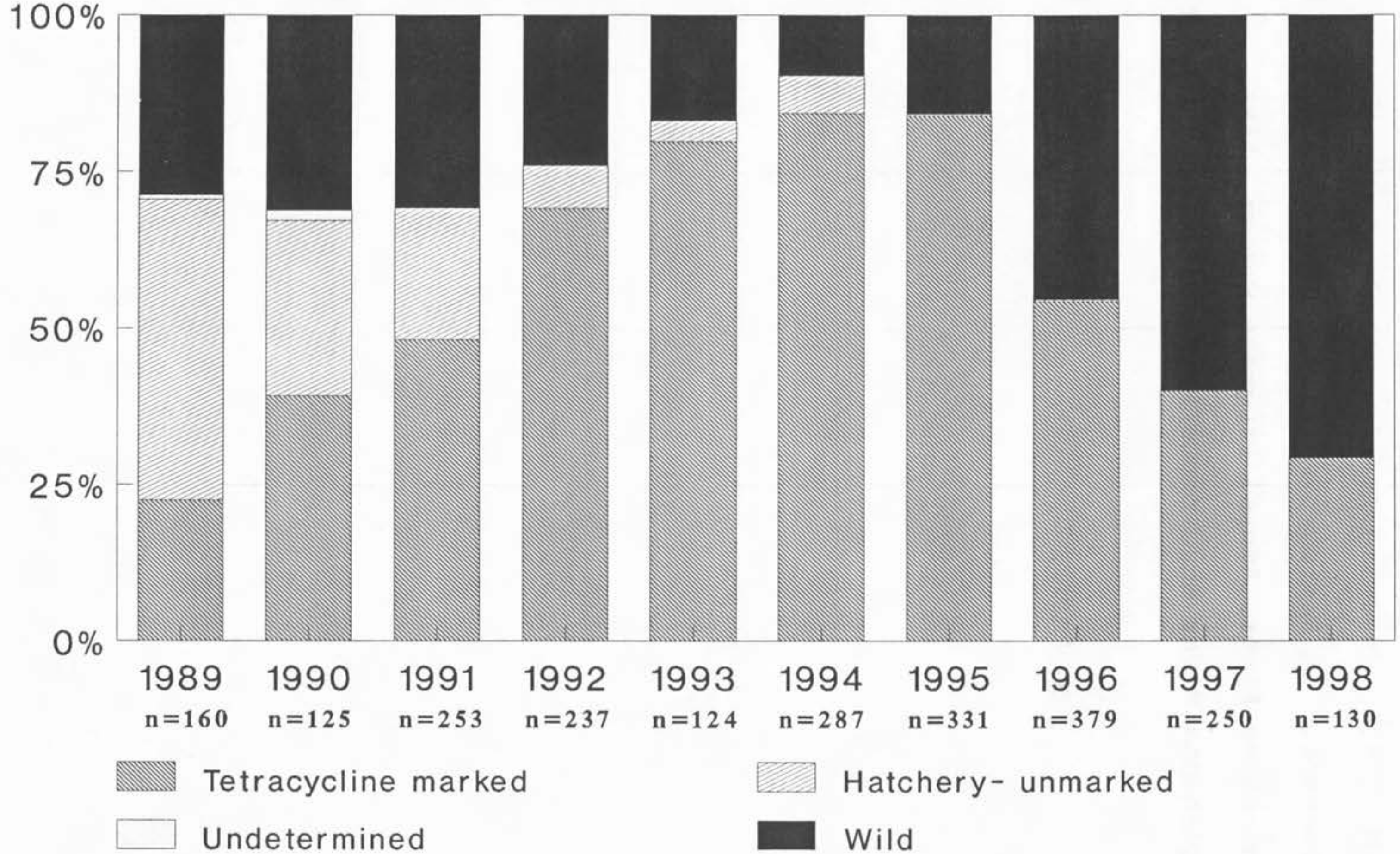


Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts, 1972-1998.

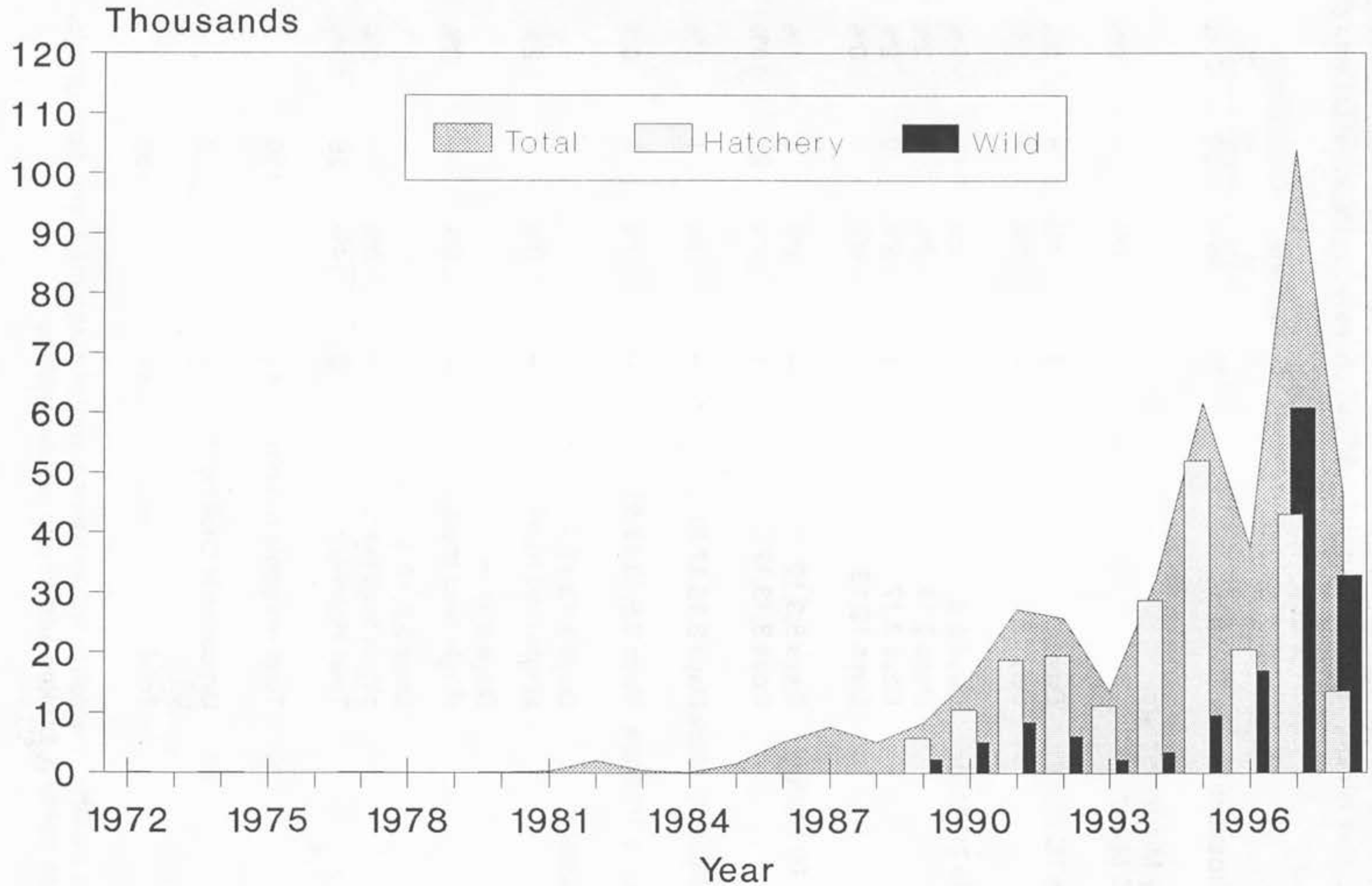


Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna Flats pound nets, Conowingo Dam West Fish Lift and Safe Harbor Dam Fish Lift, 1998. One of every 50 fish collected in the West Lift was sacrificed.

		Susq. Flats		Conowingo		Safe Harbor	
		N	%	N	%	N	%
Wild Microstructure, No TC Mark		38	86%	92	71%	49	71%
Hatchery Microstructure							
No TC Mark*		–	0%	–	0%	–	0%
Single TC Mark	Day 5	3	7%	6	5%	4	6%
	Day 18	–	0%	–	0%	1	1%
Double TC Mark	Days 5,9	1	2%	3	2%	–	0%
	Days 3,11	–	0%	2	2%	–	0%
	Days 3,17	1	2%	2	2%	–	0%
	Days 12,13	–	0%	–	0%	1	1%
Triple TC Mark	Days 5,9,13	–	0%	1	1%	2	3%
	Days 3,13,17	1	2%	21	16%	9	13%
Quadruple TC Mark	Days 3,13,17,21	–	0%	1	1%	1	1%
Quintuple TC Mark	Days 5,9,13,17,21	–	0%	–	0%	2	3%
Feed Marks	Days 3,13,17 + single feed mark	–	0%	2	2%	–	0%
	Days 3,17 + single feed mark	–	0%	–	0%	–	0%
	Days 5,9,13 + single feed mark	–	0%	–	0%	–	0%
	Total Hatchery	6	14%	38	29%	20	29%
	Total readable otoliths	44		130		69	
	Unreadable Otoliths**	–		2		1	
	Total	44		132		70	

*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 size
Year	N	%*	N	%*	N	%*	N	N	%	
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
Totals	1,191	62	120	6	24	1	241	698	31	2,274

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

Table 3. Origin of adult American shad collected in upper Chesapeake Bay pound nets, based on otolith analysis. Dead or moribund fish were sacrificed for analysis.

	Pound net											
	Hatchery											
	Larvae											
	Susquehanna		below Conowingo Dam		Fingerling		Unmarked	Naturally reproduced		Naturally reproduced in lift catch	Total pound net sample size
Year	N	%	N	%	N	%	N	N	%	%	size
1993	9	36	3	12		0	11	25	52	17	48
1994	12	26	14	30	–	0	7	26	44	10	59
1995	34	30	29	25	3	3	–	48	42	16	114
1996	20	17	12	10	2	2	–	81	70	45	115
1997	26	16	8	5	1	1	–	125	78	60	160
1998	4	9	2	5	0	0	–	38	86	71	44
Totals	105	21	68	14	6	1	18	343	64	–	540

Table 4. Microstructure classification and tetracycline marking of adult American shad collected in the Nanticoke River, 1998.

			Nanticoke River N	Nanticoke River %
Wild Microstructure, No TC Mark			35	90%
Hatchery Microstructure	No TC Mark*		–	0%
	Single TC Mark	Day 5	–	0%
		Day 18	–	0%
	Double TC Mark	Days 5,9	–	0%
		Days 3,17	–	0%
	Triple TC Mark	Days 5,9,13	–	0%
		Days 3,13,17	–	0%
	Quadruple TC Mark	Days 5,9,13,17	–	0%
		Days 3,13,17,21	–	0%
		Days 3,7,11,21	–	0%
	Quintuple TC Mark	Days 5,9,13,17,21	–	0%
	Feed Marks	Day 7 + single feed mark	3 ***	8%
		Days 3,17 + single feed mark	1 ***	3%
		Days 3,13,17,21 + single feed mark	–	0%
		Days 5,9,13 + single feed mark	–	0%
		Total Hatchery	4	10%
		Total readable otoliths	39	
		Unreadable Otoliths**	0	
		Total	39	

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

Table 5. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1998.

Sex	2	3	4	5	6	7	8	??	Totals	Mean
Male		4	36	27				1	68	4.3
Female			12	34	14	1		1	62	5.1
Unknown				1				1	2	
Totals	0	4	48	62	14	1	0	3	132	4.7

Table 6. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1998.

Sex	2	3	4	5	6	7	8	??	Totals	Mean
Male– Wild		1	27	17					45	4.4
Male– Hatc.		3	9	10					22	4.3
Female– Wild			8	28	9	1			46	5.1
Female– Hatc.			4	6	5				15	5.1
Totals	0	4	48	61	14	1	0	0	128	4.7

Table 7. Length frequency by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 1998.

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	7	18	26	15							67
Female				1	7	14	19	20					61
Unknown								1					1
Totals	0	1	7	19	33	29	19	21	0	0	0	0	129

Table 8. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 1998.

Sex	301–325	326–350	351–375	376–400	401–425	426–450	451–475	476–500	501–525	526–550	551–575	576–600	Total
Male– Wild			5	12	19	9							45
Male– Hatc.		1	2	6	7	6							22
Female– Wild				1	6	12	12	15					46
Female– Hatc.					1	2	7	5					15
Totals	0	1	7	19	33	29	19	20	0	0	0	0	128

Table 9. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1998.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)
Male			380	(4)	401	(36)	418	(27)				
Female					434	(12)	460	(34)	476	(14)	437	(1)

Table 10. Mean length at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1998.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)
Male– Wild			380	(1)	398	(28)	422	(17)				
Male– Hatc.			380	(3)	408	(9)	411	(10)				
Female– Wild					421	(8)	461	(28)	475	(9)	437	(1)
Female– Hatc.					460	(4)	459	(6)	475	(5)		

Table 11. Recruitment of American shad to the Conowingo Dam Fish Lifts from larvae stocked in the Susquehanna River above dams.

Year	Fish lift catch	% Age composition 8	7	6	5	4	3	2	Hatchery larvae %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		13 *								
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%	373	16							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%	1,706	166	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	6,956	2,250	307	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	6,652	6,870	2,181	545	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	277	1,867	4,563	1,867	69	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	0	859	5,918	14,318	5,059	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	77%		0	1,954	10,522	29,313	5,561	301	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%			0	152	2,881	7,430	6,015	1,365	51
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%				0	0	3,676	6,363	15,695	9,191
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%					0	80	1,125	4,983	3,858
Total recruits to lifts:										15,977	12,028	14,924	27,404	37,322	16,748	13,804	22,043	13,099
Larval releases (millions):										9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42
Number of larvae to return 1 adult:										620	431	432	491	151	431	220	297	490
Mean number of larvae to return 1 adult (1986–1993):										358								

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

Table 12. Recruitment of American shad to the Conowingo Dam Fish Lifts from fingerlings stocked in the Susquehanna River above dams.

Year	Fish Lift Catch	% Age Composition 8	7	6	5	4	3	2	Fingerling Contribution %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2		0	0							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0		0	0	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	2%	188	61	8	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	1%	83	85	27	7	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	2%	7	50	122	50	2	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	1%	0	12	80	195	69	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	1%		0	30	163	455	86	5	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	1%			0	3	66	171	139	31	1
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	1%				0	0	132	228	563	330
1998	46481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	2%					0	6	78	344	266
Total Recruits to Lifts:										278	208	268	418	592	395	449	938	597
Fingerlings stocked/10,000:										7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95
No. of fingerlings to return 1 adult:										261	392	239	144	152	138	49	85	234
Mean No. of fingerlings to return 1 adult (1986–1993):										148								

Table 13. Stock/recruitment for naturally reproduced American shad collected in the Conowingo Dam Fish Lifts.

Year	Fish Lift Catch	% Age Composition 8	7	6	5	4	3	2	Naturally Reproduced %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993	1994
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		4 *								
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	18%	83	4							
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	26%	612	59	0						
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	27%	2814	910	124	0					
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	23%	2092	2161	686	171	0				
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	17%	73	494	1209	494	18	0			
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	10%	0	104	717	1734	613	0	0		
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	16%		0	397	2137	5954	1130	61	0	
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	45%			0	144	2742	7072	5725	1299	48
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	60%				0	0	6538	11317	27914	16346
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	71%						255	3570	15810	12240
Total Recruits to Lifts:										5,678	3,732	3,133	4,682	9,327	14,995	20,673	45,023	28,634
Adults transported/1000:										4.2	7.2	4.7	6.5	15.1	24.7	15.7	11.7	28.7
No. of adults transported to return 1 adult:										0.73	1.93	1.51	1.38	1.62	1.64	0.76	0.26	1.00

Mean No. of adults transported to return 1 adult (1986–1994): 0.87

*No estimate of contribution of naturally reproduced fish available, used mean 1989–1996.

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

Fisheries Service, Maryland Department of Natural Resources 301 Marine Academy Drive, Stevensville, MD 21666

Introduction

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

Methods and Materials

Collection procedures for adult American shad in 1998 were slightly modified to those in 1997 as only the Cherry Tree Point pound net located in Aberdeen Proving Ground was fished (Figure 1). Hook and line sampling in the Conowingo tailrace, however, remained unchanged from the previous year. Tagging procedures were also slightly modified in 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 1998 began on 25 March and continued until 11 May, while hook and line effort commenced on 6 May and ended 27 May. Of the 552 adult American shad captured, 373 (68%) were tagged and 34 (9.1%) subsequently recaptured (Table 1). The 34 total does not reflect the 9 fish marked in 1997 and subsequently recaptured this year. Recapture data for the 1998 season is summarized as follows:

34 fish recaptured by the Conowingo Fish Lifts
0 fish recaptured by pound net
0 fish recaptured by hook and line from the tailrace
0 fish recaptured outside the system
0 multiple recaptures
9 1997 marked fish recaptured

The 1998 adult American shad Petersen population index for the upper Chesapeake Bay was 487,810 (Table 2, Figure 2), and has been increasing exponentially since 1980 (r^2=0.86, P=0.002). The Conowingo tailrace population index for 1998 was 314,904 (Table 3, Figure 3), and has also been increasing exponentially since 1984 (r^2=0.99, P=0.0045). A 3% adjustment for tag loss was included in both calculations.

Effort, catch, and catch-per-unit-effort (CPUE) by gear type for adult American shad in the upper Bay during 1998 and comparison with previous years is presented in Table 4. Estimates of pound net (1980-1998) and hook and line (1984-1998) CPUE have increased linerally during these time periods (r^2=0.41, P=0.01; r^2=0.65, $P \leq 0.001$, respectively).

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. These errors would, therefore, reduce the accuracy of the Petersen statistic.

Relative abundance of American shad can also be estimated and associated trends noted by examining annual CPUE data of the various 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 linerally increasing in all three gear types over time: pound net (1980-1998) r^2 = 0.41, P = 0.01; hook and line (1984-1998) r^2 = 0.65, P = <0.001;, fish lifts (1980-1998) r^2 = 0.69, P < 0.001 (Figure 4). Comparisons of these CPUE estimates to both the upper Bay and tailrace Petersen indices for these respective years indicate that:

* pound net, hook and line, and fish lift CPUE's were correlated with log e transformed upper Bay indices (Table 5, Figure 5);
* hook and line and fish lift CPUE's were correlated with log e transformed tailrace indices (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 1998. This indicates that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay continued in 1998.

A total of 463 adult American shad (157 pound net, 306 hook and line) were examined for physical characteristics by DNR biologists in 1998 (Table 6). The 1994 and 1993 year-classes (ages 4 and 5, sexes combined) were the most abundant age groups sampled in the upper Bay by pound net and hook and line, accounting for 41% and 40%, respectively, 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 ages 4 and 5 for both pound net and hook and line catches, respectively. Males (gears combined) were present in age groups 2-7 while females were found in age groups 4-9. Both sexes, however, were most abundant at ages 4 and 5. The overall incidence of repeat spawning in male American shad decreased from 25.4% in 1997 to 16.9% in 1998. Similarly, female American shad repeat spawning declined from 28.9% in 1997 to 16.8% in 1998.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1998.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	215	85
Hook and Line	Conowingo Tailrace	337	288
Fish Lifts	Conowingo Tailrace	46481	
	TOTALS	47033	373

Table 2. Upper Chesapeake Bay relative population estimate of adult American shad in 1998 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 1998 survey -

C = 47,033
R = 34
M = 362*

Therefore -

$$N = \frac{(47{,}033 + 1)\ (362 + 1)}{(34 + 1)}$$

= 487,810

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)

$$\text{Upper } N^* = \frac{(47{,}033 + 1)\ (362 + 1)}{23.5 + 1} = 696{,}871$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(47{,}033 + 1)\ (362 + 1)}{47.5 = 1} = 352{,}028$$ @ .95 confidence limits

M* adjusted for 3% tag loss

Table 3. Conowingo Dam tailrace relative population estimate of adult American shad in 1998 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 1998 survey -

C = 35,988
R = 31
M = 279*

Therefore -

$$N = \frac{(35,988 + 1)(279 + 1)}{(31 + 1)}$$

= **314,904**

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)

$$\text{Upper } N^* = \frac{(35,988 + 1)(279 + 1)}{21.0 + 1} = 458,042$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(35,988 + 1)(279 + 1)}{44.0 + 1} = 223,932$$ @ .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 1980-1998 tagging program in the upper Chesapeake Bay.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POPULATION ESTIMATE
A. Pound Net					
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
1988	Rocky Pt.	33	87	2.64	
	Cherry Tr.	41	75	1.83	
	Romney Cr.	41	8	0.20	
	TOTALS	115	170	1.48	38,386
1989	Rocky Pt.	32	91	2.84	
	Cherry Tr.	62	295	1.83	
	Beaver Dam	11	14	1.27	
	TOTALS	105	400	3.81	75,820
1990	Rocky Pt.	38	221	5.82	
	Cherry Tr.	71	178	2.50	
	TOTALS	109	399	3.66	123,830
1991	Rocky Pt.	38	251	6.61	
	Cherry Tr.	56	594	10.61	
	Bohemia R.	54	209	3.87	
	TOTALS	148	1054	7.12	139,862
1992	Cherry Tr.	56	147	2.63	
	Bohemia R.	47	43	0.87	
	TOTALS	103	190	1.80	105,255
1993	Cherry Tr.	48	255	5.31	
	Cara Cove	45	26	0.58	
	TOTALS	93	281	3.02	47,563
1994	Cherry Tr.	48	320	6.67	
	Cara Cove	46	26	0.57	
	TOTALS	94	346	0.57	129,482

Table 4, continued.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POPULATION ESTIMATE
A. Pound Net					
1995	Rocky Pt.	48	425	8.85	
	Cherry Tr.	57	472	8.28	
	Beaver Dam	23	262	11.39	
	TOTALS	128	1159	9.05	333,891
1996	Rocky Pt.	60	315	5.25	
	Cherry Tr.	58	330	5.69	
	White Pt.	40	311	7.76	
	TOTALS	158	956	6.05	203,216
1997	Rocky Pt.	56	658	11.25	
	Cherry Tr.	55	510	9.27	
	TOTALS	111	1168	10.52	708,628
1998	Cherry Tr.	48	215	4.50	487,810

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPBH*	CPUE HTC**	POPULATION ESTIMATE
B. Hook and Line					
1982	***	88	-	-	37,551
1983	***	11	-	-	12,059
1984	52.0	126	2.42	0.41	8,074
1985	85.0	182	2.14	0.47	14,283
1986	147.5	437	2.96	0.34	22,902
1987	108.8	399	3.67	0.27	27,354
1988	43.0	256	5.95	0.17	38,386
1989	42.3	276	6.52	0.15	75,820
1990	61.8	309	5.00	0.20	123,830
1991	77.0	437	5.68	0.18	139,862
1992	62.8	383	6.10	0.16	105,255
1993	47.6	264	5.55	0.18	47,563
1994	88.5	498	5.63	0.18	129,482
1995	84.5	625	7.40	0.14	333,891
1996	44.3	446	10.10	0.10	203,216
1997	58.0	607	10.47	0.10	708,628
1998	20.3	337	16.60	0.06	487,810

* Catch-per-boat-hour
** Hours to catch one American shad
*** Hours fished not recorded

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 (1980-1998), annual Conowingo tailrace Petersen population indices, and geometric mean CPUE's for two gear types (1984-1998) where N = number of years.

GEAR TYPE	PETERSEN POPULATION ESTIMATES UPPER BAY	TAILRACE
Pound Net		
r_p	0.74	NA
N	19	
P	0.0004	
Hook & Line		
r_p	0.82	0.83
N	15	15
P	<0.0001	0.0001
Fish Lifts		
r_p	0.88	0.81
N	19	15
P	<0.0001	0.0002

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 1998 upper Chesapeake Bay spring tagging operation.

AGE GROUP	N	RPTS	MALE MEAN	RANGE	N	RPTS	FEMALE MEAN	RANGE
Pound Net								
II	0	0	-	-	0	0	-	-
III	6	0	342	310-350	0	0	-	-
IV	30	2	385	350-430	22	0	420	390-470
V	40	15	413	370-460	27	5	436	400-480
VI	9	8	442	400-485	21	12	469	420-500
VII	0	0	-	-	2	2	483	475-490
VIII	0	0	-	-	0	0	-	-
% RPTS	29.4				26.4			
Hook and Line								
II	1	0	280	-	0	0	-	-
III	8	0	339	310-365	0	0	-	-
IV	60	0	387	344-421	77	0	419	375-460
V	54	7	410	378-460	64	6	439	399-480
VI	5	3	444	430-460	30	11	464	440-520
VII	1	1	455	-	6	5	486	460-510
VIII	0	0	-	-	1	1	525	-
IX	0	0	-	-	1	1	562	-
% RPTS	8.6				12.9			
Gears Combined								
II	1	0	280	-	0	0	-	-
III	14	0	346	310-365	0	0	-	-
IV	90	2	387	349-430	99	0	419	375-470
V	94	22	411	370-460	91	11	439	399-480
VI	14	11	442	400-485	51	23	466	420-520
VII	1	0	455	-	8	7	485	460-510
VIII	0	0	-	-	1	1	525	-
IX	0	0	-	-	1	1	552	-
% RPTS	16.9				16.8			

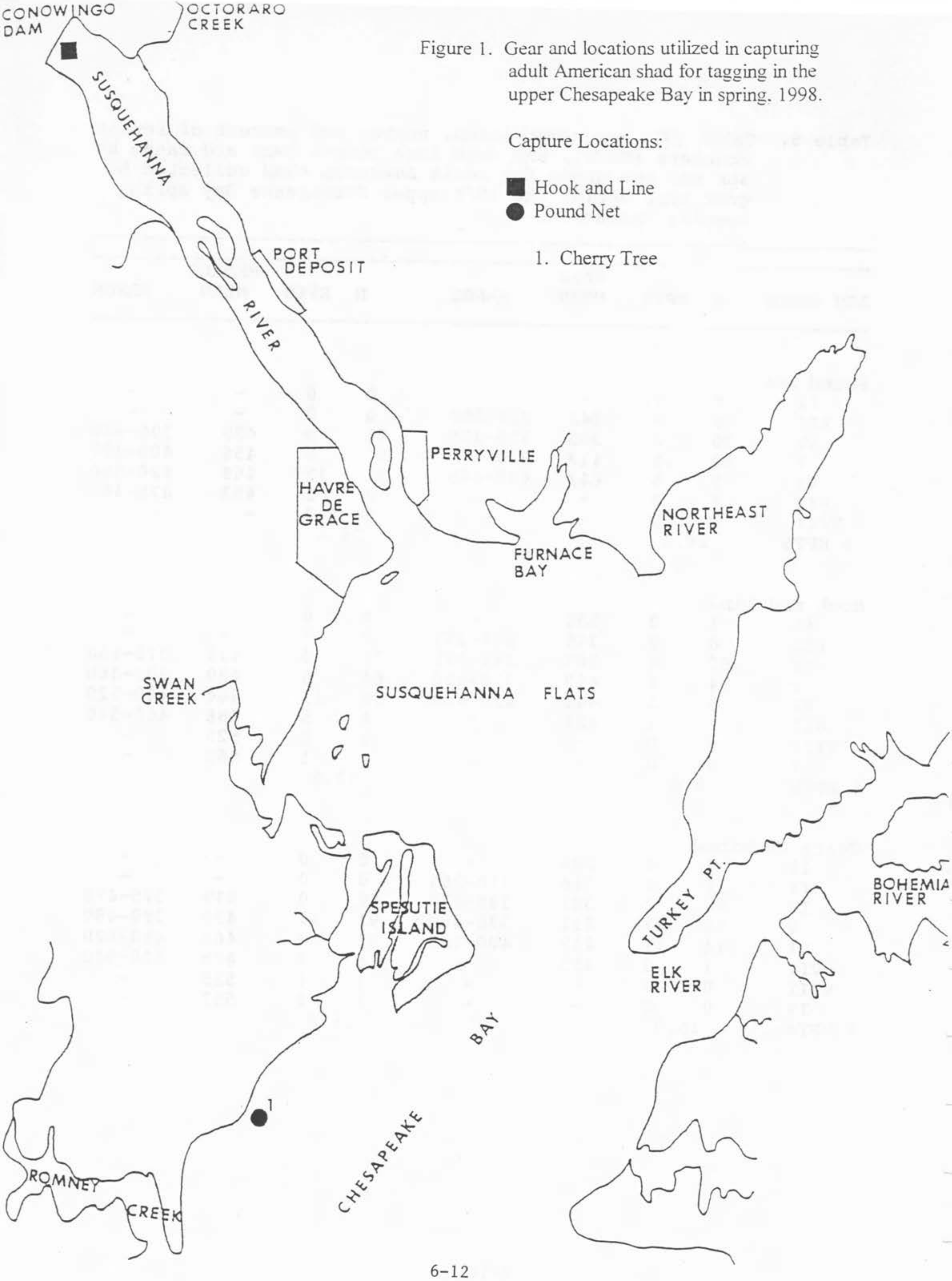


Figure 1. Gear and locations utilized in capturing adult American shad for tagging in the upper Chesapeake Bay in spring, 1998.

Figure 2. Upper Chesapeake Bay population indices of American shad, 1980-1998. Bars indicate 95% confidence ranges and numbers above indicate the yearly population index.

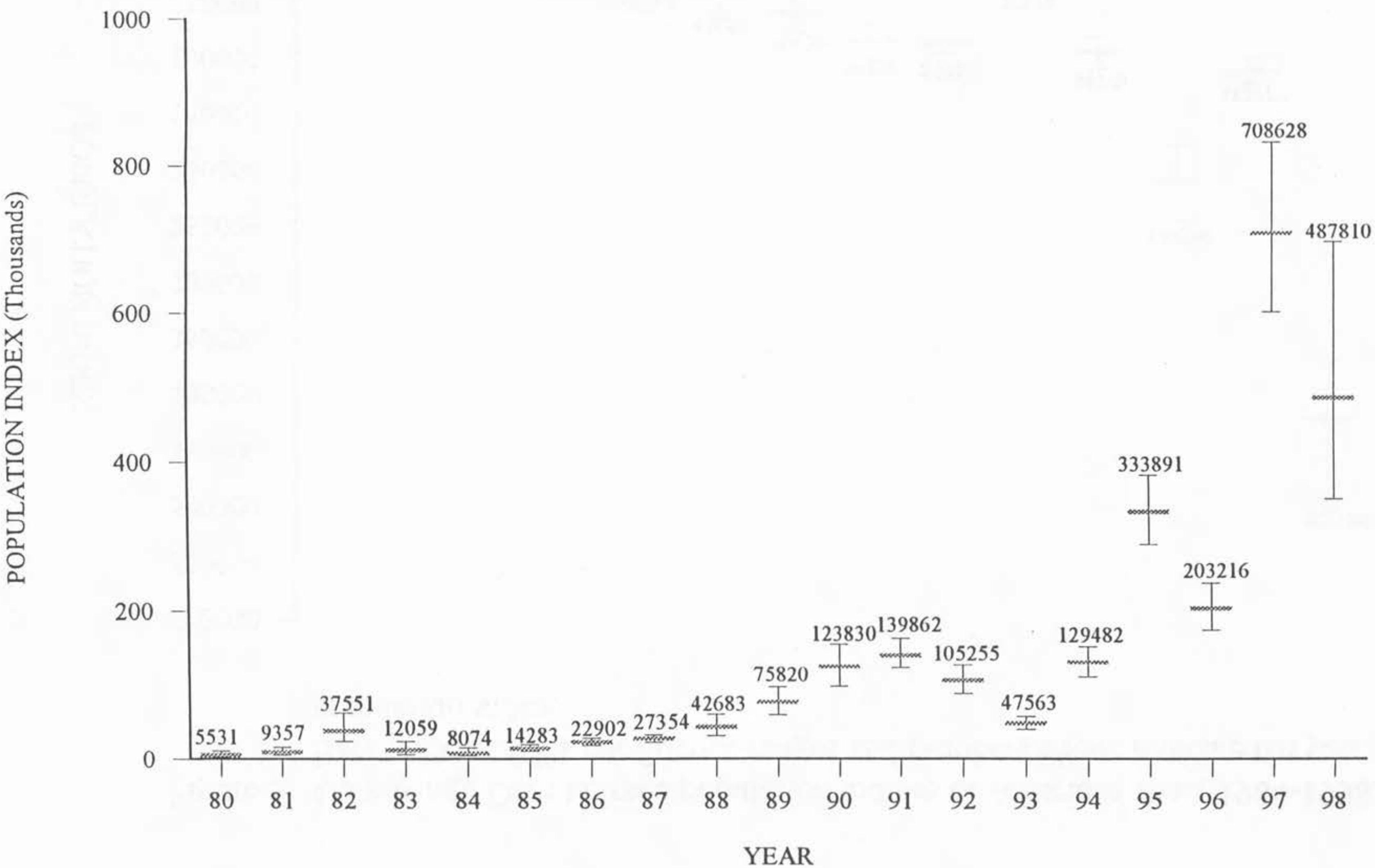


Figure 3. Conowingo Dam tailrace population indices of American shad, 1984-1998. Bars indicate 95% confidence ranges and numbers above indicate the yearly population index.

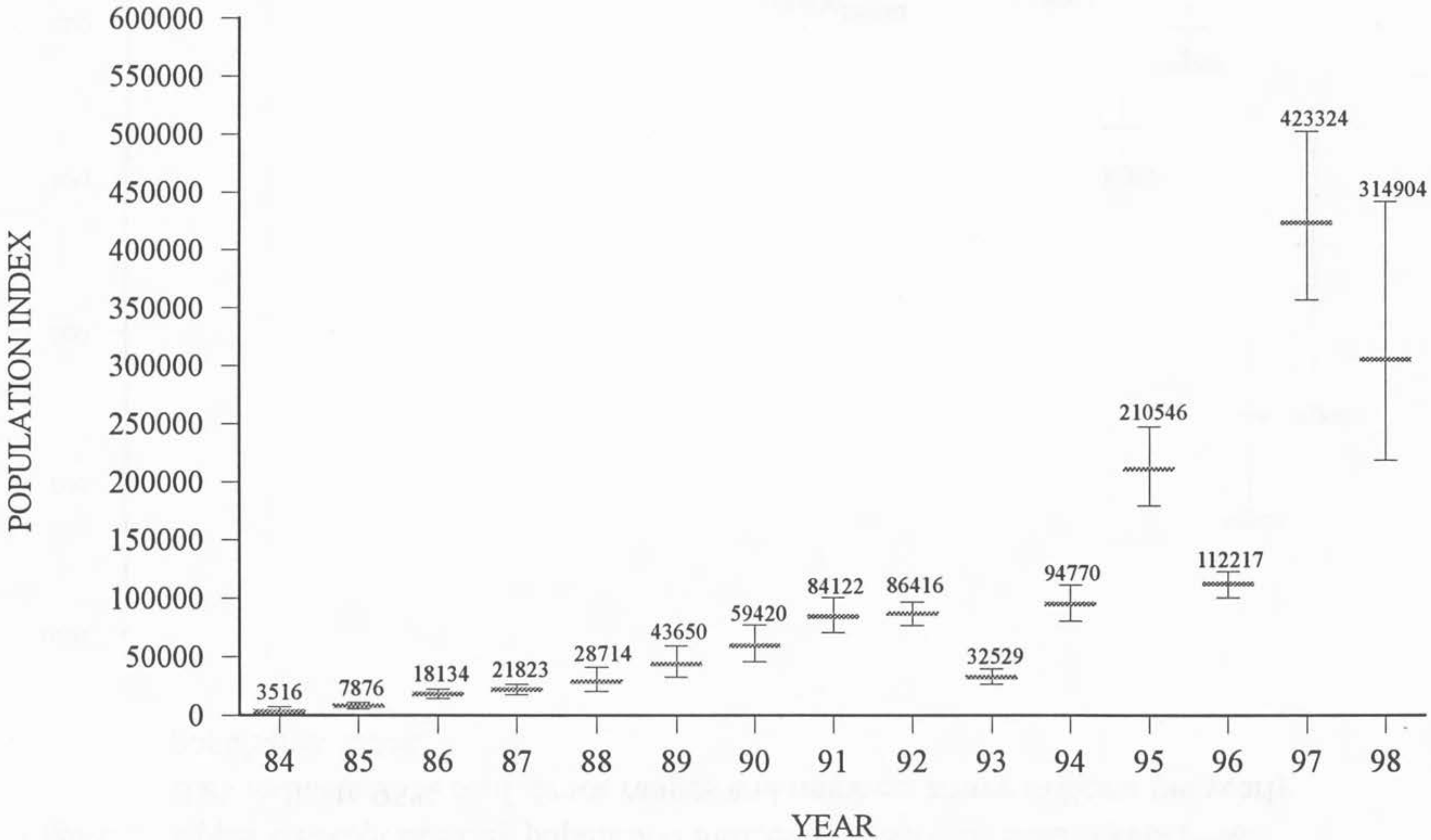


Figure 4. Regression analysis of geometric mean catch-per-unit-effort (CPUE) of American shad sampled by pound net, hook and line, and Conowingo fish lifts in the upper Chesapeake Bay, 1980-1998.

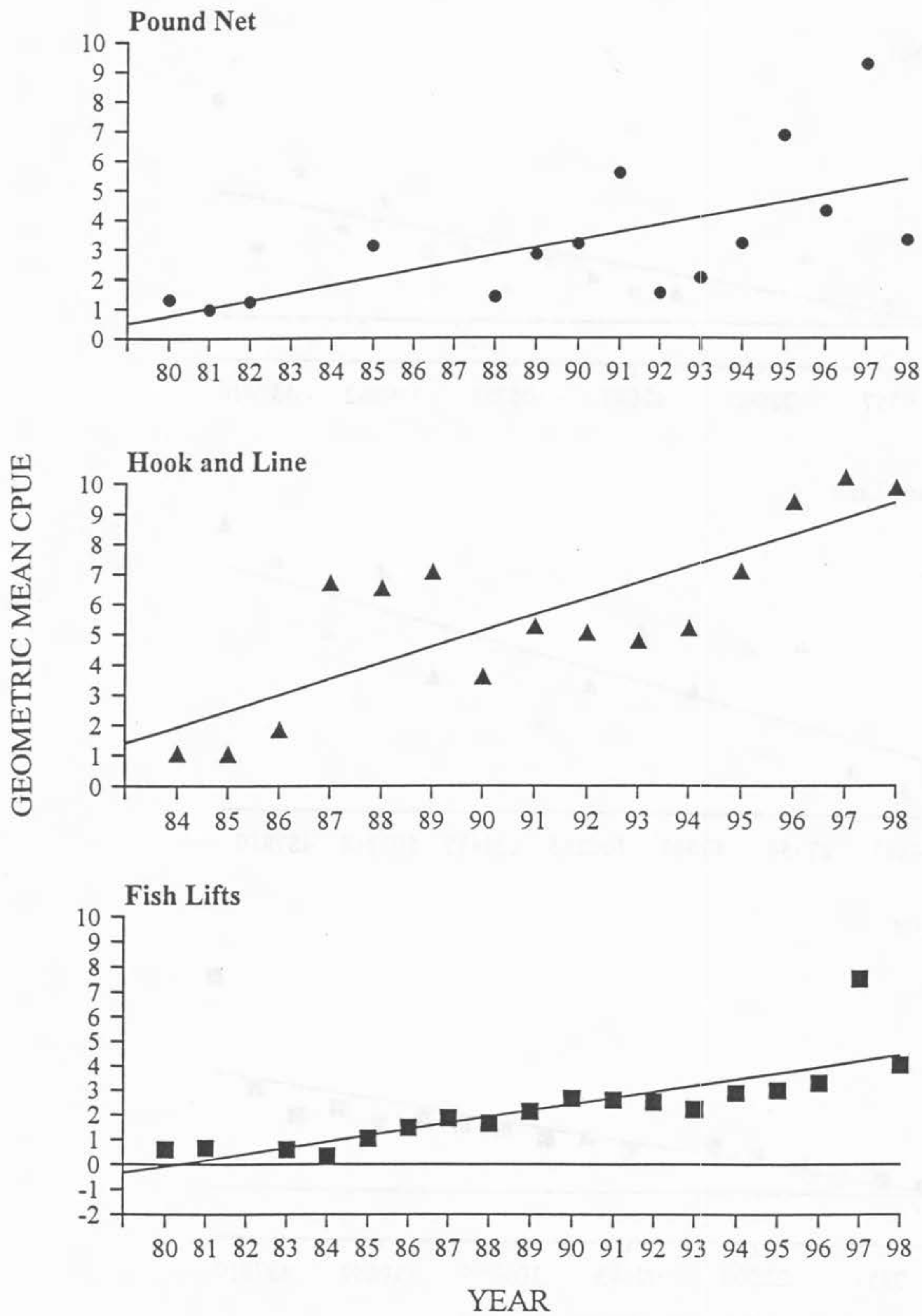


Figure 5. Pound net, hook and line, and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus population indices of American shad in the upper Chesapeake Bay, 1980-1998.

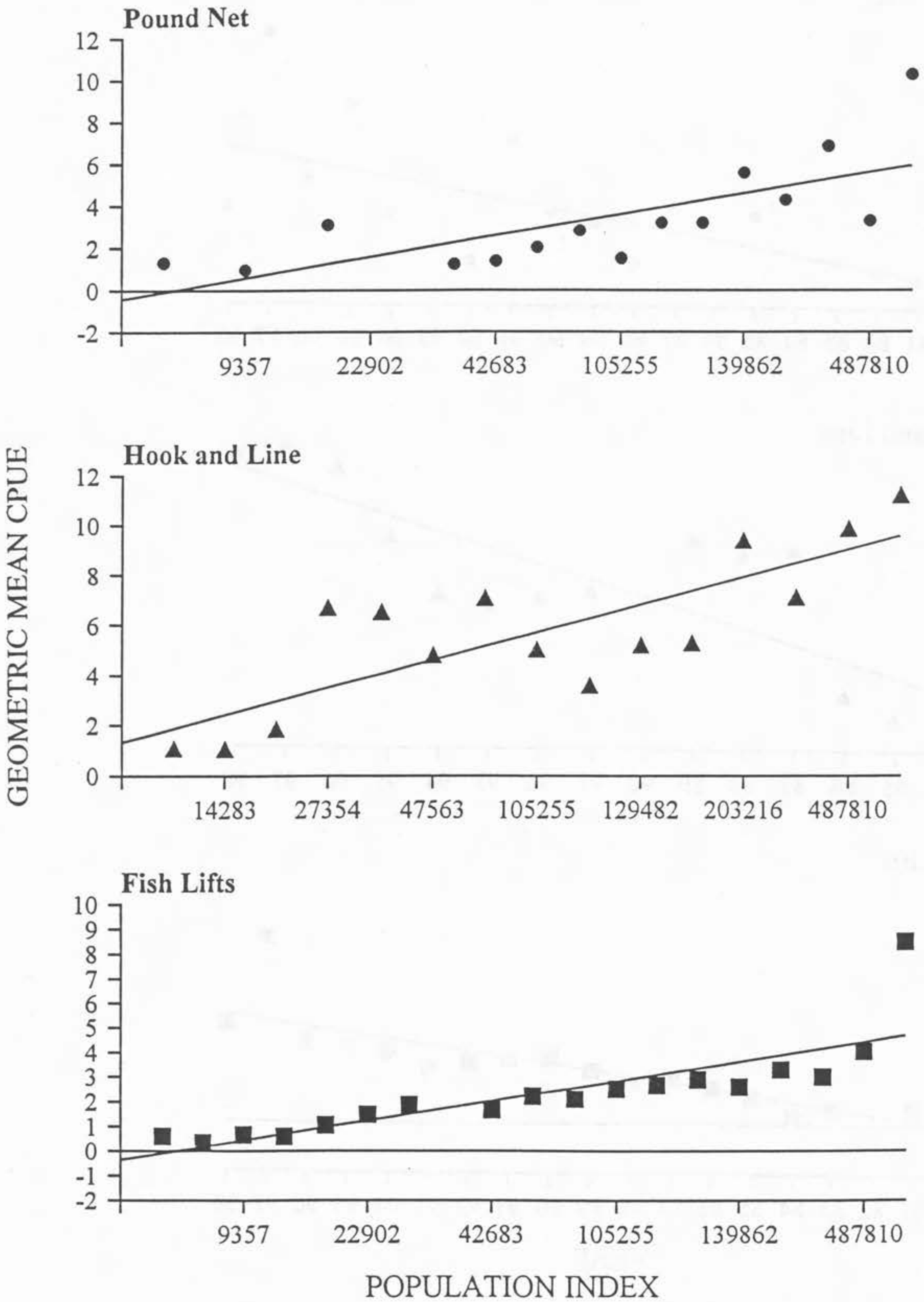
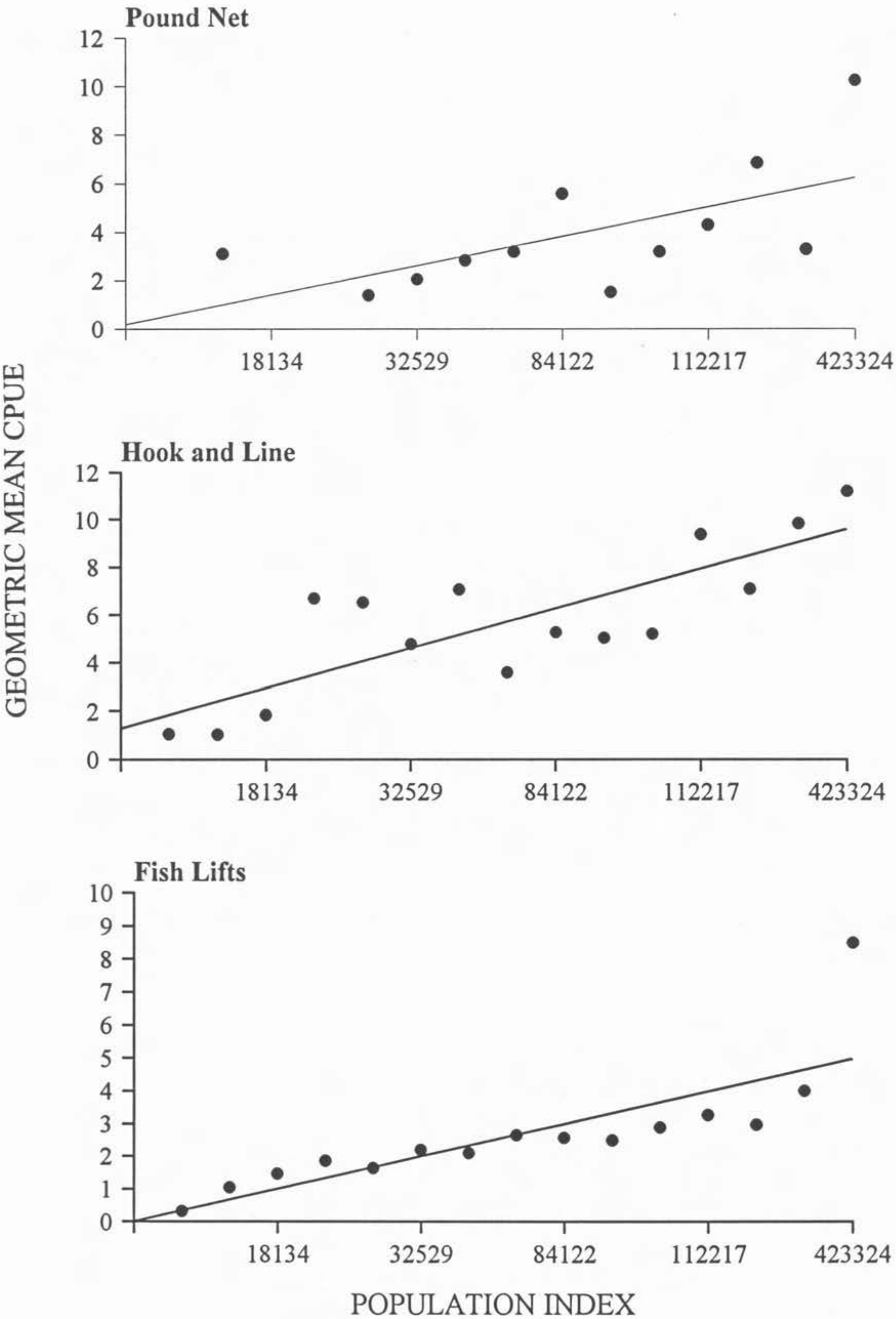


Figure 6. Pound net, hook and line, and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus Conowingo Dam tailrace population indices of American shad, 1980-1998.



LAST
PAGE