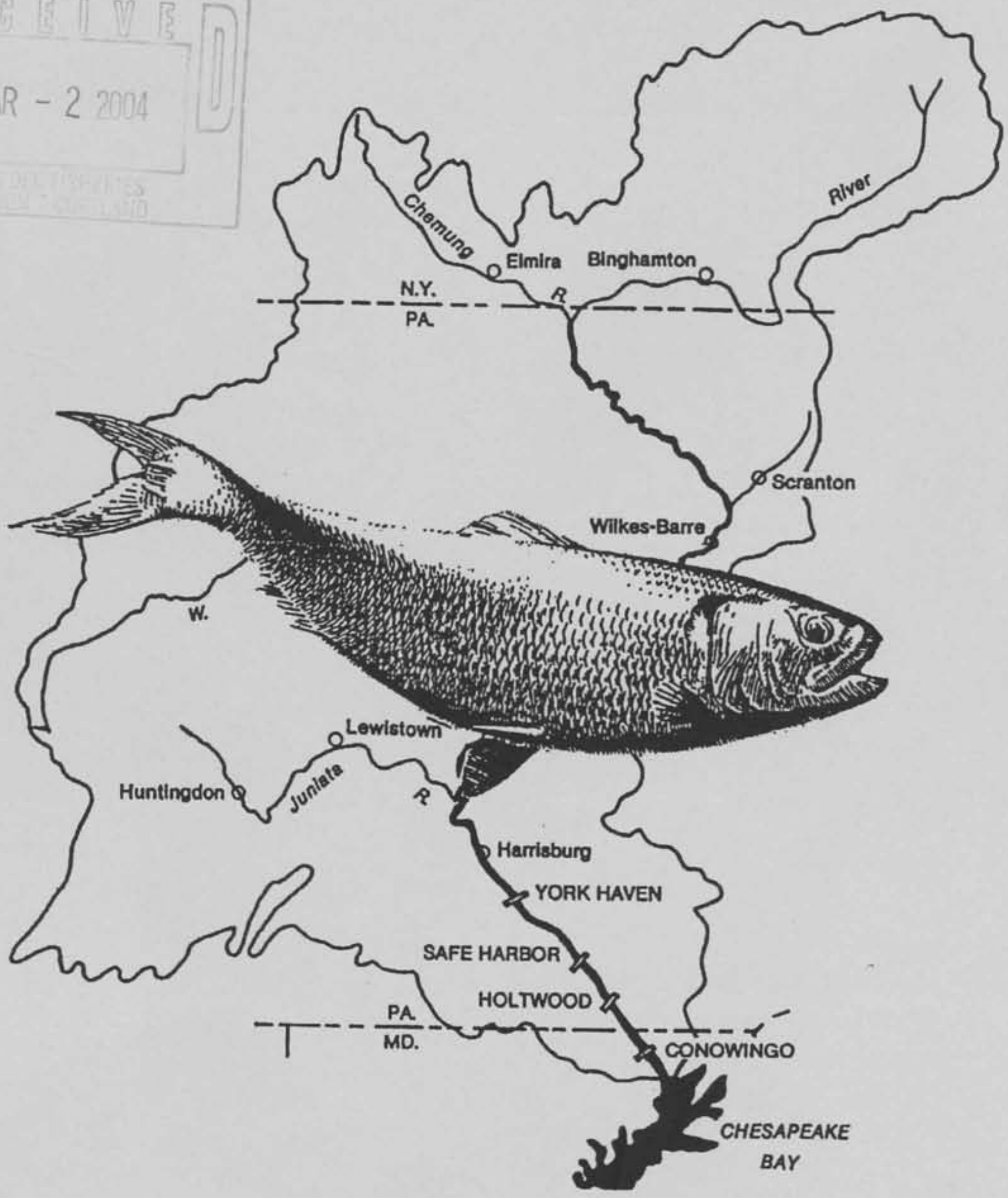
Restoration of American Shad to the Susquehanna River

Annual Progress Report
2003

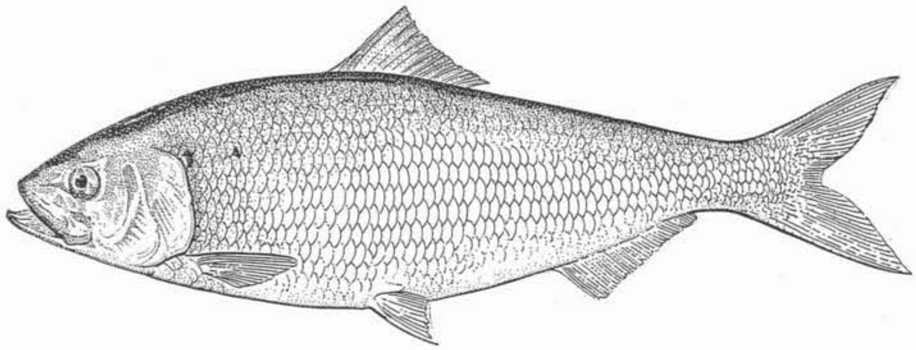
RECEIVED
MAR - 2 2004



Susquehanna River
Anadromous Fish Restoration Committee

February 2004

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

2003

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

Maryland Department of Natural Resources
New York Div. of Fish, Wildlife & Marine Resources
Pennsylvania Fish and Boat Commission
Susquehanna River Basin Commission
United States Fish and Wildlife Service
NOAA Fisheries

FEBRUARY 2004

TABLE OF CONTENTS

JOB I - Part 1. SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY IN SPRING 2003

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

JOB I - Part 2. SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2003

Richard St. Pierre
U.S. Fish & Wildlife Service
P. O. Box 67000
Harrisburg, PA 17106

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

JOB I - Part 3. SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY IN SPRING 2003

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

JOB I - Part 4. SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY IN SPRING 2003

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

JOB I - Part 5. SUMMARY OF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THE YORK HAVEN HYDROELECTRIC PROJECT IN 2003

Kleinschmidt
2 East Main Street
Strasburg, PA 17579

JOB II - Part 1. AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2003

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 IN 2003

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

JOB II - Part 3. HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN AND HICKORY SHAD AT CONOWINGO DAM, SPRING 2003

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

JOB II - Part 4. AMERICAN SHAD EGG COLLECTION FROM THE LOWER SUSQUEHANNA RIVER

Richard St. Pierre
U.S. Fish and Wildlife Service
P. O. Box 67000
Harrisburg, PA 17106-7000

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2003

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

Appendix 1. Egg Viability and Survival of Larvae from American Shad Eggs Incubated in Various Egg Jar Configurations at Van Dyke, 2003

Appendix 2. Survival of American Shad Larvae Released at Various Sites in the Susquehanna River Drainage, 2003

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

Michael L. Hendricks and R. Scott Carney
Pennsylvania Fish and Boat Commission
Benner Spring Fish Research Station
State College, PA 16801

Job V - Task 1. ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 2003

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

EXECUTIVE SUMMARY

This 2003 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 is aimed at rebuilding anadromous American shad and river herring stocks based on hatchery releases and natural reproduction of adult fish directly passed through fish lifts at Conowingo, Holtwood, Safe Harbor dams and a fish ladder at York Haven dam. The restoration program represents a continuing commitment among all parties to return migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

Spring 2003 was characterized by persistent and near record May precipitation in the lower basin, unusually cool and stable water temperatures, but fairly modest river flows of 40,000-60,000 cfs until early June. The Conowingo East lift began operations on April 15, shad first appeared in abundance on April 25, and the lift operated every day thereafter until June 2 when high water and low catch terminated operations. For the season the East lift operated 44 days, made 645 lifts and passed 589,177 fish representing 25 taxa. Gizzard shad (459,634) and American shad (125,135) comprised over 99% of all fish passed. Other alosids included only 530 blueback herring and 21 alewives. About 84% of the season total of American shad passed the East lift prior to May 16. A total of 197 Maryland DNR tags were observed here most of which were 2003 fish tagged in the tailrace.

The Conowingo West lift operated on 30 days during the period April 27 through June 2, fishing for 171.8 hours and making 367 separate lifts. Total catch amounted to 147,388 fish of 30 taxa including 118,852 gizzard shad, 14,476 white perch, 9,802 American shad, 183 bluebacks, 16 alewives and 1 hickory shad. Sex ratio in the American shad run was 1.2 to 1 favoring males. Every 50th shad collected throughout the season was killed for otolith analysis and scale samples. Shad used for tank spawning included 460 provided to Maryland DNR and 1,504 kept on-site at Conowingo Dam. No fish were transported upstream in 2003.

The tailrace lift at Holtwood operated on 34 days during April 28 through June 2, fishing for 312 hours and making 453 lifts. The spillway lift operated on 17 days making 123 lifts in 99 hours. Some spillage occurred at Holtwood on all but one day during the 2003 season. A total of 25,254 American shad were passed in 2003 - 21,201 at the tailrace and 4,053 at the spillway. Other fish in combined Holtwood collections included 145,732 gizzard shad, 3 bluebacks and 8,242 others. Peak passage days for American shad were April 30 - May 13 with 21,981 fish (87% of season). Shad passage rate at Holtwood in 2003 was only 20.2% of those passed at Conowingo East lift, a slight increase from 2002 but substantially less than the record 56.8% seen in 2001.

The Safe Harbor fish lift operated for 307.9 hours during 37 days between May 2 and June 16 and made 320 lifts. Operations were suspended during May 14-15 for mechanical repairs and June 4-10 due to high water. Total fish passage for the season was 152,407 fish including 16,646 American shad and 117,031 gizzard shad. Peak American shad passage coincided with Holtwood with 11,805 (71%) counted during May 2-16. Safe Harbor passed about 66% of the shad passing Holtwood.

Fish ladder operations at York Haven's East Channel Dam occurred on 39 days between May 6 and June 19 with American shad observed passing the site on 38 days. For the season, total fish passage at York Haven amounted to 146,420 fish including 113,513 gizzard shad, 2,536 American shad (15.2% of Safe Harbor total), and 30,371 others (25 species). Most American shad (75%) passed York Haven during the periods May 7-12 (850), May 19-22 (615) and May 30-June 1 (422).

No pound nets were set in upper Chesapeake Bay and Maryland DNR collected shad for tag and release only by angling in the Conowingo tailrace. Total catch was 774 shad of which 757 were tagged and released. Using recapture (tag sightings) primarily from the East lift, a shad population index was calculated for the Conowingo tailrace of 487,073, slightly lower than in 2002. Scale analysis from angling samples showed that most males were aged 4-5 with 21% repeat spawning, and most females were ages 5-6 with 26% repeat spawners (compared to 48% last year).

Based on analysis of 196 readable otoliths from adult shad taken at Conowingo West lift, 146 (74%) were of hatchery origin and 50 (26%) were wild. This is the lowest percentage of wild fish in collections since 1995. The majority of hatchery fish (105 or 72%) carried the single day 3 or 5 tetracycline mark suggesting that they were stocked in the Juniata River or mainstem Susquehanna below Sunbury. Of the remaining tagged fish, 20 carried various triple marks, 16 were quadruple marked, and five had 5 marks. Based on the analysis of hatchery vs. wild adult shad returning to Conowingo, age of fish, and known stocking numbers, PFBC calculated that, on average for the almost fully recruited year-classes of 1986-1997, it took an average 183 stocked larvae, 133 stocked fingerlings, and/or 0.64 transplanted or passed adults to produce each adult return.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River at Coxsackie, NY and PFBC completed Delaware River egg collections at Smithfield Beach, PA. The Hudson produced 17.12 million eggs with 68.5% viability. Delaware River collections amounted to 3.61 million eggs with 61.8% viable. In a third year attempt at tank spawning at Conowingo Dam, Normandeau Associates used two tanks and completed 12 spawning trials using 1,504 fish (605 females) to produce 11.97 million eggs of which 17.7% were viable. Fish received 150 ug doses of LHRH hormone in either pellet or liquid injections. In a first attempt, Normandeau also tank spawned hickory shad collected by angling and produced 14.4 million eggs of which 44.1% were viable. Also new in 2003, USFWS initiated netting and strip spawning of shad in the lower Susquehanna River. During seven nights of netting near Lapidum and Port Deposit in May, 218 shad were collected (mostly hard) and 555,000 eggs were shipped to Van Dyke with 67.6% viability. Total American shad egg collections in 2003 amounted to 33.04 million and the 16.3 million viable eggs was the highest number produced since 1991.

Van Dyke Hatchery personnel resolved the unusually high post-hatch mortality problems from 2002 which was attributed to chemically treated foam bottoms used in the Van Dyke incubation jars. Total production in 2003 was 12.743 million American shad fry and 2.95 million hickory shad. Of the American shad, 10.685 million were stocked in the Susquehanna drainage as follows: 4.01 million in the Juniata River; 3.65 million in the Susquehanna below Sunbury; 907,000 in NY waters of the Susquehanna and Chemung rivers; 800,000 in the North Branch in PA; 592,000 in the West Branch; and 727,000 in four lower river tributaries. Van Dyke shad were also stocked into the Schuylkill (1.02 million), Lehigh (783,000) and Raritan (255,000) rivers. Hickory shad larvae were stocked at the Muddy Creek access in Conowingo Pond (1 million) and Ridley Creek in the Delaware drainage (1.95 million). All fish were distinctively marked with tetracycline.

As was the case in 2002, juvenile shad collections were very weak in 2003. Although hatchery stocking was substantial, relatively few adults passed into spawning waters above Safe Harbor and York Haven fishways. Haul seining at Columbia, PA was scheduled for 15 weeks but only 8 events occurred due to frequent high water. At total of 17 American shad were taken in 48 hauls, all between August 27 and September 12. No shad were taken by push nets in Conowingo Pond, by seines in four lower river tributaries, or by electrofishing in the mainstem near Clemson Island. Seven shad were collected with electrofisher in the Juniata River at Mifflintown during mid-September. A total of 61 juvenile shad was taken with lift net at Holtwood's inner forebay on five dates between September 28 and October 19. Peach Bottom screens produced 7 shad, 48 bluebacks, and 2 alewives, while intake strainers at Conowingo provided 18 shad, 2 bluebacks and 4 alewives. No juvenile shad were collected in New York waters or from intakes screens at Susquehanna SES in Berwick, PA. During July-September seine sampling in the upper Chesapeake Bay, Maryland DNR collected 140 juvenile American shad in 57 hauls.

Otoliths from 102 juvenile shad were examined for hatchery marks from combined collections made at and above Conowingo Dam. Of these, about 92% were hatchery marked with the majority of those having been stocked at various locations in the Juniata or mainstem Susquehanna River. Most of the remaining hatchery fish examined came from stockings in the North Branch in Pennsylvania

(7 fish) with smaller numbers from the West Branch (4), West Conewago Creek (3), and North Branch-NY (2). In terms of relative survival from stocking site to juvenile recovery, larvae stocked in the Juniata and mainstem Susquehanna above Clarks Ferry from Susquehanna egg sources produced best results followed by West Conewago, Swatara, North Branch (PA) and West Branch (all Hudson eggs).

Fish passage facility maintenance, operations, fish counting and reporting were paid by each of the affected utility companies in accordance with guidelines established by separate fish passage advisory committees. American shad egg collections from the Hudson and Delaware rivers, Van Dyke hatchery culture and marking, juvenile shad netting and other surveys above Conowingo Dam, and otolith mark analysis were funded by the PA Fish and Boat Commission. Maryland DNR funded the adult shad population assessment, stock analysis, and juvenile shad seining in the upper Chesapeake Bay. USFWS covered most costs associated with lower Susquehanna River shad egg collections. Costs related to Conowingo West fish lift operations including tank spawning and hormones were paid from a SRAFRC contributed funds account administered by USFWS. This account also paid for services of a contract fisherman to work with USFWS on Susquehanna egg collections. Contributions to the special account in 2003 came from Maryland DNR and PFBC.

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

Richard St. Pierre
Susquehanna River Coordinator
U. S. Fish and Wildlife Service
P. O. Box 67000
Harrisburg, Pennsylvania 17106-7000

phone: 717-705-7838; fax 717-705-7901
e-mail: richard_stpierre@fws.gov

Job I – Part 1
SUMMARY OF OPERATIONS AT THE CONOWINGO DAM EAST FISH PASSAGE FACILITY IN SPRING 2003

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

INTRODUCTION

Susquehanna Electric Company (SECO), a subsidiary of Exelon Generation, has operated a West lift fish passage facility at 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 had been to monitor fish populations below Conowingo Dam and transport pre-spawned migratory fishes upriver.

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

With the completion of fishways at Holtwood, Safe Harbor, and York Haven dams, the East lift has been operated to pass fish directly into Conowingo Pond since spring 1997. Objectives of 2003 operation were: (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway and trough effectiveness and make modifications as feasible.

CONOWINGO OPERATION

Project Operation

The Conowingo Hydroelectric Station, built in 1928, is located at river mile 10 on the Susquehanna River (RMC 1992). The powerhouse has a peaking generating capacity of 512 MW and a hydraulic capacity of approximately 85,000 cfs. Flows in excess of station draft are spilled over two regulating and 50 crest gates. The powerhouse contains seven vertical Francis (numbered 1 through 7) and four Kaplan (numbered 8 through 11) turbines. The seven Francis units have been equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The four original Kaplan turbines installed in 1964 were replaced over a period of four years (1992 to 1996), with more efficient mixed-flow Kaplan type turbines.

Minimum flow releases from the station during the spring spawning and fishway operating season follow the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500, and 5,000 cfs were maintained from 1 to 30 April, 1 to 31 May, and 1 and 2 June, respectively.

Fishway Operation

East lift operation began on 15 April and generally operated on an every day basis from 25 April through 2 June. Lift operation was suspended on 2 June due to a high river flow event and the season was terminated soon thereafter. The lift was operated a total of 44 days during the 2003 season.

Generally, daily operation began at 0800 h and continued until approximately 1900 h. Fishway operation was conducted by a staff of three people: a lift operator, a supervising biologist, and a biological technician.

The mechanical aspects of the East lift operation in 2003 were similar to those described in RMC (1992) and Normandeau Associates, Inc. (1999). Fishing time and/or lift frequency was determined by fish abundance, but the hopper was cycled at least hourly throughout the day. The method of lift operation was also influenced by fish abundance. When a great number of fish were in the fishing channel, the crowder was not operated; instead the crowder screen was raised and then lowered trapping fish over the hopper. This mode of operation, called "fast fish", involved leaving the crowder in the normal fishing position and raising the hopper frequently to remove fish that accumulated in the holding channel.

The specific entrance(s) used to attract fishes was dictated by the station discharge and which turbine units were operating. For example, when turbine units 8, 9, 10, and 11 or any combination of large turbines were operating, entrance C was the primary entrance used to attract fishes. Under these conditions the attraction flow through the other entrances was negated or disrupted. Entrance A or C was used to attract fishes during the 2003 season.

Fish Counts

Fish that were lifted and sluiced into the trough were guided by a series of fixed screens. The fixed screens directed the fish to swim up and through a 3 ft wide channel and past a 4 ft by 10 ft counting window located on the west wall of the trough. Fish passing the counting window were identified to species and enumerated by a biologist and/or technician. Passage of fish by the window and out of the trough system was controlled by a set of gates located downstream of the counting window. During periods of peak passage, two people were used to identify and count fish.

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

RESULTS

Relative Abundance

The number of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 1. A total of 589,177 fish of 25 species was passed upstream into Conowingo Pond. Gizzard shad (459,634), American shad (125,135), and white perch (1,572) were the dominant species passed. Gizzard shad and American shad comprised 78% and 21% respectively of the season total; the two species together accounted for 99% of the total fish passed. Other common fishes included carp (561), quillback (548), and blueback herring (530). Alosids (American shad, blueback herring, and alewife) comprised 21% of the total catch. Peak passage occurred on 12 May when 29,767 fish, (91.5% gizzard shad), were passed.

American Shad Passage

The East lift collected and passed 125,135 American shad (Table 1). The first shad was passed on 25 April. Collection and passage of shad varied daily with 76% (95,430) of the shad collected and passed during the sixteen day period between 28 April and 13 May (Figures 1 and 2). The lift collected and passed over 10,000 American shad on two separate days. On 10 of the 44 days of operation, American shad passage exceeded 5,000 fish. Peak passage occurred on 4 May when 13,749 American shad were passed.

American shad were collected at water temperatures of 57.2 to 68.9°F and at natural river flows of 32,800 to 75,500 cfs (Table 2 and Figure 1). The average daily river flow on those days when American shad passage exceeded 1000 fish was approximately 38,600 cfs. The average daily river flow during the operational season was 45,970 cfs.

The hourly passage of American shad for the East lift is given in Table 3. Peak hourly passage of shad (15,903) occurred between 1500 to 1559 h. Generally, shad passage was steady, all hour periods from 1200 to 1859 h had passage greater than 12,000 shad.

Alosids

A total of 21 alewife was collected and passed (Table 1). The alewife were passed between 28 April and 6 May. No hickory shad were collected or passed in spring 2003.

A total of 530 blueback herring was collected and passed (Table 1). Most blueback herring (nearly 87%) were passed from 23 to 25 May at a water temperature of approximately 63.0°F and an average river flow of 39,733 cfs.

SUMMARY

East fish lift operation was initiated on 15 April following a period of high river flows and water temperatures below 50°F. The first American shad was not passed until 25 April. The East fish lift successfully passed 125,135 American shad from 25 April through 2 June. The total number of American shad passed during the 2003 season was the third highest passage total since East lift operations began in 1991 and the fourth consecutive year in which American shad passage at Conowingo has surpassed 100,000 fish (Table 4).

Fish viewing conditions were not significantly impacted by the occurrence of sustained spring river flows in 2003. Decent water clarity allowed technicians to observe well over 25 inches of the viewing area throughout most of the season. Visual counting accuracy was maximized by utilizing two people during periods of increased fish passage and/or poor viewing conditions

Modifications made to the fish trough, particularly the valve grating and hopper trough chute since 1999 have diminished the potential for the valve grating to clog with various types of debris and have decreased the number of American shad lift mortalities observed throughout the last several fish passage seasons. Since the valve grating was modified prior to the start of the 2000 season, loss of water flow in the trough has not occurred, particularly during high river flow periods when large amounts of debris may enter the trough through the fish exit area. An aeration system was also installed prior to the 2000 passage season to diminish low dissolved oxygen levels when the American shad population is heavy in the trough. Prior to fishway operations in 2002, a 30 inch diameter fiberglass elbow was attached to the hopper extension chute, which had been installed in 2001. The modification allows fish to enter the trough center stream, instead of being directed toward the east trough wall. A decrease in lift mortalities has also been observed since the fiberglass elbow was installed. A total of 170 American shad lift mortalities, (0.1% of the total shad passed), were observed in 2003, lower than the lift mortalities observed in recent years (0.3% to 1.0%) and less than values observed during trap and transport operations (1.5% to 10.5%).

RECOMMENDATIONS

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

2) Continue the use of two fish counters during periods of increased fish passage to accurately reflect the number of fish that pass through the East lift.

3) Continue to inspect cables, limit switches, and lift components to enhance season operability, and continue to evaluate effectiveness of fish trough modifications.

LITERATURE CITED

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

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 2003. No operation on April 17, 19, 20, 22, and 24.

Date:	*15 Apr*	*16 Apr*	*18 Apr*	*21 Apr*	*23 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Hours of Operation:	*2.0*	*4.5*	*5.8*	*6.0*	*7.0*	*9.6*	*10.0*	*7.8*
Number of Lifts:	*1*	*5*	*6*	*8*	*7*	*13*	*12*	*12*
Water Temperature (°F):	*54.5*	*54.5*	*55*	*57.2*	*56.3*	*57.2*	*58.1*	*58.1*
American shad	0	0	0	0	0	2,405	2,181	668
Blueback herring	0	0	0	0	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	127	753	7,495	6,937	4,440	7,975	8,327	8,705
Sea lamprey	0	0	0	0	0	0	0	1
Rainbow trout	0	0	0	1	0	0	0	0
Carp	0	0	0	0	0	0	0	0
Blacknose dace	0	0	0	0	0	0	0	0
Quillback	0	0	0	0	0	0	1	0
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	0	0	0	1	0	3	0	0
White catfish	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	1
White perch	0	0	0	0	0	0	0	0
Striped bass	0	0	1	0	0	0	0	0
Rock bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Bluegill	0	2	2	0	0	1	0	1
Smallmouth bass	0	2	3	8	1	0	3	0
Largemouth bass	0	0	0	1	0	1	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	0	0	0	0	1	0	0	0
TOTAL	***127***	***757***	***7,501***	***6,948***	***4,442***	***10,385***	***10,512***	***9,376***

Table 1

Continued.

Date:	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*	*02 May*	*03 May*	*04 May*	*05 May*
Hours of Operation:	*9.3*	*10.8*	*10.5*	*10.8*	*11.0*	*10.3*	*11.3*	*10.9*
Number of Lifts:	*16*	*18*	*17*	*19*	*18*	*17*	*25*	*20*
Water Temperature (°F):	*60.8*	*62.6*	*61.7*	*62.6*	*65.3*	*65.3*	*64.4*	*65.3*
American shad	10,016	4,622	6,396	7,513	8,857	6,856	13,749	2,056
Blueback herring	0	0	0	0	0	0	0	0
Alewife	3	1	0	4	3	2	7	0
Gizzard shad	10,194	20,659	14,974	6,855	15,441	11,312	3,926	25,241
Sea lamprey	0	4	1	2	4	3	4	5
Rainbow trout	0	0	0	0	0	0	0	0
Carp	1	5	2	3	7	5	4	140
Blacknose dace	0	0	0	0	0	0	0	0
Quillback	0	6	4	3	3	4	0	8
White sucker	0	2	0	1	1	0	0	3
Shorthead redhorse	5	72	28	12	10	1	0	5
White catfish	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	0	0	0	0	0	0	0	3
White perch	0	3	12	3	10	2	1	14
Striped bass	0	0	0	0	1	0	0	1
Rock bass	0	0	1	0	2	0	0	1
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Bluegill	3	2	1	0	2	0	4	3
Smallmouth bass	10	23	13	16	21	24	4	22
Largemouth bass	1	0	2	2	1	0	0	1
Yellow perch	0	0	1	1	4	1	0	1
Walleye	1	2	0	0	2	1	0	0
TOTAL	***20,234***	***25,401***	***21,435***	***14,415***	***24,369***	***18,211***	***17,699***	***27,504***

Table 1

Continued.

Date:	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*
Hours of Operation:	*10.5*	*10.5*	*10.8*	*11.0*	*10.3*	*11.0*	*10.5*	*10.0*
Number of Lifts:	*18*	*17*	*17*	*20*	*20*	*24*	*19*	*17*
Water Temperature (°F):	*63.5*	*63.5*	*68.9*	*65.3*	*64.4*	*67.1*	*65.7*	*66.2*
American shad	7,380	2,449	2,644	6,725	4,394	6,865	2,423	2,485
Blueback herring	1	3	0	33	0	0	0	2
Alewife	1	0	0	0	0	0	0	0
Gizzard shad	17,888	14,897	14,838	12,630	12,502	4,742	27,262	17,343
Sea lamprey	9	5	3	1	2	2	1	1
Rainbow trout	0	0	1	1	0	0	0	0
Carp	2	6	16	1	2	4	6	0
Blacknose dace	0	0	0	0	0	0	0	0
Quillback	2	13	13	0	59	21	35	3
White sucker	1	1	0	0	0	0	0	0
Shorthead redhorse	4	9	16	9	11	3	3	2
White catfish	0	0	0	0	0	0	0	1
Yellow bullhead	0	0	1	0	0	0	0	0
Brown bullhead	2	1	0	1	0	0	1	0
Channel catfish	0	4	6	0	1	0	3	0
White perch	59	71	67	95	25	11	13	17
Striped bass	6	4	4	3	9	2	7	8
Rock bass	0	1	2	0	2	0	2	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	6	1
Smallmouth bass	6	16	12	7	3	0	4	2
Largemouth bass	0	4	3	0	0	0	0	0
Yellow perch	1	6	10	5	1	1	1	0
Walleye	0	0	1	5	3	3	0	3
TOTAL	***25,362***	***17,490***	***17,637***	***19,516***	***17,014***	***11,654***	***29,767***	***19,868***

Table 1

Continued.

Date:	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*
Hours of Operation:	*10.5*	*9.5*	*10.5*	*10.3*	*10.8*	*9.8*	*9.8*	*10.0*
Number of Lifts:	*12*	*14*	*20*	*16*	*15*	*15*	*13*	*16*
Water Temperature (°F):	*63.9*	*64.4*	*63.9*	*62.8*	*61.4*	*60.8*	*60*	*61.4*
American shad	721	3,448	1,760	966	700	678	747	1,935
Blueback herring	6	11	5	3	0	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	14,123	10,798	17,445	10,350	10,116	15,464	6,371	9,841
Sea lamprey	1	3	1	1	1	1	1	0
Rainbow trout	0	0	0	0	0	0	0	0
Carp	4	2	0	5	1	0	0	7
Blacknose dace	0	25	0	0	0	0	0	0
Quillback	2	6	16	0	0	3	16	10
White sucker	0	0	0	0	0	0	0	0
Shorthead redhorse	11	16	11	5	16	3	1	9
White catfish	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	1	0	0	0	1	0
Channel catfish	1	1	2	0	1	2	1	3
White perch	177	66	48	31	177	307	22	15
Striped bass	9	6	15	5	14	28	10	19
Rock bass	3	0	1	0	2	0	0	1
Redbreast sunfish	2	0	0	1	0	1	0	0
Green sunfish	0	0	0	0	0	0	0	0
Bluegill	0	0	0	3	0	0	0	0
Smallmouth bass	0	2	3	0	1	2	5	4
Largemouth bass	0	0	0	1	0	0	0	1
Yellow perch	1	1	0	0	0	0	1	0
Walleye	5	0	1	3	0	1	0	0
TOTAL	***15,066***	***14,385***	***19,309***	***11,374***	***11,029***	***16,490***	***7,176***	***11,845***

Table 1

Continued.

Date:	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Hours of Operation:	*11.3*	*10.8*	*10.5*	*10.5*	*10.7*	*10.8*	*10.4*	*10.0*
Number of Lifts:	*19*	*18*	*15*	*16*	*14*	*17*	*16*	*13*
Water Temperature (°F):	*60.8*	*60.3*	*63.2*	*64.1*	*61.9*	*61.7*	*61.7*	*63.5*
American shad	2,874	2,726	1,546	2,589	1,397	504	603	309
Blueback herring	0	64	303	94	3	0	0	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	12,624	9,522	10,304	11,670	4,664	13,060	7,062	7,911
Sea lamprey	2	1	2	1	2	1	0	1
Rainbow trout	0	0	0	0	0	0	0	0
Carp	3	16	59	43	5	9	19	43
Blacknose dace	0	0	0	0	0	0	0	0
Quillback	9	27	79	37	17	40	61	17
White sucker	0	1	0	0	0	0	0	0
Shorthead redhorse	4	5	5	1	0	12	2	6
White catfish	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0
Brown bullhead	0	0	1	0	1	1	0	0
Channel catfish	4	1	0	0	2	0	3	3
White perch	19	5	4	2	53	67	68	30
Striped bass	16	4	4	8	8	13	19	11
Rock bass	0	0	0	0	0	0	0	0
Redbreast sunfish	0	0	0	0	0	0	0	0
Green sunfish	0	0	2	0	0	0	0	0
Bluegill	1	0	0	2	0	0	0	0
Smallmouth bass	1	5	3	5	2	0	7	3
Largemouth bass	0	0	0	0	0	0	0	1
Yellow perch	0	0	0	1	0	0	0	0
Walleye	3	2	1	5	0	6	1	3
TOTAL	***15,560***	***12,379***	***12,313***	***14,458***	***6,154***	***13,713***	***7,845***	***8,338***

Table 1

Continued.

Date:	*30 May*	*31 May*	*01 Jun*	*02 Jun*	***Total***
Hours of Operation:	*10.7*	*8.0*	*9.0*	*0.5*	***416.6***
Number of Lifts:	*13*	*8*	*8*	*1*	***645***
Water Temperature (°F):	*64.4*	*66.1*	*66.2*	*65.9*	
American shad	352	405	184	7	**125,135**
Blueback herring	0	1	1	0	**530**
Alewife	0	0	0	0	**21**
Gizzard shad	5,686	4,197	2,548	415	**459,634**
Sea lamprey	1	0	0	0	**68**
Rainbow trout	0	0	0	0	**3**
Carp	3	5	130	3	**561**
Blacknose dace	0	0	0	0	**25**
Quillback	14	0	19	0	**548**
White sucker	0	0	0	0	**10**
Shorthead redhorse	1	1	1	0	**304**
White catfish	0	0	0	0	**1**
Yellow bullhead	0	0	0	0	**1**
Brown bullhead	0	0	0	0	**10**
Channel catfish	4	1	6	4	**57**
White perch	11	2	47	18	**1,572**
Striped bass	4	8	18	7	**272**
Rock bass	0	0	0	0	**18**
Redbreast sunfish	0	0	0	0	**4**
Green sunfish	0	0	0	0	**2**
Bluegill	0	0	3	0	**37**
Smallmouth bass	1	3	0	0	**247**
Largemouth bass	0	1	0	1	**21**
Yellow perch	0	0	0	0	**37**
Walleye	1	5	0	0	**59**
TOTAL	***6,078***	***4,629***	***2,957***	***455***	**589,177**

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 2003. No operation on April 17, 19, 20, 22, and 24.

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
15 Apr	0	*0*	89,500	54.5	14	11	C	310	23.5	108.3	0
16 Apr	0	*0*	79,300	54.5	18	11	C	310	23.5	107.2	0
18 Apr	0	*0*	63,400	55.0	23	11	C	310	20.0-23.0	106.5	0
21 Apr	0	*0*	49,000	57.2	26	11	C	310	22.5-23.0	107.9	0
23 Apr	0	*0*	47,100	56.3	27	11	C	310	22.0-23.0	106.7	0
25 Apr	2,405	*0*	38,500	57.2	27	11	A,C	267	18.0-23.0	106.4	0
26 Apr	2,181	*2OR*	39,800	58.1	27	8	A,C	310	17.5-23.0	107.2	0
27 Apr	668	*0*	39,400	58.1	27	6	A,C	310	17.5-21.0	107.0	0
28 Apr	10,016	*0*	39,400	60.8	27	8	C	310	21.0-22.5	107.3	0
29 Apr	4,622	*1GR*	38,500	62.6	28	8	C	310	20.5-22.5	106.7	0
30 Apr	6,396	*1OR,1GR*	36,200	61.7	28	8	C	310	18.5-22.0	106.6	0
01 May	7,513	*1OR*	35,400	62.6	28	7	C	310	20.0-21.5	107.5	0
02 May	8,857	*1OR*	35,800	65.3	28	8	C	310	19.5-22.5	106.4	0
03 May	6,856	*6OR*	34,200	65.3	28	8	C	310	17.5-22.5	107.0	0
04 May	13,749	*20OR,1GR*	32,800	64.4	27	4	C	267	17.5-18.0	107.0	0
05 May	2,056	*6OR,1GR*	36,500	65.3	28	8	C	310	21.5-23.0	107.2	0
06 May	7,380	*22OR*	35,400	63.9	26	7	C	310	21.0	106.5	0
07 May	2,449	*2OR*	36,400	65.3	30	6	C	310	21.0-23.0	107.8	0
08 May	2,644	*3OR*	34,700	68.9	27	8	C	310	20.0-22.5	106.7	0
09 May	6,725	*17OR*	33,700	65.3	26	8	C	310	19.5-22.5	107.1	0
10 May	4,394	*9OR,2GR*	37,500	64.4	26	6	A,C	267/310	17.1-22.0	107.6	0
11 May	6,865	*14OR*	40,000	67.1	26	4	A	267	18.5-19.0	106.6	0
12 May	2,423	*6OR*	41,400	65.7	27	11	C	310	21.5-22.5	106.7	0
13 May	2,485	*8OR*	43,600	66.2	30	8	C	310	21.0-22.5	106.7	0
14 May	721	*1OR*	42,200	63.9	25	10	C	310	21.0-22.5	106.1	0
15 May	3,448	*5OR*	40,500	64.4	27	11	C	310	19.5-23.0	106.0	0
16 May	1,760	*9OR*	37,500	63.9	23	11	C	310/285	19.0-23.0	106.5	0

Table 2

Continued.

Date	American Shad Catch	MD DNR Recaptures*	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)	Crest Gates
17 May	966	*2OR*	48,600	62.8	22	10	C	310	17.5-23.5	108.2	0
18 May	700	*0*	56,500	61.4	23	10	C	310	21.5-23.0	106.4	0
19 May	678	*3OR*	53,600	60.8	24	11	C	310	23.0	106.3	0
20 May	747	*1OR*	51,000	60.0	23	11	C	310	22.5-23.0	106.8	0
21 May	1,935	*10OR,1GR*	45,000	61.4	24	11	C	310	21.5-23.0	107.4	0
22 May	2,874	*5OR*	39,800	60.8	26	11	C	310	20.0-23.0	107.9	0
23 May	2,726	*12OR*	40,800	60.3	25	11	C	310	19.5-23.5	106.8	0
24 May	1,546	*3OR*	35,900	63.2	30	8	C	310	20.0-23.0	107.7	0
25 May	2,589	*5OR*	42,500	64.1	30	8	C	310	19.5-23.0	108.3	0
26 May	1,397	*6OR*	51,200	61.9	29	11	C	310	22.0-22.5	108.6	0
27 May	504	*1OR*	53,100	61.7	22	11	C	310	22.0-23.0	107.3	0
28 May	603	*2OR,1GR*	57,300	61.7	26	11	C	310	22.5-23.0	106.2	0
29 May	309	*3OR*	59,300	63.5	26	11	C	310	21.0-23.0	106.6	0
30 May	352	*1OR*	53,100	66.4	25	11	C	310	22.0-23.5	107.5	0
31 May	405	*2OR*	50,900	66.1	26	11	C	310	20.0-22.5	107.7	0
01 Jun	184	*0*	50,900	66.2	22	8	C	310	21.5-22.5	107.9	0
02 Jun	7	*0*	75,500	65.9	22	11	C	310	23.0	105.1	0

* Tag color: GR=green, OR=orange

Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 2003. No operation on April 17, 19, 20, 22, and 24.

Date:	*15 Apr*	*16 Apr*	*18 Apr*	*21 Apr*	*23 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*01 May*
Observation Time-Start:	*12:30*	*9:52*	*9:00*	*10:00*	*10:00*	*10:00*	*9:15*	*9:30*	*10:00*	*8:20*	*9:00*	*9:00*
Observation Time-End:	*14:00*	*14:45*	*15:30*	*15:30*	*16:45*	*19:15*	*19:30*	*17:30*	*19:33*	*19:45*	*19:30*	*19:30*
Military Time (hrs)												
0800 to 0859										410		
0900 to 0959		0	0				120	75		220	269	473
1000 to 1059		0	0	0	0	0	24	77	90	147	157	306
1100 to 1159		0	0	0	0	2	9	30	100	231	261	746
1200 to 1259	0	0	0	0	0	0	36	108	209	179	319	1146
1300 to 1359	0	0	0	0	0	2	79	99	455	258	431	954
1400 to 1459		0	0	0	0	250	181	165	825	348	715	774
1500 to 1559			0	0	0	601	275	59	2127	525	925	727
1600 to 1659					0	384	463	21	2275	817	597	798
1700 to 1759						554	402	34	1833	559	785	812
1800 to 1859						460	434		1512	463	1337	562
1900 to 1959						152	158		590	465	600	215
Total	**0**	**0**	**0**	**0**	**0**	**2,405**	**2,181**	**668**	**10,016**	**4,622**	**6,396**	**7,513**

Date:	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*
Observation Time-Start:	*9:00*	*8:30*	*8:00*	*8:30*	*8:40*	*8:30*	*8:15*	*8:30*	*8:30*	*8:15*	*8:00*	*8:30*
Observation Time-End:	*19:30*	*19:00*	*19:45*	*19:15*	*19:45*	*19:45*	*19:45*	*19:20*	*19:20*	*19:30*	*19:10*	*19:30*
Military Time (hrs)												
0800 to 0859		259	48	128	13	23	29	26	38	15	26	3
0900 to 0959	804	61	66	273	38	148	101	241	373	138	62	43
1000 to 1059	719	52	50	186	216	374	169	553	1476	845	50	69
1100 to 1159	798	271	302	162	662	473	157	969	738	1173	84	77
1200 to 1259	939	969	2031	156	1043	261	332	734	212	906	148	109
1300 to 1359	632	1346	2635	173	1028	358	279	739	121	1103	336	255
1400 to 1459	843	888	2453	119	1233	299	346	724	264	1040	253	527
1500 to 1559	1070	553	1935	98	950	158	289	919	398	652	278	481
1600 to 1659	863	837	1375	230	889	113	165	859	245	514	298	312
1700 to 1759	727	1013	1361	283	664	61	198	585	231	274	498	291
1800 to 1859	916	607	961	172	426	128	352	321	246	163	355	225
1900 to 1959	546		532	76	218	53	227	55	52	42	35	93
Total	**8,857**	**6,856**	**13,749**	**2,056**	**7,380**	**2,449**	**2,644**	**6,725**	**4,394**	**6,865**	**2,423**	**2,485**

Table 3

Continued.

Date:	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*
Observation Time-Start:	*8:35*	*9:00*	*8:10*	*8:00*	*8:11*	*8:15*	*8:10*	*8:40*	*8:15*	*8:15*	*8:00*	*8:00*
Observation Time-End:	*19:00*	*19:00*	*19:00*	*18:30*	*19:15*	*18:30*	*18:20*	*19:00*	*20:00*	*19:20*	*19:00*	*18:50*
Military Time (hrs)												
0800 to 0859	2		107	38	29	30	4	11	83	13	37	67
0900 to 0959	72	51	80	60	43	72	8	78	77	82	75	208
1000 to 1059	39	175	79	137	16	27	7	50	170	96	32	211
1100 to 1159	37	336	88	152	14	41	24	151	280	149	115	202
1200 to 1259	74	257	129	97	11	75	96	252	268	190	280	126
1300 to 1359	41	307	142	79	17	61	55	403	384	260	239	282
1400 to 1459	71	284	172	137	37	143	116	294	338	394	156	445
1500 to 1559	63	371	268	65	82	130	125	189	305	377	96	366
1600 to 1659	94	347	306	66	139	46	127	174	337	436	184	281
1700 to 1759	91	705	222	92	134	32	111	207	319	348	232	261
1800 to 1859	137	615	167	43	141	21	74	126	203	320	100	140
1900 to 1959					37				110	61		
Total	**721**	**3,448**	**1,760**	**966**	**700**	**678**	**747**	**1,935**	**2,874**	**2,726**	**1,546**	**2,589**

Date:	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	
Observation Time-Start:	*8:05*	*8:30*	*8:00*	*8:00*	*8:20*	*8:00*	*8:00*	*10:00*	
Observation Time-End:	*19:15*	*19:30*	*19:00*	*19:30*	*19:15*	*17:20*	*17:30*	*12:00*	***Total***
Military Time (hrs)									
0800 to 0859	83	21	21	4	11	8	43		***1,630***
0900 to 0959	32	18	60	15	23	1	4		***4,564***
1000 to 1059	110	11	51	12	18	22	19	2	***6,844***
1100 to 1159	181	19	61	8	32	15	34	5	***9,189***
1200 to 1259	173	15	58	46	24	28	24		***12,060***
1300 to 1359	141	38	60	41	12	35	9		***13,889***
1400 to 1459	118	63	66	15	33	122	17		***15,268***
1500 to 1559	160	73	68	3	55	72	15		***15,903***
1600 to 1659	163	84	54	30	64	76	18		***15,081***
1700 to 1759	147	64	44	35	44	26	1		***14,280***
1800 to 1859	79	59	60	53	31				***12,009***
1900 to 1959	10	39		47	5				***4,418***
Total	**1,397**	**504**	**603**	**309**	**352**	**405**	**184**	**7**	***125,135***

Table 4

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 2003.

Year	Number of Days Operated	Number of Lifts	Operating Time (hrs)	Catch (millions)	Number of Species	American Shad	Blueback Herring	Alewife	Hickory Shad
1991	60	1168	647.2	0.651	42	13,897	13,149	323	0
1992	49	599	454.1	0.492	35	26,040	261	3	0
1993	42	848	463.5	0.53	29	8,203	4,574	0	0
1994	55	955	574.8	1.062	36	26,715	248	5	1
1995	68	986	706.2	1.796	36	46,062	4,004	170	1
1996	49	599	454.1	0.492	35	26,040	261	3	0
1997	64	652	640.0	0.719	36	90,971	242,815	63	0
1998	50	652	640.0	0.713	33	39,904	700	6	0
1999	52	610	467.0	1.184	31	69,712	130,625	14	0
2000	45	570	367.8	0.494	30	153,546	14,963	2	0
2001	43	559	359.8	0.922	30	193,574	284,921	7,458	0
2002	49	560	440.7	0.657	31	108,001	2,037	74	6
2003	**44**	**645**	**416.6**	**0.589**	**25**	**125,135**	**530**	**21**	**0**

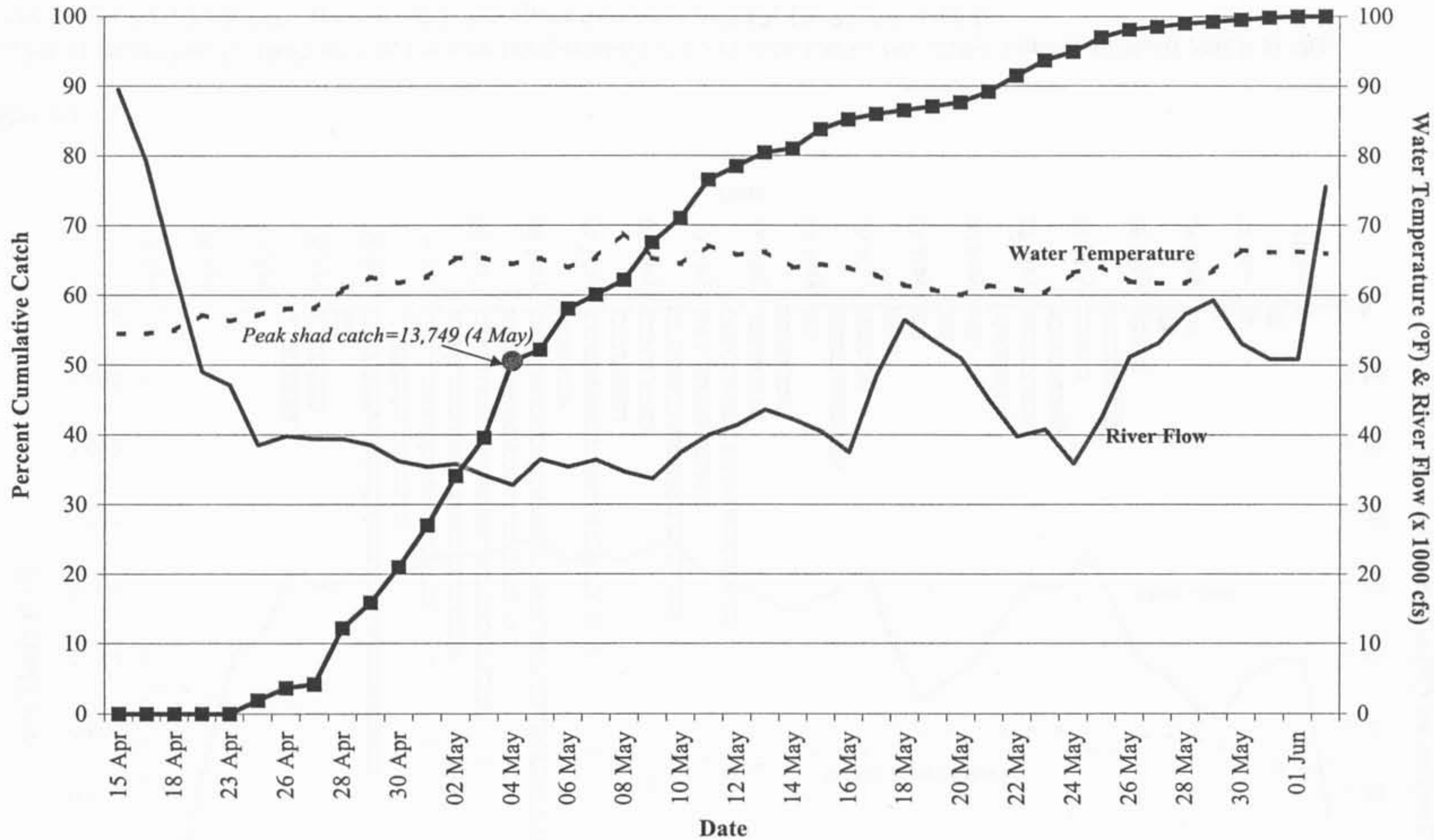


Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Conowingo East Fish Lift, spring 2003. No operation on April 17, 19, 20, 22, and 24.

Job I - Part 2

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2003

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

Normandeau Associates
1921 River Road
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 purpose.

With fish passage available at Holtwood and Safe Harbor dams since 1997, the Conowingo East lift was operated to pass all fish into the project head pond in spring 2003 (see Part 1). Upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam but Susquehanna Electric Company (SECO) has agreed to keep the West lift operational, to provide a lift operator, and to administer an annual contract for West lift trapping operations. Project details are coordinated with the resource agencies through the Susquehanna River Technical Committee (SRTC). Funding to reimburse SECO for contractor expenses for these operations, as well as shad tank spawning trials in 2003 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, PA Fish and Boat Commission, and Maryland DNR. These contributed funds are administered by the USFWS Susquehanna River Coordinator.

The objectives of Conowingo West lift operations in 2003 included collection and enumeration of shad, river herring, other migratory and resident fishes; provision of live adult shad broodfish to Maryland DNR for tank spawning; and, for on-site tank spawning and shad egg collection at Conowingo Dam. Shad taken here are also monitored for DNR tags and sex ratios, and scale and head samples are taken for age and otolith analysis. No fish were trucked for release in upstream waters in 2003.

METHODS

West lift operational procedures adopted by the SRTC included limiting the period of operation to the peak six weeks of the run (late April through the first week in June) and limiting daily lift operations to 8 hours (1100-1900 hrs.). Within these parameters the West lift was operated as in past years, maintaining appropriate entrance velocities and curbing use of adjacent units 1 and 2 whenever river flow dropped below 60,000 cfs. Normandeau Associates, Inc. (NAI) was contracted by SECO to operate both Conowingo fish lifts and to conduct American shad tank spawning trials with egg deliveries to Van Dyke hatchery.

Average daily river flows at Conowingo were relatively modest (35-60 K cfs) during late April through the end of May, spiking above that point only at the very end of the trap season. West lift operations began on April 27 and continued on most days until June 2. Total fishing effort over 31 operating days in 2003 included 367 lifts and a fishing time of 171.7 hours.

American shad collected in the trap were counted and either placed into holding or spawning tanks. Fish in excess of on-site spawning needs or not being held for DNR were returned alive to the tailrace. Other species were identified, enumerated and returned to the tailrace. Live shad broodfish were provided to Maryland DNR for tank spawning. Every 50th shad in the West lift collection was sacrificed for otoliths and a scale sample was taken. Lengths and weights were measured, and sex ratio of shad in daily catches were recorded.

RESULTS

Figure 1 shows daily West lift shad catch, river flow and water temperatures for the 2003 season. Total catch at the West lift amounted to 147,388 fish of 30 taxa (Table 1). Gizzard shad and white perch comprised 90% of this total. Alosine catch included 9,802 American shad, 183 blueback herring, 16 alewives, and one hickory shad. Catch of American shad averaged 316 per operating day with a single peak day catch of 2,539 fish on May 4. Daily operating parameters and catch by major species is shown in Table 2.

American shad transfers from the West lift amounted to 460 fish (255 males and 175 females) provided on five dates to Maryland DNR for tank spawning. These occurred on April 29-30, and May 5, 14, and 22. Normandeau Associates used 1,504 shad at the lift for tank spawning (Job II, Part 3). Of those shad sacrificed for hatchery vs. wild analysis by PFBC, 196 fish produced readable otoliths and 146 (74%) were shown to be of hatchery origin. Males averaged 473 mm in total length and 1024 g while females averaged 547 mm and 1742 g. A total of 29 Maryland DNR tags were recovered at the West lift including 27 which were hook and line tagged in the tailrace in 2003 and two in 2002. Overall male to female sex ratio of shad in the West lift in 2003 was 1.2 to 1.0 (Table 3).

Discussion

Spring 2003 was unusually cool and rainy but river flows remained modest throughout the collection season. Except for the peak day on May 4, shad catch was fairly uniform throughout the 37-day period with most days producing 100-600 fish. As mentioned, most shad collected in 2003 were released alive back to the tailrace.

West lift catch per effort of about 57 shad per fishing hour, 27 shad per lift, and 316 shad per day were comparable to values measured in recent years (Table 4). Operations and fish catch at the West lift during 1985-2003 are summarized in Table 5.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 2003.

Number of Days	**31**
Number of Lifts	**367**
Fishing Time (hours : minutes)	**171:46:00**
Number of Taxa	**30**
AMERICAN SHAD	9,802
HICKORY SHAD	1
BLUEBACK HERRING	183
ALEWIFE	16
GIZZARD SHAD	118,852
STRIPED BASS	703
White perch	14,476
American eel	20
Carp	1,110
Comely shiner	22
Quillback	91
White sucker	1
Shorthead redhorse	749
White catfish	7
Yellow bullhead	3
Brown bullhead	104
Channel catfish	626
Rock bass	100
Redbreast sunfish	19
Pumpkinseed	3
Bluegill	45
Smallmouth bass	232
Largemouth bass	32
White crappie	5
Black crappie	3
Yellow perch	102
Walleye	68
Sea lamprey	7
Greenside darter	1
Banded darter	5
Total	**147,388**

Table 2

Daily summary of fishes collected at the Conowingo Dam West Fish Lift, 2003.

Date:	27 Apr	28 Apr	29 Apr	30 Apr	01 May	02 May	04 May	05 May
Day:	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Sunday	Monday
Number of Lifts:	16	15	14	4	9	6	10	9
Time of First Lift:	12:10	13:05	11:05	14:45	11:10	11:15	11:10	11:25
Time of Last lift:	18:10	18:00	16:25	15:50	16:30	15:15	17:52	17:00
Operating time (hours):	6:00	4:55	5:20	1:05	5:20	4:00	6:42	5:35
Average Water Temperature (°F):	57.7	58.9	60.0	60.9	61.5	64.2	64.0	63.5
American shad	418	88	472	18	16	2	2,539	33
Blueback herring	0	0	0	0	0	0	0	1
Alewife	0	1	12	1	1	0	0	1
Gizzard shad	18,850	5,750	6,025	1,350	2,250	1,825	770	790
Hickory shad	0	1	0	0	0	0	0	0
Striped bass	2	1	0	0	1	0	1	6
Carp	1	1	1	5	1	5	0	13
Other species	44	42	77	89	195	435	387	627
Total	**19,315**	**5,884**	**6,587**	**1,463**	**2,464**	**2,267**	**3,697**	**1,471**

Date:	06 May	07 May	08 May	09 May	11 May	12 May	13 May	14 May
Day:	Tuesday	Wednesday	Thursday	Friday	Sunday	Monday	Tuesday	Wednesday
Number of Lifts:	8	20	6	11	14	17	11	15
Time of First Lift:	12:30	10:30	13:00	11:00	9:35	10:50	13:45	10:35
Time of Last lift:	17:45	17:55	16:30	17:00	15:43	17:00	18:15	16:15
Operating time (hours):	5:15	7:25	3:30	6:00	6:08	6:10	4:30	5:40
Average Water Temperature (°F):	63.7	64.7	64.9	64.6	63.9	65.6	64.3	63.1
American shad	6	239	1	208	605	406	166	424
Blueback herring	2	2	138	18	0	0	1	0
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	1,645	5,575	730	2,975	2,700	3,251	2,075	14,890
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	4	16	15	30	14	45	22	57
Carp	5	181	0	4	2	5	9	83
Other species	1,813	1,307	3,178	1,824	660	431	452	824
Total	**3,475**	**7,320**	**4,062**	**5,059**	**3,981**	**4,138**	**2,725**	**16,278**

Table 2

Continued.

Date:	15 May	16 May	18 May	19 May	20 May	21 May	22 May	23 May
Day:	Thursday	Friday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
Number of Lifts:	8	13	11	14	13	12	13	10
Time of First Lift:	13:50	11:10	10:10	11:25	12:40	9:30	10:50	11:55
Time of Last lift:	16:56	16:55	16:00	16:45	18:15	15:50	15:50	16:00
Operating time (hours):	3:06	5:45	5:50	5:20	5:35	6:20	5:00	4:05
Average Water Temperature (°F):	64.2	62.5	60.1	59.7	60.5	59.3	60.4	61.2
American shad	73	588	519	322	156	483	380	19
Blueback herring	0	0	0	0	0	0	0	1
Alewife	0	0	0	0	0	0	0	0
Gizzard shad	1,750	2,285	2,325	6,440	2,185	2,420	2,850	10,200
Hickory shad	0	0	0	0	0	0	0	0
Striped bass	40	40	25	73	46	17	36	13
Carp	1	1	1	12	17	22	75	178
Other species	1,105	686	562	220	240	77	75	136
Total	**2,969**	**3,600**	**3,432**	**7,067**	**2,644**	**3,019**	**3,416**	**10,547**

Date:	25 May	26 May	27 May	28 May	29 May	30 May	02 Jun	**TOTAL**
Day:	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Monday	
Number of Lifts:	14	10	18	10	12	11	13	**367**
Time of First Lift:	9:30	8:40	10:45	11:15	9:10	11:20	10:50	
Time of Last lift:	19:00	16:00	18:15	17:00	16:45	16:30	15:10	
Operating time (hours):	9:30	7:20	7:30	5:45	7:35	5:10	4:20	**171:46:00**
Average Water Temperature (°F):	61.7	62.2	62.0	62.2	62.5	65.1	66.1	
American shad	128	176	55	91	549	201	421	**9,802**
Blueback herring	19	0	0	1	0	0	0	**183**
Alewife	0	0	0	0	0	0	0	**16**
Gizzard shad	1,860	1,880	4,555	497	3,604	995	3,555	**118,852**
Hickory shad	0	0	0	0	0	0	0	**1**
Striped bass	49	25	51	20	14	17	23	**703**
Carp	3	1	50	17	32	361	23	**1,110**
Other species	226	101	305	285	106	119	93	**16,721**
Total	**2,285**	**2,183**	**5,016**	**911**	**4,305**	**1,693**	**4,115**	**147,388**

Table 3

American shad sex ratio information, Conowingo West Fish Lift, 2003.
No operation on May 3, 10, 17, 24, 31, and June 1.

Date	Total Catch	Male	Female	Male:Female
27 Apr	104	73	31	2.4
28 Apr	88	59	29	2.0
29 Apr	137	99	38	2.6
30 Apr	18	15	3	5.0
01 May	16	12	4	3.0
02 May	2	2	0	--
04 May	140	85	55	1.5
05 May	27	22	5	4.4
06 May	6	4	2	2.0
07 May	124	92	32	2.9
08 May	1	1	0	--
09 May	130	79	51	1.5
11 May	111	61	50	1.2
12 May	149	88	61	1.4
13 May	112	71	41	1.7
14 May	129	74	55	1.3
15 May	73	40	33	1.2
16 May	113	74	39	1.9
18 May	155	77	78	1.0
19 May	111	53	58	0.9
20 May	127	59	68	0.9
21 May	140	71	69	1.0
22 May	111	58	53	1.1
23 May	19	10	9	1.1
25 May	128	52	76	0.7
26 May	104	48	56	0.9
27 May	55	28	27	1.0
28 May	91	41	50	0.8
29 May	100	39	61	0.6
30 May	139	59	80	0.7
02 Jun	197	69	128	0.5
Total	**2,957**	**1,615**	**1,342**	**1.2**

Table 4

Catch and effort of American shad taken at the Conowingo Dam West Fish Lift during primary collection periods* in 1985-2003.

Year	Number Days	Number Lifts	Fishing Hours	Total Catch	Catch Per Day	Catch Per Lift	Catch Per Hour
1985	37	839	328.6	1,518	41	2	4.6
1986	53	737	431.5	5,136	97	7	11.9
1987	49	1,295	506.5	7,659	156	6	15.1
1988	54	1,166	471.7	5,137	95	4	10.9
1989	46	1,034	447.2	8,216	179	8	18.4
1990	62	1,247	541.0	15,958	257	13	29.5
1991	59	1,123	478.5	13,273	225	12	27.7
1992	61	1,517	566.0	10,323	169	7	18.2
1993	41	971	398.0	5,328	130	5	13.4
1994	44	918	414.0	5,595	127	6	13.5
1995	64	1,216	632.2	15,588	244	13	24.7
1996	27	441	245.2	11,458	424	26	46.7
1997	44	611	295.1	12,974	295	21	44.0
1998	26	476	238.6	6,577	253	14	27.6
1999	43	709	312.6	9,658	225	14	30.9
2000	34	424	206.5	9,785	288	23	47.4
2001	41	425	195.1	10,940	267	26	56.1
2002	31	417	147.1	9,347	302	22	63.5
2003	**31**	**367**	**171.5**	**9,802**	**316**	**27**	**57.2**

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

Table 5

Operations and fish catch at Conowingo West Fish Lift, 1985 - 2003.

Year	Number of Days	Total Fish (Millions)	Number of Taxa	American Shad	Hickory Shad	Alewife	Blueback Herring
1985	55	2.318	41	1,546	9	377	6,763
1986	59	1.831	43	5,195	45	2,822	6,327
1987	60	2.593	43	7,667	35	357	5,861
1988	60	1.602	49	5,169	64	712	14,570
1989	53	1.066	45	8,311	28	1,902	3,611
1990	72	1.188	44	15,964	77	425	9,658
1991	63	0.533	45	13,330	120	2,649	15,616
1992	64	1.560	46	10,335	376	3,344	27,533
1993	45	0.713	37	5,343	0	572	4,052
1994	47	0.564	46	5,615	1	70	2,603
1995	68	0.995	44	15,588	36	5,405	93,859
1996	28	1.233	39	11,473	0	1	871
1997	44	0.346	39	12,974	118	11	133,257
1998	41	0.575	38	6,577	6	31	5,511
1999	43	0.722	34	9,658	32	1,795	8,546
2000	34	0.458	37	9,785	1	9,189	14,326
2001	41	0.310	38	10,940	36	7,824	16,320
2002	31	0.419	35	9,347	0	141	428
2003	**31**	**0.147**	**30**	**9,802**	**1**	**16**	**183**

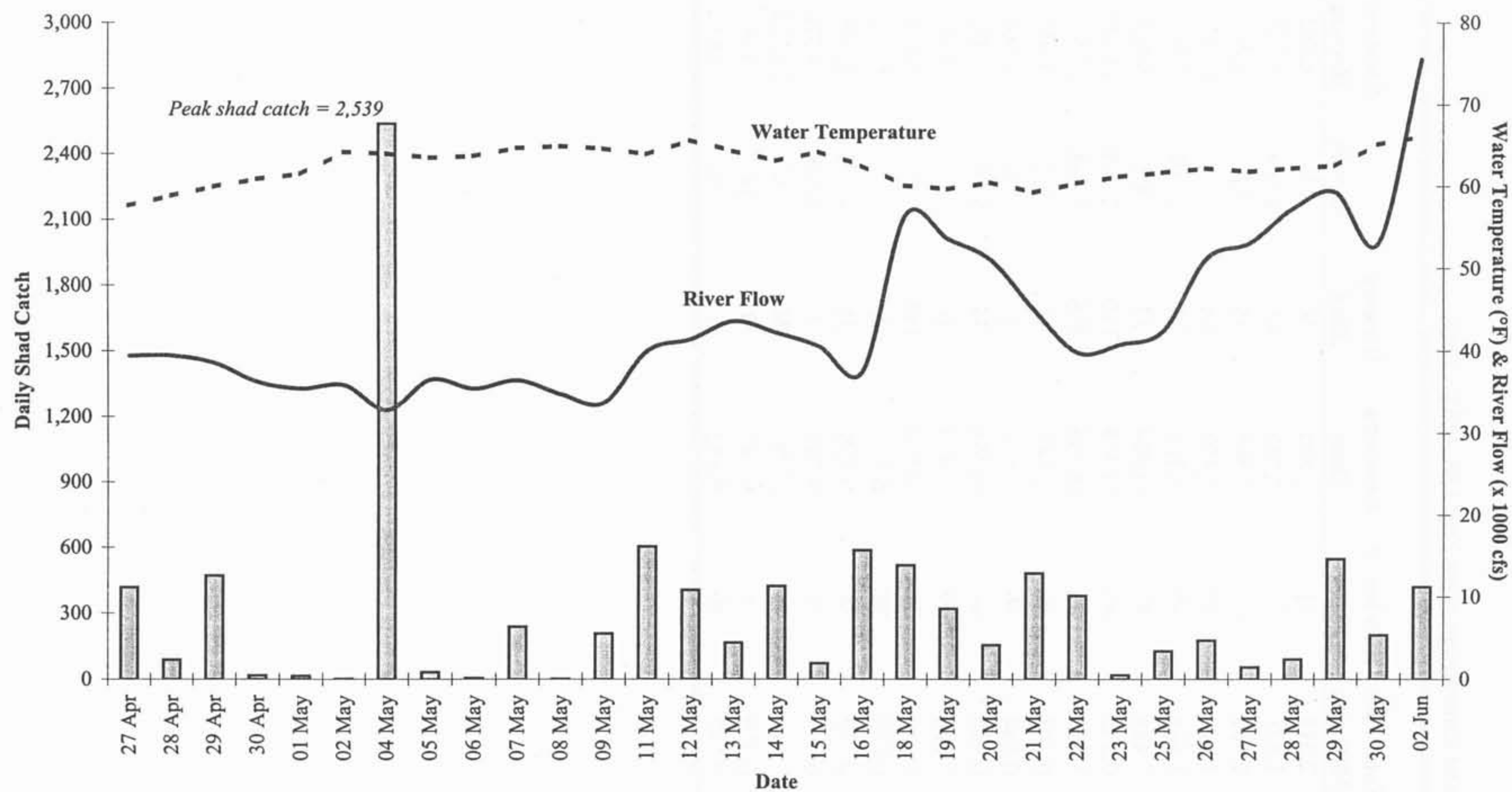


Figure 1

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 2003. No operation on May 3, 10, 17, 24, 31, and June 1.

Job 1 – Part 3
SUMMARY OF OPERATIONS AT THE HOLTWOOD DAM FISH PASSAGE FACILITY IN SPRING 2003

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

EXECUTIVE SUMMARY

Fishway operations at Holtwood Dam began on 28 April 2003. The tailrace lift was operated for 34 days while the spillway lift operated on 17 days. We terminated lift operations for the season on 2 June. The tailrace and spillway lifts were functional 96% and 100% of the time during the 2003 season, respectively. We did not operate either lift on 29 April stemming from a limit switch malfunction with the tailrace hopper. PPL dispatched a repair crew and lift operations resumed on 30 April. The fishway was not operated on 9 May due to installation of the flash boards and slick bar.

The lifts passed 179,231 fish of 23 taxa plus one hybrid. Gizzard and American shad dominated the catch, and comprised 95% of the total fish collected. *Alosa* species captured included 25,254 American shad, 2 alewife, and 3 blueback herring.

A total of 21,201 American shad (84% of total catch) was passed in the tailrace lift while the spillway lift accounted for 4,053 American shad (16% of total catch). Collection and passage of shad varied daily with 87% of total shad (21,981) passed from 30 April to 13 May. The highest daily shad catch occurred on 11 May when 2,979 shad moved upstream during 11 hours of operation. On a daily basis, most shad passed through the fishway between 1200 hrs and 1859 hrs. American shad were collected and passed at water temperatures ranging from 57.0°F to 66.5°F, and river flows between 32,800 and 75,500 cfs.

Sustained river flows created spillage on all but one day at Holtwood, and coupled with colder spring-time weather, limited American shad passage this year. Shad numbers were the third lowest recorded since fishway start-up in 1997. Future operations will build on the past seven years of experience.

INTRODUCTION

On 1 June 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (Holtwood) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood, to construct and place a fishway into operation by 1 April 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream facility consisting of a tailrace and spillway lift successfully operated during spring 1997 through spring 2002. This year marked the seventh fish passage effort.

A meeting of the Holtwood Fish Passage Technical Advisory Committee (HFPTAC) comprised of PPL, United States Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held at Holtwood on 19 March 2003. The meetings included disçussions of, and a consensus on operation of the fishway during the 2003 spring migration season.

Objectives of 2003 upstream fishway operation were (1) monitor passage of migratory and resident fishes through the fishway; (2) continue to assess fishway operation; (3) manipulate valve 4 to improve/increase water flow through the tailrace crowder area; and (4) investigate lighting systems to improve conditions inside the "tunnel" located directly upstream of the tailrace crowder.

HOLTWOOD OPERATION

Project Operation

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units having a combined generating capacity of 107 MW, and a reservoir (Lake Aldred) of 2,400 acres surface area. Each unit is capable of passing approximately 3,000 cfs. Spills occur at the project when river flow or project inflow exceeds the station capacity of approximately 32,000 cfs.

Hydraulic conditions in the spillway at the project are controlled by numerous factors that change hourly, daily and throughout the fishway operating season. The primary factors are river flows, operation of the power station, installation and integrity of the flash boards, operation of three rubber dams installed as part of the fishway project, and operation of the Safe Harbor Hydroelectric Station. Fishway operations at Holtwood began on 28 April 2003. In Spring 2003, spill events occurred every day except for one. Damage to rubber dam #2 prevented it from being inflated during fishway operations in 2003, therefore flash boards were installed on 9 May to reduce the discharge of water into the east channel of the spillway. Failure of some of the flash boards adjacent to the spillway lift soon after installation impacted the spillway lift attraction flow on various occasions.

Fishway Design and Operation

Fishway Design

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

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough through which the fish swim into Lake Aldred. Attraction flows, in, through, and from the lifts are supplied through a piping system and five diffusers that are gravity fed from two trough intakes. Generally, water conveyance and attraction flow is controlled by regulating the three entrance gates and seven motor-operated valves. Fish that enter the tailrace and/or spillway entrances are attracted by water flow into the mechanically operated crowder chambers. Once inside, fish are crowded into the hoppers (6,700 gal capacity). Fish are then lifted in the hoppers and sluiced into the trough. Fish swim upstream through the trough past a counting facility and into the forebay through a 14 ft wide fish lift exit gate.

Three inflatable rubber dams, operated from the hydro control room, are an integral component of effective spillway lift operation. During fish lift operations in 2003, two of the three rubber crest dams (#'s 3 and 4) were usually kept inflated. Flash boards were installed in front of the damaged #2 rubber dam during spring 2003.

Design guidelines for fishway operation included three entrance combinations. These were: (1) entrance A, B, and C; (2) entrance A and B; and (3) entrance C. Completion of the attraction water system after the 1997 season resulted in the drafting of operating protocols and guidelines that were flexible and utilized experience gained in the first year of fish lift operation. Following these updated protocols/guidelines, entrances A and B, A, B, and C, or a combination of A and C or B and C were used in 2003.

Fishway Operation

Daily operation of the Holtwood fishway was based on the American shad catch, and managed to maximize that catch. Constant oversight by PPL and Normandeau staff ensured that maintenance activities and mechanical or electrical problems were dealt with immediately to minimize fish lift operational interruptions. The tailrace and spillway lifts were functional 96% and 100% of the time throughout the 2003 season, respectively. A maintenance program that included periodic cleaning of the exit channel, nightly inspections, and cleaning of picket screens contributed to this excellent operating performance. Pre-season equipment preparations began in March, and lifts were fully operational on April 1. The catch of shad at Conowingo Dam triggered the start of Holtwood operations on 28 April. We operated the tailrace lift for 34 days during the season while the spillway lift operated on 17 days. Sustained river flows ranging from 35,900 cfs to 59,300 cfs, (11-31 May), may have limited fish passage in May 2003. Operational hours varied throughout the season to maximize the catch of American shad.

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

Fish Counts

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

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

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

RESULTS

Relative Abundance

We present the diversity and abundance of fishes collected and passed in the Holtwood fishway during the spring 2003 operational period in Table 1. A total of 179,231 fish of 23 taxa and one hybrid passed upstream into Lake Aldred. Gizzard shad (145,732) comprised 81% of the fishes passed. American shad numbered 25,254 (14% of the total) and represented the second largest portion of the catch. The 2003 American shad passage total was the third lowest observed, (based on Conowingo results), in the seven years of fish lift operations (Tables 1 and 5). Other abundant fishes passed included shorthead redhorse (3,430), channel catfish (1,936) and walleye (748). The peak one-day passage of all species occurred on 10 May, when 17,433 fish were passed, 85% of which were gizzard shad.

Other migratory species collected by the fishway included 2 alewife, 3 blueback herring, 2 striped bass, and 2 white perch (Table 1).

American Shad Passage

During thirteen days of operation (30 April to May 13) the lifts passed 21,981 American shad representing 87% of the season total. Sustained high river flows in May (40,000 to 60,000 cfs range) appears to have limited fish passage during a large portion of the migratory period, and the fishway collected and passed more than 2,000 shad/day only on five days during the thirteen day period mentioned previously. River flows averaged 36,300 cfs during those five days whereas the average river flow for the entire month of May was approximately 43,100 cfs. The highest single day catch occurred on 11 May when 2,979 American shad were captured and passed. American shad were collected and passed at water temperatures ranging from 57.0°F and 66.5°F, and river flows between 32,800 cfs to 75,500 cfs (Table 2 and Figure 1).

The capture of shad at the fishway occurred over a wide range of station operation and discharge conditions (Table 2). Shad were attracted to the tailrace lift at water elevations ranging from 114 ft. to 118 ft. Typically, tailrace elevations correspond to unit operation, which varies from 0 to 10 units. During spring 2003, nearly all tailrace fishway operation coincided with constant ten-turbine operation/generation due to sustained spring river flows. The spillway lift operated at spillway elevations of 116 ft to 125 ft. Spillage occurred on all but one day during fishway operation in Spring 2003.

Passage of shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 165 ft to 173.5 ft (Table 2). Visual observations indicated that shad passed through the fishway into Lake Aldred at this range of forebay elevations. New flash boards and the slick bar were installed on 9 May. Shortly after installation, some of the flash boards adjacent to the spillway fish lift entrance failed, thus allowing spillage that directly competed with the attraction water flowing from the spillway lift entrance. Repairs to the flash boards could not be completed until well after the passage season ended due to sustained river flows.

The hourly passage numbers of American shad at Holtwood are provided in Table 3. Most shad (19,978) passed through the fishway between 1200 hrs and 1859 hrs. Generally, shad passage was strongest from 1500 hrs to 1859 hrs, then declined sharply until operation was ended each evening.

We completed a qualitative assessment of the relative number of shad using the tailrace and spillway lifts by viewing each hopper of fish and estimating the number of shad in each lift as they were sluiced into the trough. We summarized this information by lift, and applied results to the daily shad passage count. We determined the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 21,201 and 4,053 shad (84% and 16%) were captured in the tailrace and spillway lifts over the total operating period, respectively (Table 4). The contribution of each lift's catch to daily passage varied throughout the season. Both lifts appeared to catch shad effectively based on visual observations of fish movement up to, and in the vicinity of the lift entrances. The spillway lift collected nearly 79% of its total American shad catch between 8 and 13 May. This is attributable to intermittent periods of spillage during this time frame which created small "windows of opportunity" for lift operators to fish with little or no competition from spillway flows.

In 2003, spill events were common due to consistent spring river flows. The spillway lift was operated a total of 17 days during the season. As stated above, nearly 79% (3,196 shad) of the total spillway catch was collected during five days of operation (Table 4).

Passage Evaluation

In 2003, our fishway evaluation efforts focused on addressing American shad behavior in the vicinity of the tailrace lift entrances based on findings disclosed in the telemetry report conducted in Spring, 2001. In an attempt to reduce the number of American shad that nose into the entrance way and then exit, or spend time in the "corner" of the tailrace upstream of the tailrace lift entrances, some operational and physical modifications were implemented. Evaluation of these modifications was difficult due to higher than normal river flow conditions and overall poor water clarity.

On 28 April, a brighter lighting system was installed inside the tailrace tunnel area. The area is brighter than previously observed, but we were unable to determine if there was any impact to fish passage due to the unfavorable conditions experienced this spring.

Throughout the season, valve 4, which supplies water to the tailrace lift entrances, was manipulated to increase water flow through the tailrace crowder area. We believe flow through the tailrace crowder area has been improved. Entrance gate B was utilized on seven occasions this spring; six times in conjunction with the operation of gate A, and once with gate C. Although sufficient water flow is available, the attraction water passing through gate B is influenced mostly by the discharge from unit 3 and quickly loses its integrity a short distance downstream of the gate, whereas the attraction flow from gate A, (located farther away from the turbine discharge), maintains its integrity for several meters downstream of the entrance.

We present a summary of American shad passage at three river flow ranges in Table 5. As stated in previous reports, low, stable river flows are more conducive to fish passage. In 2003, it is quite evident that the majority (80%) of American shad passage occurred when river flows were at or below 40,000 cfs (Table 5 and Figure 2). Due to the consistency of spillage and damaged sections of flash boards adjacent to the spillway lift, opportunities to operate in between or around spill events were limited. This may account for the lower number of shad passed in 2003 when river flows ranged between 40,000 and 60,000cfs as compared to the passage values observed from 2000 to 2002 for the same river flow range.

We hope to optimize future fishway operations by utilizing knowledge gained through these observations and modifications. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis. Fish survival in the fishways was excellent; we observed no mortalities.

SUMMARY

In 2003, the Holtwood tailrace fish lift was operated for 34 days while the spillway lift operated on 17 days. The tailrace and spillway lifts were functional 96% and 100% of the time, respectively. Fishway systems and equipment functioned as designed and only minor difficulties were encountered. Minor problems resulted from safeguards designed into the electrical and/or mechanical aspects of equipment operation.

A total of 25,254 American shad were passed into Lake Aldred, the third lowest total and third lowest percentage of shad passed (based on Conowingo passage results) since operations started in 1997 (Table 6). A total of 2 alewife and 3 blueback herring also passed through the fishway.

The late catch of shad at Conowingo Dam triggered the start of Holtwood operations on 28 April. A total of 21,201 American shad (84% of total catch) was passed in the tailrace lift while the spillway lift accounted for 4,053 American shad (16% of total catch). Collection and passage of shad varied daily with 87% of total shad (21,981) passed between 30 April and 13 May. The highest daily shad catch occurred on 11 May when 2,979 shad moved upstream in 11 hours of operation. On a daily basis, most shad passed through the fishway between 1200 hrs and 1859 hrs. American shad were collected and passed at water temperatures ranging from 57.0°F to 66.5°F, and river flows between 32,800 and 75,500 cfs.

During spring 2003, gillnet surveys to collect ripe American shad/eggs for the PFBC shad hatchery program were conducted below the Holtwood project. Locations where Normandeau staff collected American shad are shown in Figure 3. Most American shad collected were green, (not ripe), and we obtained very few eggs. We captured these fish downstream of the Holtwood project, and collected several below the Muddy Run project. It appears that during periods of continuous spillage at Holtwood, some portion of the American shad passed at Conowingo hold in areas well below the Holtwood project, making it difficult to attract and pass large numbers of shad during spill events.

A low, stable, river flow appears to be critical for enhancing shad passage rates. The sustained river flows and consistent spillage over Holtwood Dam in Spring 2003 made fish passage difficult, but did allow personnel to experiment with various lift component settings that may improve passage rates in upcoming years. Future operations of the fishway will build on the past seven years of operation experience.

RECOMMENDATIONS

1) Operate the fishway at Holtwood Dam under annual operational guidelines developed and approved by the HFPTAC. Fishway operation should adhere to these guidelines; however, personnel must retain the ability to make "on-the-spot" modifications to maximize fishway performance.

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

3) As river flow conditions permit install the "Slick Bar" in front of the fishway exit channel to reduce debris from entering and accumulating at the exit/entrance of the trough. After the "slick bar" is installed implement protocols/guidelines that utilize the hydro control room operator to spill trash by lowering the 10 ft rubber dam. This should be done on an as needed basis prior to the scheduled start of fishway operations.

4) Continue to assess effectiveness of manipulating water flow through valve 4.

5) Develop a matrix to assess the effects of behavioral enhancements to the tailrace entranceway including operation of valve #4, improved lighting and acoustics associated with falling water for the 2004 season.

6) Develop a test to evaluate the effect of discharge of Units 1 and 2 on the tailrace entranceways to be done during the period of peak shad passage.

7) Review fish lift and plant operational records to identify conditions that contribute to spillway lift effectiveness. Prepare spillway lift operational plans to improve effectiveness based on findings.

LITERATURE CITED

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

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

Table 1

Summary of the daily number of fish passed by the Holtwood fish passage facility in 2003. No operation on April 29 and May 9.

Date:	*28 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*
Hours of Operation - Tailrace:	*2.2*	*8.9*	*8.3*	*10.0*	*8.9*	*11.1*	*11.5*	*11.3*	*9.7*	*9.7*
Number of Lifts - Tailrace:	*3*	*14*	*13*	*16*	*14*	*19*	*18*	*16*	*16*	*12*
Hours of Operation - Spillway:	*2.8*	*2.6*	*3.5*	*4.7*	*2.5*	*0.0*	*0.0*	*0.0*	*0.0*	*2.0*
Number of Lifts - Spillway:	*4*	*3*	*6*	*7*	*4*	*0*	*0*	*0*	*0*	*3*
Water Temperature (°F):	*59.0*	*61.9*	*63.4*	*64.8*	*65.7*	*66.0*	*65.0*	*63.5*	*62.0*	*62.4*
American shad	106	1,156	2,180	2,969	1,719	2,124	1,605	657	457	1,074
Alewife	0	1	1	0	0	0	0	0	0	0
Blueback herring	0	0	0	0	0	0	0	0	0	0
Gizzard shad	680	6,224	10,340	6,364	5,504	6,955	3,685	2,870	3,740	5,484
Striped bass	0	2	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	1	0	0	0	1
Brown trout	0	5	2	1	1	1	2	0	0	6
Tiger muskie	0	0	1	0	0	0	0	0	0	0
Carp	0	19	22	13	10	4	2	2	0	3
Quillback	0	73	17	48	166	28	6	0	0	19
White sucker	0	14	7	0	0	0	0	0	0	5
Shorthead redhorse	14	460	185	235	498	445	227	136	69	192
Channel catfish	0	35	21	151	108	148	242	60	39	69
White perch	0	1	0	0	0	0	0	0	0	0
Rock bass	0	20	9	1	3	4	5	1	1	6
Redbreast sunfish	0	0	0	0	0	0	0	0	0	4
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	0	1	1	4	1	1	2	0	0	2
Smallmouth bass	4	117	74	66	66	31	25	23	20	29
Largemouth bass	0	15	16	18	4	2	0	0	0	4
White crappie	0	0	0	0	0	0	1	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	0	3	1	3	1	1	0	0	0	0
Walleye	0	32	16	52	15	31	44	36	24	40
Total	***804***	***8,178***	***12,893***	***9,925***	***8,096***	***9,776***	***5,846***	***3,785***	***4,350***	***6,938***

Table 1

Continued.

Date:	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
Hours of Operation - Tailrace:	*6.2*	*11.1*	*10.4*	*10.6*	*8.8*	*7.2*	*10.0*	*10.8*	*8.0*	*7.5*
Number of Lifts - Tailrace:	*9*	*18*	*15*	*16*	*14*	*9*	*11*	*13*	*13*	*11*
Hours of Operation - Spillway:	*3.0*	*10.0*	*10.0*	*10.6*	*8.8*	*7.3*	*2.5*	*3.1*	*0.0*	*0.0*
Number of Lifts - Spillway:	*5*	*11*	*12*	*17*	*12*	*11*	*2*	*3*	*0*	*0*
Water Temperature (°F):	*64.3*	*65.2*	*65.2*	*65.1*	*62.8*	*61.4*	*60.5*	*60.1*	*58.0*	*57.0*
American shad	2,307	2,979	1,357	1,397	66	37	236	153	16	11
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback herring	0	0	0	0	0	1	0	0	0	0
Gizzard shad	14,816	13,751	4,597	4,245	2,829	4,032	4,147	3,734	855	613
Striped bass	0	0	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	1	0	0	0	0	0	0
Brown trout	2	0	0	0	0	1	0	2	3	3
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	16	33	65	137	11	1	5	1	3	1
Quillback	30	12	46	125	3	2	2	0	0	2
White sucker	0	0	0	0	5	1	0	0	0	0
Shorthead redhorse	154	52	334	226	32	8	0	10	3	0
Channel catfish	60	28	179	100	25	5	7	40	26	19
White perch	0	0	0	0	0	0	0	0	0	0
Rock bass	3	1	9	4	2	4	0	0	1	0
Redbreast sunfish	0	0	2	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0
Bluegill	1	8	5	0	5	0	1	0	0	0
Smallmouth bass	11	11	26	22	15	1	5	3	3	0
Largemouth bass	1	5	1	0	0	0	2	0	0	0
White crappie	0	0	2	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0	0	0
Yellow perch	1	1	5	3	0	0	0	0	0	0
Walleye	31	4	77	96	22	25	12	8	10	14
Total	***17,433***	***16,885***	***6,705***	***6,356***	***3,015***	***4,118***	***4,417***	***3,951***	***920***	***663***

Table 1

Continued.

Date:	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
Hours of Operation - Tailrace:	*7.7*	*7.7*	*10.7*	*11.0*	*10.9*	*9.7*	*11.0*	*9.5*	*10.7*	*9.8*
Number of Lifts - Tailrace:	*11*	*11*	*12*	*18*	*12*	*8*	*19*	*15*	*18*	*12*
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*9.8*	*6.7*	*8.8*	*0.0*	*0.0*	*0.0*	*0.0*
Number of Lifts - Spillway:	*0*	*0*	*0*	*11*	*5*	*7*	*0*	*0*	*0*	*0*
Water Temperature (°F):	*57.4*	*61.0*	*61.9*	*61.8*	*60.8*	*60.3*	*60.5*	*61.3*	*62.4*	*62.5*
American shad	24	25	379	703	281	52	236	126	309	128
Alewife	0	0	0	0	0	0	0	0	0	0
Blueback herring	0	0	0	1	0	0	1	0	0	0
Gizzard shad	1,250	2,000	8,051	3,869	2,748	1,113	1,635	2,015	2,692	4,246
Striped bass	0	0	0	0	0	0	0	0	0	0
Rainbow trout	1	4	0	9	2	1	2	0	0	0
Brown trout	0	0	0	0	2	0	0	0	2	1
Tiger muskie	0	0	0	0	0	0	0	0	0	0
Carp	1	6	7	9	3	3	5	0	5	8
Quillback	0	0	8	5	0	1	1	5	8	13
White sucker	0	0	0	0	0	0	0	0	0	0
Shorthead redhorse	8	19	15	3	33	6	8	17	27	4
Channel catfish	29	12	31	41	53	38	39	26	43	47
White perch	0	0	0	0	0	0	0	1	0	0
Rock bass	0	0	0	0	2	0	0	0	1	3
Redbreast sunfish	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	1	0	0	0	0	0	0	0
Bluegill	0	0	0	6	0	0	2	1	0	1
Smallmouth bass	3	13	30	10	7	2	1	3	3	8
Largemouth bass	0	0	0	0	0	0	0	0	0	0
White crappie	0	0	0	0	0	0	0	0	0	0
Black crappie	0	0	0	2	0	0	1	0	0	0
Yellow perch	0	0	0	5	0	0	0	0	0	0
Walleye	7	21	21	24	10	9	19	12	9	6
Total	***1,323***	***2,100***	***8,543***	***4,687***	***3,141***	***1,225***	***1,950***	***2,206***	***3,099***	***4,465***

Table 1

Continued.

Date:	*30 May*	*31 May*	*1 Jun*	*2 Jun*	***TOTAL***
Hours of Operation - Tailrace:	*9.6*	*9.7*	*8.6*	*3.5*	***312.3***
Number of Lifts - Tailrace:	*17*	*12*	*14*	*4*	***453***
Hours of Operation - Spillway:	*0.0*	*0.0*	*0.0*	*0.0*	***98.7***
Number of Lifts - Spillway:	*0*	*0*	*0*	*0*	***123***
Water Temperature (°F):	*63.0*	*65.2*	*66.5*	*64.8*	
American shad	134	181	64	6	***25,254***
Alewife	0	0	0	0	***2***
Blueback herring	0	0	0	0	***3***
Gizzard shad	2,548	5,481	2,111	508	***145,732***
Striped bass	0	0	0	0	***2***
Rainbow trout	1	2	0	0	***25***
Brown trout	0	1	1	0	***36***
Tiger muskie	0	0	0	0	***1***
Carp	6	30	36	11	***478***
Quillback	3	2	26	1	***652***
White sucker	0	0	0	0	***32***
Shorthead redhorse	0	4	5	1	***3,430***
Channel catfish	89	37	43	46	***1,936***
White perch	0	0	0	0	***2***
Rock bass	0	1	2	2	***85***
Redbreast sunfish	0	0	0	0	***6***
Pumpkinseed	0	0	0	1	***2***
Bluegill	8	0	0	0	***50***
Smallmouth bass	2	13	7	3	***657***
Largemouth bass	0	0	0	0	***68***
White crappie	0	0	0	0	***3***
Black crappie	0	0	0	0	***3***
Yellow perch	0	0	0	0	***24***
Walleye	4	10	3	4	***748***
Total	***2,795***	***5,762***	***2,298***	***583***	***179,231***

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 2003. No operation on April 29 and May 9.

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)
28 Apr	39,400	58.6	24	9	150		220	115	125	168
30 Apr	36,200	62.3	26	9	150		220	116	120	167
30 Apr	36,200	62.3	26	9	150	150		117	121	168
1 May	35,400	63.5	24	10			220	118	118	166
1 May	35,400	63.5	24	10	150			118	118	166
2 May	35,800	65.0	24	10	150		220	118	120-123	166-167
3 May	34,200	65.8	24	10			220	116	117	165
3 May	34,200	65.8	24	10	150			117-118	119	166-167
4 May	32,800	66.2	24	10	150			114-117	117	166-167
5 May	36,500	64.8	24	10	150			117.5	118	166.5
6 May	35,400	63.5	24	10	150			117	117	165
7 May	36,400	62.1	24	10	150			118	118	167
8 May	34,700	62.3	24	10	150			117	118	165
8 May	34,700	62.3	24	10			220	117.5	116.5	165
10 May	37,500	64.2	24	10	150			116-117	116	165-166
10 May	37,500	64.2	24	10	150		220	115	117	168
11 May	40,000	65.1	24	10	150		220	116	123	170.5
12 May	41,400	65.2	24	10	150	150	220	118	121	171
12 May	41,400	65.2	24	10	150		220	118	120	170.5
13 May	43,600	64.8	24	10	150	150	220	118	121	170
13 May	43,600	64.8	24	10	150		220	118	119	169
14 May	42,200	62.8	22	10	150	150		118	123.5	170.5
14 May	42,200	62.8	22	10		150	220	118	120	170
14 May	42,200	62.8	22	10	150		220	118	121	170
15 May	40,500	61.2	22	10	150		220	118	122.5	171
15 May	40,500	61.2	22	10	150	150	220	118	122	171

Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
16 May	37,500	60.4	22	10	150		220	115	122	171
16 May	37,500	60.4	22	10	150	150		115	127	172
16 May	37,500	60.4	22	10	150			115	127	171
17 May	48,600	59.9	22	10	150		220	117	120	170
17 May	48,600	59.9	22	10	150			116	125	171
18 May	56,500	57.9	24	10	150			117.5	128	172.5
19 May	53,600	57.3	24	10	150			115	128	172
20 May	51,000	58.4	26	10	150			115.5	129	172
21 May	45,000	60.9	26	10	150			116	129	172.5
22 May	39,800	62.4	26	10	150			115	122	171
23 May	40,800	61.4	26	10	150		220	115	121	170
24 May	35,900	60.7	26	10	150		220	116	119	169.5
25 May	42,500	60.3	26	10	150		220	115.5	125	171
26 May	51,200	60.6	28	10	150			116	128	171
27 May	53,100	61.6	28	10	150			115	127.5	171
28 May	57,300	62.7	28	10	150			117	130	172
29 May	59,300	62.7	16	10	150			115.7	127.5	171.3
30 May	53,100	63.2	18	10	150			116.5	131	173.5
31 May	50,900	65.6	24	10	150			115.2	125.3	171
1 Jun	50,900	66.2	24	10	150			115.5	128	171.5
2 Jun	75,500	64.2	24	10	150			115.1	129	172

Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 2003. No operation on April 29 and May 9.

Date:	*28 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*
Observation Time (Start):	*14:00*	*10:00*	*7:30*	*8:20*	*7:45*	*7:30*	*8:00*
Observation Time (End):	*17:00*	*19:10*	*19:15*	*19:15*	*19:1`5*	*19:00*	*19:00*
Military Time (hrs)							
0700 to 0759			48			13	
0800 to 0859			59	21	228	19	102
0900 to 0959			177	72	32	16	37
1000 to 1059		52	102	132	16	27	38
1100 to 1159		82	26	135	67	16	142
1200 to 1259		122	132	212	138	136	116
1300 to 1359		150	246	259	191	318	201
1400 to 1459	21	105	308	201	143	277	248
1500 to 1559	41	293	304	762	237	325	213
1600 to 1659	44	152	249	448	250	477	296
1700 to 1759		92	224	331	296	364	119
1800 to 1859		80	198	396	111	136	93
1900 to 1959		28	107		10		
2000 to 2059							
Total	**106**	**1,156**	**2,180**	**2,969**	**1,719**	**2,124**	**1,605**

Date:	*6 May*	*7 May*	*8 May*	*10 May*	*11 May*	*12 May*	*13 May*
Observation Time (Start):	*7:15*	*9:00*	*8:00*	*13:22*	*8:30*	*8:30*	*7:30*
Observation Time (End):	*18:45*	*18:30*	*20:15*	*20:00*	*19:30*	*0:00*	*0:00*
Military Time (hrs)							
0700 to 0759	16						4
0800 to 0859	45		41		369	46	11
0900 to 0959	33	10	15		298	131	17
1000 to 1059	12	5	9		166	32	47
1100 to 1159	36	5	23		151	69	180
1200 to 1259	36	21	44		149	321	444
1300 to 1359	52	62	30	3	150	180	281
1400 to 1459	76	72	74	133	160	92	193
1500 to 1559	48	32	193	71	297	55	141
1600 to 1659	75	56	127	81	308	238	57
1700 to 1759	157	123	136	635	328	80	22
1800 to 1859	71	71	221	729	462	113	
1900 to 1959			109	655	141		
2000 to 2059			52				
Total	**657**	**457**	**1,074**	**2,307**	**2,979**	**1,357**	**1,397**

Table 3

Continued.

Date:	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*
Observation Time (Start):	*8:30*	*8:30*	*8:00*	*8:00*	*8:00*	*8:00*	*8:30*
Observation Time (End):	*17:30*	*16:30*	*18:45*	*18:40*	*16:15*	*16:00*	*16:00*
Military Time (hrs)							
0700 to 0759							
0800 to 0859	0	0	7	17	7	6	0
0900 to 0959	0	6	10	5	6	1	0
1000 to 1059	0	6	8	7	1	1	1
1100 to 1159	2	7	7	4	0	2	1
1200 to 1259	25	1	2	2	1	0	1
1300 to 1359	10	4	3	6	0	0	3
1400 to 1459	2	4	19	24	1	0	6
1500 to 1559	13	6	34	34	0	1	12
1600 to 1659	14	3	81	19	0		
1700 to 1759	0		53	27			
1800 to 1859			12	8			
1900 to 1959							
2000 to 2059							
Total	**66**	**37**	**236**	**153**	**16**	**11**	**24**

Date:	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Observation Time (Start):	*8:05*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	*8:15*
Observation Time (End):	*16:00*	*18:55*	*19:00*	*18:55*	*18:00*	*19:15*	*17:30*
Military Time (hrs)							
0700 to 0759							
0800 to 0859	5	18	70	20	4	15	28
0900 to 0959	1	15	30	11	7	6	6
1000 to 1059	1	10	37	9	4	3	1
1100 to 1159	2	11	41	16	2	11	15
1200 to 1259	2	20	59	18	0	6	14
1300 to 1359	2	18	46	21	1	12	15
1400 to 1459	5	27	34	59	0	6	19
1500 to 1559	7	52	89	52	2	19	17
1600 to 1659		50	114	37	15	45	10
1700 to 1759		68	129	16	17	47	1
1800 to 1859		90	54	22		56	
1900 to 1959						10	
2000 to 2059							
Total	**25**	**379**	**703**	**281**	**52**	**236**	**126**

Table 3

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	
Observation Time (Start):	*8:15*	*8:00*	*8:00*	*8:00*	*8:00*	*8:00*	
Observation Time (End):	*19:00*	*18:00*	*17:50*	*17:55*	*17:00*	*12:00*	***Total***
Military Time (hrs)							
0700 to 0759							***81***
0800 to 0859	6	10	32	12	25	1	***1,224***
0900 to 0959	17	15	14	2	4	0	***994***
1000 to 1059	41	5	0	7	4	1	***785***
1100 to 1159	6	6	2	5	4	4	***1,080***
1200 to 1259	6	5	7	22	2		***2,064***
1300 to 1359	29	13	18	36	10		***2,370***
1400 to 1459	21	6	16	26	2		***2,380***
1500 to 1559	50	14	13	23	7		***3,457***
1600 to 1659	42	39	25	23	6		***3,381***
1700 to 1759	45	15	7	25			***3,357***
1800 to 1859	46						***2,969***
1900 to 1959							***1,060***
2000 to 2059							***52***
Total	**309**	**128**	**134**	**181**	**64**	**6**	***25,254***

Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 2003. No operation on April 29 and May 9.

	Shad	Number Collected		Percent Collected	
Date	Catch	Tailrace	Spillway	Tailrace	Spillway
28 Apr	106	106	0	100%	0%
30 Apr	1,156	1,100	56	95%	5%
1 May	2,180	1,794	386	82%	18%
2 May	2,969	2,744	225	92%	8%
3 May	1,719	1,619	100	94%	6%
4 May	2,124	2,124	0	100%	0%
5 May	1,605	1,605	0	100%	0%
6 May	657	657	0	100%	0%
7 May	457	457	0	100%	0%
8 May	1,074	766	308	71%	29%
10 May	2,307	1,463	844	63%	37%
11 May	2,979	2,700	279	91%	9%
12 May	1,357	814	543	60%	40%
13 May	1,397	175	1,222	13%	87%
14 May	66	12	54	18%	82%
15 May	37	27	10	73%	27%
16 May	236	236	0	100%	0%
17 May	153	150	3	98%	2%
18 May	16	16	0	100%	0%
19 May	11	11	0	100%	0%
20 May	24	24	0	100%	0%
21 May	25	25	0	100%	0%
22 May	379	379	0	100%	0%
23 May	703	693	10	99%	1%
24 May	281	273	8	97%	3%
25 May	52	47	5	90%	10%
26 May	236	236	0	100%	0%
27 May	126	126	0	100%	0%
28 May	309	309	0	100%	0%
29 May	128	128	0	100%	0%
30 May	134	134	0	100%	0%
31 May	181	181	0	100%	0%
1 Jun	64	64	0	100%	0%
2 Jun	6	6	0	100%	0%
Total	***25,254***	***21,201***	***4,053***	***84%***	***16%***

Table 5

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

	1997	1998*	1999	2000*	2001	2002*	2003*
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun
Season duration (days)	58	47	40	40	43	55	36
Number of days of operation	55	41	40	36	42	35	34
American shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135
American shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254
River flow ≤40,000 cfs							
Number of days	48	22	34	19	40	19	15
Percent of season	87%	54%	85%	53%	95%	54%	44%
Number of American shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229
Daily average of American shad passed	546	341	1,002	1,037	2,733	543	1,348
Percent of total passage	93%	91%	98%	67%	99%	59%	80%
River flow 40,001 to 60,000 cfs							
Number of days	7	2	6	12	2	14	18
Percent of season	13%	5%	15%	33%	5%	40%	53%
Number of American shad passed	1,862	230	633	9,536	634	7,029	5,019
Daily average of American shad passed	266	115	106	795	317	502	279
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.80%
River flow >60,000 cfs							
Number of days	0	17	0	5	0	2	1
Percent of season	0%	41%	0%	14%	0%	6%	3%
Number of American shad passed	0	493	0	173	0	171	6
Daily average of American shad passed	0	29	0	35	0	86	6
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%

* Denotes seasons of high river flow.

Table 6

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2003.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		Number	Passed	Number	Passed	Number	Passed
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,675	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%

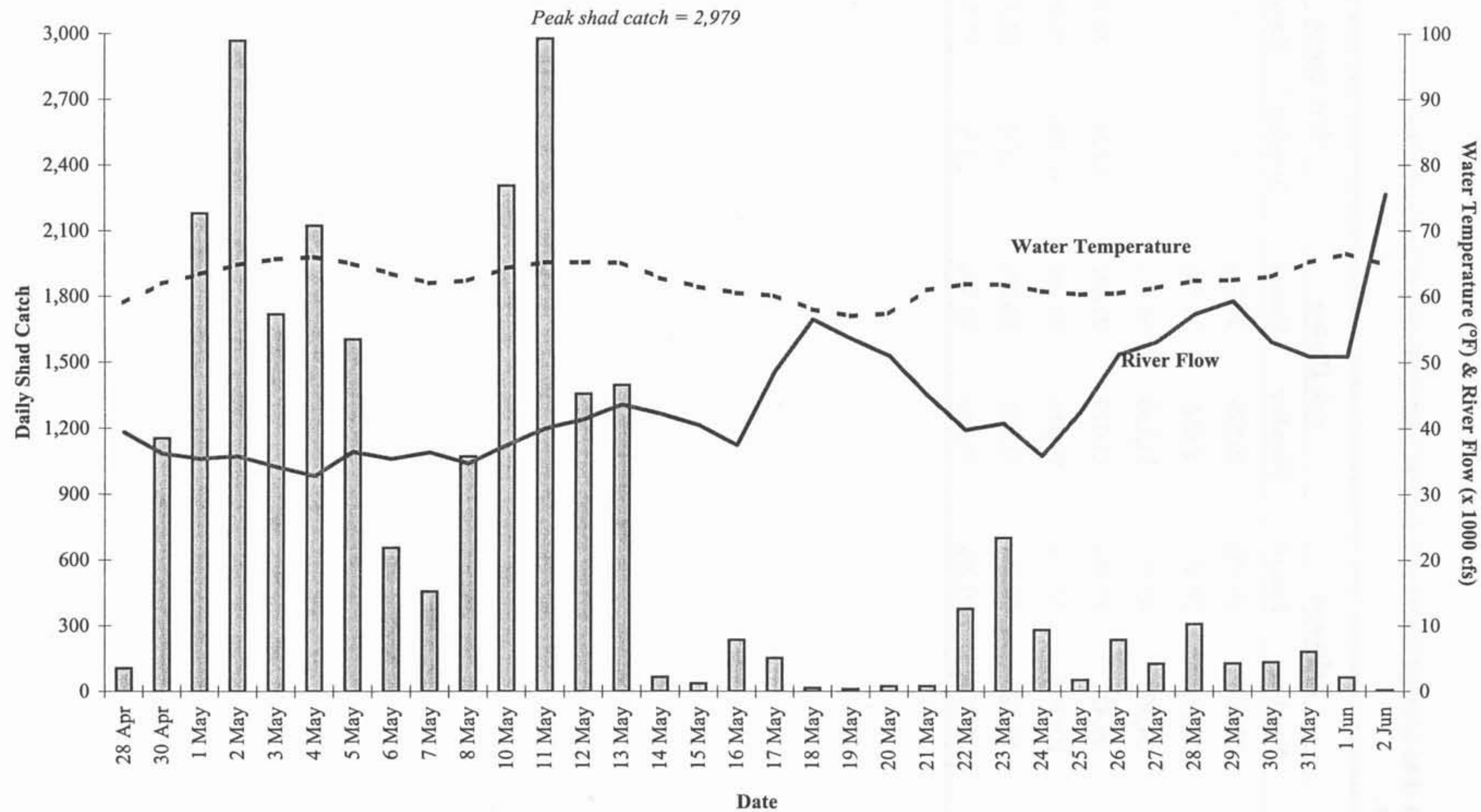


Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Holtwood Fish Passage Facility, spring 2003. No operation on April 29 and May 9.

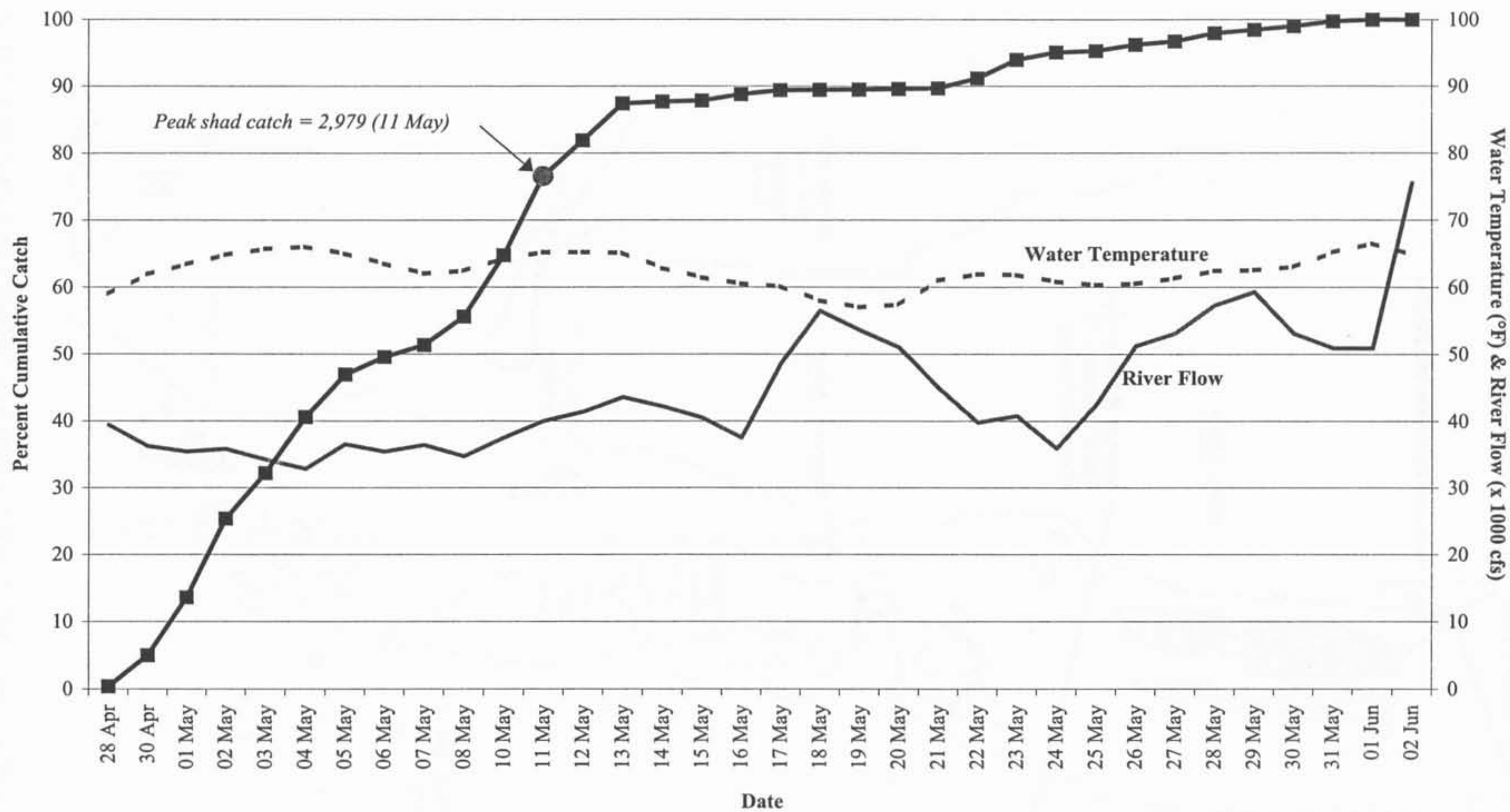


Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Holtwood Fish Passage Facility, spring 2003. No operation on April 29 and May 9.

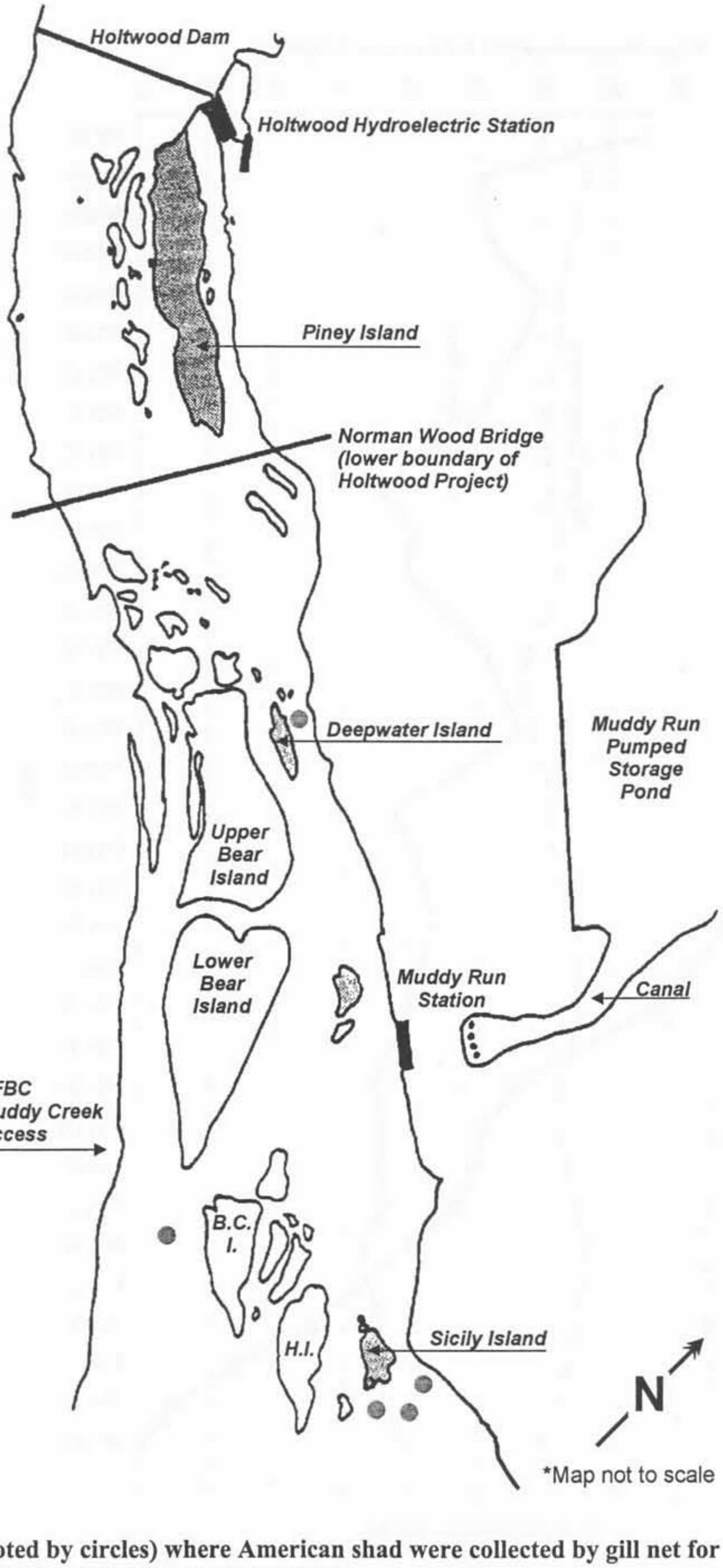


Figure 3

Locations (denoted by circles) where American shad were collected by gill net for the PFBC American shad hatchery program, spring 2003.

Job 1 – Part 4
SUMMARY OF OPERATIONS AT THE SAFE HARBOR FISH PASSAGE FACILITY IN SPRING 2003

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

INTRODUCTION

On June 1, 1993 representatives of Safe Harbor Water Power Corporation (SHWPC), two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed Safe Harbor, Holtwood, and York Haven Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. A major element of this agreement was for SHWPC, the operator of the Safe Harbor Hydroelectric Project (Safe Harbor), to construct and place in operation an upstream fishway by April 1, 1997. The fishway that provides fish access into Lake Clarke was placed into service in April of 1997.

Objectives for 2003 operation were to (1) monitor passage of migratory and resident fishes through the fishway; and (2) assess fishway effectiveness.

SAFE HARBOR OPERATION

Project Operation

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

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

Fishway Design and Operation

Fishway Design

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

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

Conceptual design guidelines for fishway operation included several entrance combinations. They are (1) entrance A, B, and C; (2) entrance B and C; (3) entrance A and C, and (4) entrance A, B, and C individually. Operation during the 2003 season utilized a combination of entrances A and C (Table 2).

Fishway Operation

Fishway operation was scheduled to commence two days after passage of 500 American shad via the Holtwood Fishway, which occurred on 30 April.

The Safe Harbor fishway began operation on 2 May and continued through 13 May. Repairs were made to the hopper shieve bearing on 14 and 15 May. Operations resumed on 16 May and continued through 3 June at which time high river flows curtailed operations until 11 June. Lift operations ended on 16 June due to the dwindling fish catch and rising water temperatures; indications that the migration run was ending.

Throughout the 2003 season, operation of the Safe Harbor fishway was based on methods established during previous spring migration seasons. A detailed description of the fishway's major components and their operation is found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998, 1999).

Daily operation of the Safe Harbor fishway was dependent on the American shad catch and managed in a flexible fashion. To minimize interruptions to fishway operation, SHWPC performed maintenance activities that included periodic cleaning of the exit channel, daily inspections, cleaning of picket screens, and other routine maintenance activities. Mechanical and/or electrical problems were addressed as needed.

During the 2003 season, two days of fishing time was lost due to mechanical problems with the fish lift hopper shieve bearing.

Fish Counts

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

A 1,500 watt halogen lamp mounted above the viewing window and three adjustable 500 watt underwater lights (two at mid-depth on either side of the window and one on the bottom) gave the biologist and/or technician a degree of control over lighting conditions at the window. Overhead and underwater light intensity was adjusted daily, based on the constantly changing ambient light conditions. In addition, a screen capable of reducing the channel width at the counting window from 36 in down to 18 in (and a range of intermediate widths) was adjusted as viewing conditions and fish passage dictated. For the entire season, the adjustable screen was set at 18 in.

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

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed in 2003 by the Safe Harbor fishway is presented in Table 1. A total of 152,407 fish of 23 species and 1 hybrid passed upstream into Lake Clarke. Gizzard shad (117,031) was the dominant species passed and comprised nearly 77% of the catch. Some 16,646 American shad were passed upstream through the fishway. Other predominant fishes passed included smallmouth bass (5,673), quillback (3,944), walleye (3,117), shorthead redhorse (2,575), and channel catfish (1,664). Peak passage occurred on 11 May, when 17,042 fish were passed.

American Shad Passage

The Safe Harbor fishway passed 16,646 American shad in 2003 during 37 days of operation (Table 1). Though collection and passage of shad varied daily, numbers were generally lower than in recent years due to sustained spring river flows and fewer American shad passed by the downstream fish passage facilities. Peak shad passage occurred on 8 May when 1,239 shad were captured and passed in approximately nine hours of operation.

American shad were passed at water temperatures of 57.0°F to 71.0°F and river flows of 32,800 to 139,900 cfs (Table 2 and Figures 1and 2). Water temperature and river flow on those days when more than 1,000 American shad were passed, averaged 63.1°F (59°F to 65.0°F) and 36,683 cfs (34,200 cfs to 41,400 cfs), respectively.

The number of American shad observed passing through the trough by hour is shown in Table 3. With the season's shad catch broken down based on hour of observation, passage rates were generally steady from 0900 to 1559 hr, with a sharp, then steady decrease in catch from 1600 to 1859 hr. A total of 14,744 American shad (88% of total shad passage) passed during the eight-hour period between 0900 and 1659 hr. The highest hourly passage (2,405) occurred between 1300 and 1359 hr.

During the 2003 season, one American shad tagged downstream of Conowingo dam by the MDDNR, (2003 orange tag), was observed at the Safe Harbor fishway.

Alosids

Passage of other alosids, (alewife, blueback herring, and hickory shad), at the Safe Harbor fishway was not observed in 2003. Sustained river flows may have hindered migration efforts of herring since only a total of 2 alewife and 3 blueback herring were observed passing through the Holtwood fish passage facility.

SUMMARY

The 2003 Safe Harbor fishway operating season was successful; only two operating days were impacted due to mechanical problems. In 37 days, 16,646 American shad were passed into Lake Clarke, or nearly 66% of the American shad that were passed into Lake Aldred by the Holtwood fishway (Table 4). Future operations of the fishway will build on the past seven years of experience.

RECOMMENDATIONS

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

LITERATURE CITED

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

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

Table 1

Number and disposition of fish passed by the Safe Harbor fishway in 2003. No operation on May 14-15 and June 4-10.

Date:	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*	*09 May*
Hours of Operation:	*5.3*	*7.8*	*7.6*	*7.8*	*7.0*	*7.9*	*9.0*	*7.2*
Start Time:	*10:30*	*8:00*	*7:55*	*8:00*	*8:35*	*7:50*	*7:30*	*7:35*
End Time:	*15:45*	*15:45*	*15:30*	*15:45*	*15:35*	*15:45*	*16:30*	*14:45*
Numbers of Lifts:	*7*	*9*	*8*	*9*	*9*	*9*	*11*	*8*
Water Temperature (F):	*64.0*	*64.0*	*64.0*	*64.5*	*62.0*	*61.0*	*62.0*	*63.0*
American shad	1,008	1,181	847	1,037	608	415	1,239	680
Gizzard shad	4,009	4,787	3,237	4,122	1,654	2,130	5,780	4,369
Striped bass	0	0	0	0	0	0	0	0
Striped bass hybrid	0	0	0	0	0	0	0	0
Sea lamprey	0	0	0	0	0	0	0	0
Rainbow trout	1	0	0	0	1	0	0	0
Brown trout	1	1	0	0	0	0	1	0
Palamino trout	0	0	0	0	0	0	0	0
Carp	26	51	12	10	21	24	141	49
Quillback	138	159	60	47	34	18	167	53
Shorthead redhorse	166	154	72	30	22	9	133	123
Brown bullhead	2	0	0	0	0	0	0	0
Channel catfish	0	8	11	8	13	22	5	7
Rock bass	9	5	0	8	4	5	0	0
Redbreast sunfish	0	2	0	0	0	0	0	0
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	2	0	1	1
Bluegill	1	0	0	1	0	0	1	0
Smallmouth bass	1,122	1,340	991	244	102	30	151	54
Largemouth bass	1	1	6	1	2	3	6	0
White crappie	0	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	1	0	0
Yellow perch	0	0	1	0	1	2	0	0
Walleye	56	79	118	45	20	1	68	42
Total	***6,540***	***7,768***	***5,355***	***5,553***	***2,484***	***2,660***	***7,693***	***5,378***

Table 1

Continued.

Date:	*10 May*	*11 May*	*12 May*	*13 May*	*16 May*	*17 May*	*18 May*	*19 May*
Hours of Operation:	*8.2*	*8.8*	*9.3*	*9.9*	*9.6*	*8.3*	*8.8*	*8.7*
Start Time:	*8:00*	*7:40*	*8:06*	*8:24*	*9:00*	*9:30*	*7:40*	*8:17*
End Time:	*16:10*	*16:30*	*17:22*	*18:15*	*18:35*	*17:45*	*16:30*	*17:00*
Numbers of Lifts:	*8*	*10*	*12*	*11*	*11*	*8*	*8*	*8*
Water Temperature (F):	*62.0*	*62.0*	*65.0*	*64.0*	*59.0*	*59.0*	*59.0*	*57.0*
American shad	752	922	1,183	858	1,075	317	239	121
Gizzard shad	4,338	13,950	10,567	7,043	5,485	2,568	2,597	1,402
Striped bass	0	0	0	0	0	0	0	1
Striped bass hybrid	0	0	0	0	0	0	1	0
Sea lamprey	0	0	0	0	0	0	0	0
Rainbow trout	0	0	0	0	0	0	0	0
Brown trout	1	0	0	0	0	0	1	0
Palamino trout	0	0	0	0	0	0	0	0
Carp	117	112	12	22	22	1	0	4
Quillback	252	340	60	31	11	72	0	1
Shorthead redhorse	95	169	144	68	54	23	17	13
Brown bullhead	24	83	0	0	0	2	0	0
Channel catfish	14	101	59	29	59	18	15	35
Rock bass	2	0	10	10	2	4	0	0
Redbreast sunfish	0	22	0	0	0	5	3	0
Green sunfish	0	0	0	0	0	0	0	3
Pumpkinseed	0	0	1	0	1	0	0	0
Bluegill	0	3	2	1	3	0	0	0
Smallmouth bass	239	530	112	119	31	19	16	3
Largemouth bass	47	91	4	2	0	0	0	1
White crappie	0	0	3	4	1	0	0	0
Black crappie	0	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	144	719	119	82	68	66	17	14
Total	***6,025***	***17,042***	***12,276***	***8,269***	***6,812***	***3,095***	***2,906***	***1,598***

Table 1

Continued.

Date:	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*
Hours of Operation:	*10.0*	*10.0*	*9.3*	*10.5*	*10.5*	*10.3*	*9.2*	*9.9*
Start Time:	*8:40*	*9:00*	*9:00*	*8:05*	*8:00*	*8:00*	*7:35*	*7:25*
End Time:	*18:40*	*19:00*	*18:15*	*18:35*	*18:30*	*18:15*	*16:45*	*17:21*
Numbers of Lifts:	*9*	*10*	*9*	*9*	*10*	*10*	*8*	*10*
Water Temperature (F):	*58.0*	*61.0*	*61.0*	*60.8*	*61.0*	*61.0*	*61.0*	*61.0*
American shad	499	386	239	193	478	333	145	335
Gizzard shad	1,743	1,244	2,717	1,507	676	654	804	6,036
Striped bass	0	0	0	0	0	0	0	0
Striped bass hybrid	0	0	0	0	1	0	0	0
Sea lamprey	0	0	0	0	0	0	0	1
Rainbow trout	0	0	1	0	0	0	0	1
Brown trout	0	0	0	0	0	0	0	0
Palamino trout	0	0	0	0	0	0	0	0
Carp	3	2	53	4	1	2	0	12
Quillback	1	108	163	6	2	10	9	42
Shorthead redhorse	82	192	205	8	3	11	16	113
Brown bullhead	0	0	0	0	0	0	0	0
Channel catfish	31	6	15	3	1	4	0	21
Rock bass	5	1	7	2	5	3	1	8
Redbreast sunfish	0	0	0	0	2	0	1	0
Green sunfish	0	0	0	0	0	0	0	0
Pumpkinseed	2	0	0	0	0	0	2	3
Bluegill	1	5	1	1	0	0	0	1
Smallmouth bass	26	38	41	22	11	15	21	43
Largemouth bass	0	0	0	1	0	2	1	2
White crappie	1	0	0	0	0	0	0	0
Black crappie	0	0	0	0	0	0	0	0
Yellow perch	1	0	0	1	0	0	0	0
Walleye	29	77	159	41	35	39	41	146
Total	***2,424***	***2,059***	***3,601***	***1,789***	***1,215***	***1,073***	***1,041***	***6,764***

Table 1

Continued.

Date:	*28 May*	*29 May*	*30 May*	*31 May*	*01 Jun*	*02 Jun*	*03 Jun*	*11 Jun*
Hours of Operation:	*10.0*	*10.0*	*11.2*	*9.0*	*7.2*	*7.8*	*3.2*	*8.3*
Start Time:	*7:30*	*8:00*	*8:00*	*8:00*	*9:50*	*8:30*	*8:30*	*8:30*
End Time:	*17:30*	*18:00*	*19:10*	*17:00*	*17:00*	*16:15*	*11:40*	*16:45*
Numbers of Lifts:	*9*	*12*	*14*	*11*	*8*	*7*	*3*	*9*
Water Temperature (F):	*61.0*	*61.0*	*62.0*	*62.0*	*61.0*	*62.1*	*62.0*	*63.0*
American shad	346	315	423	149	248	51	3	7
Gizzard shad	4,083	3,146	4,266	2,854	934	1,623	327	3,299
Striped bass	0	0	0	0	0	0	0	0
Striped bass hybrid	0	0	0	0	0	0	0	0
Sea lamprey	0	0	0	0	0	0	0	0
Rainbow trout	1	0	0	0	0	0	0	3
Brown trout	0	0	0	0	1	0	0	1
Palamino trout	0	0	0	0	0	0	0	0
Carp	11	21	13	109	28	30	1	12
Quillback	94	32	86	366	47	2	0	168
Shorthead redhorse	105	44	52	133	22	0	4	40
Brown bullhead	1	0	0	0	0	0	0	1
Channel catfish	97	40	86	291	43	5	24	213
Rock bass	11	4	12	26	6	1	10	2
Redbreast sunfish	1	0	0	2	9	0	0	4
Green sunfish	0	0	0	0	0	0	1	1
Pumpkinseed	0	0	7	0	0	3	0	0
Bluegill	0	1	2	0	0	3	0	7
Smallmouth bass	28	18	23	56	20	15	1	47
Largemouth bass	0	1	2	1	0	1	0	2
White crappie	0	0	0	0	0	1	0	0
Black crappie	1	0	0	0	0	0	0	0
Yellow perch	0	0	0	0	0	0	0	0
Walleye	156	73	39	196	47	5	16	94
Total	***4,935***	***3,695***	***5,011***	***4,183***	***1,405***	***1,740***	***387***	***3,901***

Table 1

Continued.

Date:	*12 Jun*	*13 Jun*	*14 Jun*	*15 Jun*	*16 Jun*	*Totals*
Hours of Operation:	*8.0*	*7.5*	*4.9*	*5.5*	*5.0*	*307.9*
Start Time:	*8:00*	*8:30*	*11:37*	*11:14*	*11:00*	--
End Time:	*16:00*	*16:00*	*16:32*	*16:43*	*16:00*	--
Numbers of Lifts:	*7*	*6*	*3*	*6*	*4*	*320.0*
Water Temperature (F):	*64.6*	*68.7*	*68.5*	*70.0*	*71.0*	--
American shad	3	4	4	2	1	*16,646*
Gizzard shad	1,448	269	950	306	107	*117,031*
Striped bass	0	0	0	0	0	*1*
Striped bass hybrid	0	0	0	1	0	*3*
Sea lamprey	0	0	0	0	0	*1*
Rainbow trout	0	0	0	0	1	*9*
Brown trout	1	1	0	0	0	*9*
Palamino trout	1	0	0	0	0	*1*
Carp	13	8	27	49	3	*1,026*
Quillback	279	327	423	172	164	*3,944*
Shorthead redhorse	78	66	46	40	23	*2,575*
Brown bullhead	0	0	0	0	0	*113*
Channel catfish	81	88	81	77	53	*1,664*
Rock bass	4	12	8	11	1	*199*
Redbreast sunfish	0	0	9	26	0	*86*
Green sunfish	0	0	0	0	0	*5*
Pumpkinseed	0	2	0	0	1	*26*
Bluegill	18	16	0	0	9	*77*
Smallmouth bass	63	33	23	14	12	*5,673*
Largemouth bass	3	1	0	0	0	*182*
White crappie	0	0	0	0	0	*10*
Black crappie	0	0	0	0	0	*2*
Yellow perch	1	0	0	0	0	*7*
Walleye	157	74	19	11	5	*3,117*
Total	***2,150***	***901***	***1,590***	***709***	***380***	*152,407*

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 2003. No operation on May 14-15 and June 4-10.

Date	River Flow[1] (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
02 May	35.8	64.0	24			A & C	500	168.4-171.2	225.4-226.2
03 May	34.2	64.0	22	6	3 to7,12	A & C	500	168.5-172.3	225.3-225.6
04 May	32.8	64.0	20	8	3 to 6,9,10,12	A & C	500	169.0-169.4	225.6-225.9
05 May	36.5	64.5	20	8	3 to 7, 9,10,12	A & C	500	169.7-170.8	225.8-226.3
06 May	35.4	62.0	22	9	1,3 to 7, 9,10,12	A & C	500	168.6-170.6	226.3-226.4
07 May	36.4	61.0	22	9	1,3 to 7,9,10,12	A & C	500	171.9	224.9
08 May	34.7	62.0	24-18	8	1,3, 5 to 9,11	A & C	500	171.3-173.3	225.6-226.0
09 May	33.7	63.0	20	4	1,4 to 6	A & C	500	169.4-170.0	225.8-226.1
10 May	37.5	62.0	18-20			A & C	500	169.5-170.0	225.8-226.0
11 May	40.0	62.0	24			A & C	500	172.1-173.5	226.1-226.9
12 May	41.4	65.0	22	9	1, 3 to 11	A & C	500	173.03-173.3	226.1
13 May	43.6	64.0	22-18	7	1, 3 to 8	A & C	500	171.6	225.35-226.05
16 May	37.5	59.0	30	9	1, 3 to 10	A & C	500	171.9-172.4	224.9-225.5
17 May	48.6	59.0	30	8	3 to 10	A & C	500	172.0-173.3	226.4-226.7
18 May	56.5	59.0	28	8	3 to 10	A & C	500	173.6-174.9	226.1-226.4
19 May	53.6	57.0	24	9	1,3 to 8, 11,12	A & C	500	173.97-174.60	225.30-225.78
20 May	51.0	58.0	26	8	1,2,4,5,6,8 to 10	A & C	500	173.4-173.6	225.7-225.9
21 May	45.0	61.0	26	9	1,3 to 10	A & C	500	171.60-174.81	225.50-225.78
22 May	39.8	61.0	24	10	1 to10	A & C	500	171.4-171.8	226.0-226.2
23 May	40.8	60.8	26	11	1 to 11	A & C	500	170.8-172.8	225.4-226.2
24 May	35.9	61.0	34	6	3 to 8	A & C	500	170.5-173.0	225.8-226.3
25 May	42.5	61.0	34	8	3 to 10	A & C	500	171.5-173.4	226.0-226.6
26 May	51.2	61.0	30	8	3 to 10	A & C	500	172.4-173.4	226.0-226.2
27 May	53.1	61.0	30	6	1,4 to 7,11,12	A & C	500	172.4-175.4	225.5-225.9
28 May	57.3	61.0	22	11	1,3 to 12	A & C	500	173.5-173.8	224.7-225.8

Table 2

Continued.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
29 May	59.3	61.0	22	4	1,2,6,12	A & C	500	171.6-171.7	225.5-226.6
30 May	53.1	62.0	22	9	3 to10,12	A & C	500	172.9-173.2	224.8-226.3
31 May	50.9	62.0	24	8	3 to 10	A & C	500	172.2-173.4	225.7-226.2
01 Jun	50.9	61.0	32	8	3 to 10	A & C	500	173.2-173.7	225.9
02 Jun	75.5	62.1	22	3	1,2,12	A & C	500	172.3-172.4	225.6-226.5
03 Jun	139.9	62.0	12	11		A & C	500	173.9-175.7	226.0-226.3
11 Jun	77.7	63.0	18	11		A & C	500	176.1-176.5	225.9-226.1
12 Jun	66.5	64.6	18	11		A & C	500	173.6-174.9	224.9-225.5
13 Jun	60.2	68.7	18	11	1 to 8,10,11,12	A & C	500	172.3-175.6	224.9-225.2
14 Jun	58.5	68.5	20-26	11	1 to 8,10,11,12	A & C	500	173.9-175.4	226.0-226.3
15 Jun	56.0	70.0	20	9	3 to 11	A & C	500	171.7-173.8	226.3
16 Jun	53.5	71.0	20	10	1 to 9,12	A & C	500	172.4-173.7	225.8-226.2

1 River flow measured at Holtwood Dam.

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 2003. No operation on May 14-15 and June 4-10.

Date:	*02 May*	*03 May*	*04 May*	*05 May*	*06 May*	*07 May*	*08 May*
Observation Time (Start):	*11:00*	*8:00*	*8:10*	*7:30*	*7:45*	*8:20*	*7:40*
Observation Time (End):	*16:00*	*16:00*	*16:00*	*16:00*	*16:00*	*16:00*	*16:40*
Military time (hrs)							
0700 to 0759				12			32
0800 to 0859		167	60	6	28	92	66
0900 to 0959		238	54	87	24	2	142
1000 to 1059		322	86	128	34	0	117
1100 to 1159	211	42	144	178	30	53	80
1200 to 1259	161	133	127	202	42	24	192
1300 to 1359	229	140	144	162	85	47	143
1400 to 1459	272	80	156	90	147	109	142
1500 to 1559	135	59	76	172	218	88	214
1600 to 1659							111
1700 to 1759							
1800 to 1859							
1900 to 1959							
Total	***1,008***	***1,181***	***847***	***1,037***	***608***	***415***	***1,239***

Date:	*09 May*	*10 May*	*11 May*	*12 May*	*13 May*	*16 May*	*17 May*
Observation Time (Start):	*7:35*	*8:50*	*8:10*	*7:40*	*8:25*	*9:00*	*9:15*
Observation Time (End):	*15:00*	*16:55*	*16:56*	*17:30*	*18:20*	*18:45*	*18:30*
Military time (hrs)							
0700 to 0759	79			2			
0800 to 0859	78	94	140	24	93		
0900 to 0959	41	82	39	172	72	59	12
1000 to 1059	43	65	64	64	117	182	3
1100 to 1159	114	124	70	51	47	233	40
1200 to 1259	161	76	83	144	41	76	48
1300 to 1359	140	141	165	168	143	92	57
1400 to 1459	24	53	183	201	107	155	62
1500 to 1559		60	96	181	85	67	39
1600 to 1659		57	82	133	40	65	34
1700 to 1759				43	102	84	21
1800 to 1859					11	62	1
1900 to 1959							
Total	***680***	***752***	***922***	***1,183***	***858***	***1,075***	***317***

Table 3

Continued.

Date:	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*
Observation Time (Start):	*9:26*	*8:45*	*9:00*	*9:00*	*9:00*	*9:00*	*9:35*
Observation Time (End):	*17:00*	*17:15*	*18:50*	*19:00*	*18:30*	*18:55*	*19:00*
Military time (hrs)							
0700 to 0759							
0800 to 0859		17					
0900 to 0959	45	12	2	36	64	21	11
1000 to 1059	12	8	6	37	25	23	21
1100 to 1159	29	18	9	35	16	39	29
1200 to 1259	23	9	57	48	10	16	32
1300 to 1359	24	10	106	42	22	10	56
1400 to 1459	41	16	105	38	26	25	41
1500 to 1559	45	14	53	49	18	23	71
1600 to 1659	20	17	68	32	19	22	106
1700 to 1759			58	55	22	6	52
1800 to 1859			35	14	17	8	59
1900 to 1959							
Total	***239***	***121***	***499***	***386***	***239***	***193***	***478***

Date:	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*
Observation Time (Start):	*9:20*	*8:38*	*8:20*	*9:00*	*9:00*	*8:30*	*9:10*
Observation Time (End):	*19:00*	*16:55*	*17:45*	*18:00*	*18:30*	*19:22*	*17:25*
Military time (hrs)							
0700 to 0759							
0800 to 0859		5	31			1	
0900 to 0959	27	18	26	64	31	38	46
1000 to 1059	24	25	36	18	36	22	28
1100 to 1159	47	9	36	23	35	25	19
1200 to 1259	31	15	43	53	37	17	15
1300 to 1359	49	17	41	26	38	47	8
1400 to 1459	42	18	24	39	56	62	9
1500 to 1559	30	15	46	51	40	46	10
1600 to 1659	31	23	28	41	31	71	10
1700 to 1759	38		24	31	10	61	4
1800 to 1859	14				1	20	
1900 to 1959						13	
Total	***333***	***145***	***335***	***346***	***315***	***423***	***149***

Table 3

Continued.

Date:	*01 Jun*	*02 Jun*	*03 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*
Observation Time (Start):	*9:15*	*8:30*	*8:45*	*9:00*	*9:00*	*9:00*	*11:50*
Observation Time (End):	*17:15*	*16:30*	*12:15*	*17:00*	*16:30*	*16:00*	*16:47*
Military time (hrs)							
0700 to 0759							
0800 to 0859		9					
0900 to 0959	5	5	2		0	1	
1000 to 1059	20	4	1	1	0	0	
1100 to 1159	35	2		2	0	0	
1200 to 1259	59	12		2	0		
1300 to 1359	46	4		1	0	1	1
1400 to 1459	54	7			2	0	
1500 to 1559	12	5			0	2	3
1600 to 1659	17	3		1	1		
1700 to 1759							
1800 to 1859							
1900 to 1959							
Total	***248***	***51***	***3***	***7***	***3***	***4***	***4***

Date:	*15 Jun*	*16 Jun*	
Observation Time (Start):	*11:50*	*11:00*	
Observation Time (End):	*17:00*	*16:00*	***Total***
Military time (hrs)			
0700 to 0759			***125***
0800 to 0859			***911***
0900 to 0959			***1,478***
1000 to 1059			***1,572***
1100 to 1159	1	1	***1,827***
1200 to 1259	1		***1,990***
1300 to 1359			***2,405***
1400 to 1459			***2,386***
1500 to 1559			***2,023***
1600 to 1659			***1,063***
1700 to 1759			***611***
1800 to 1859			***242***
1900 to 1959			***13***
Total	***2***	***1***	***16,646***

Table 4

Summary of American shad passage counts and percent passage values at Susquehanna River dams, 1997-2003.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		Number	Passed	Number	Passed	Number	Passed
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,675	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%

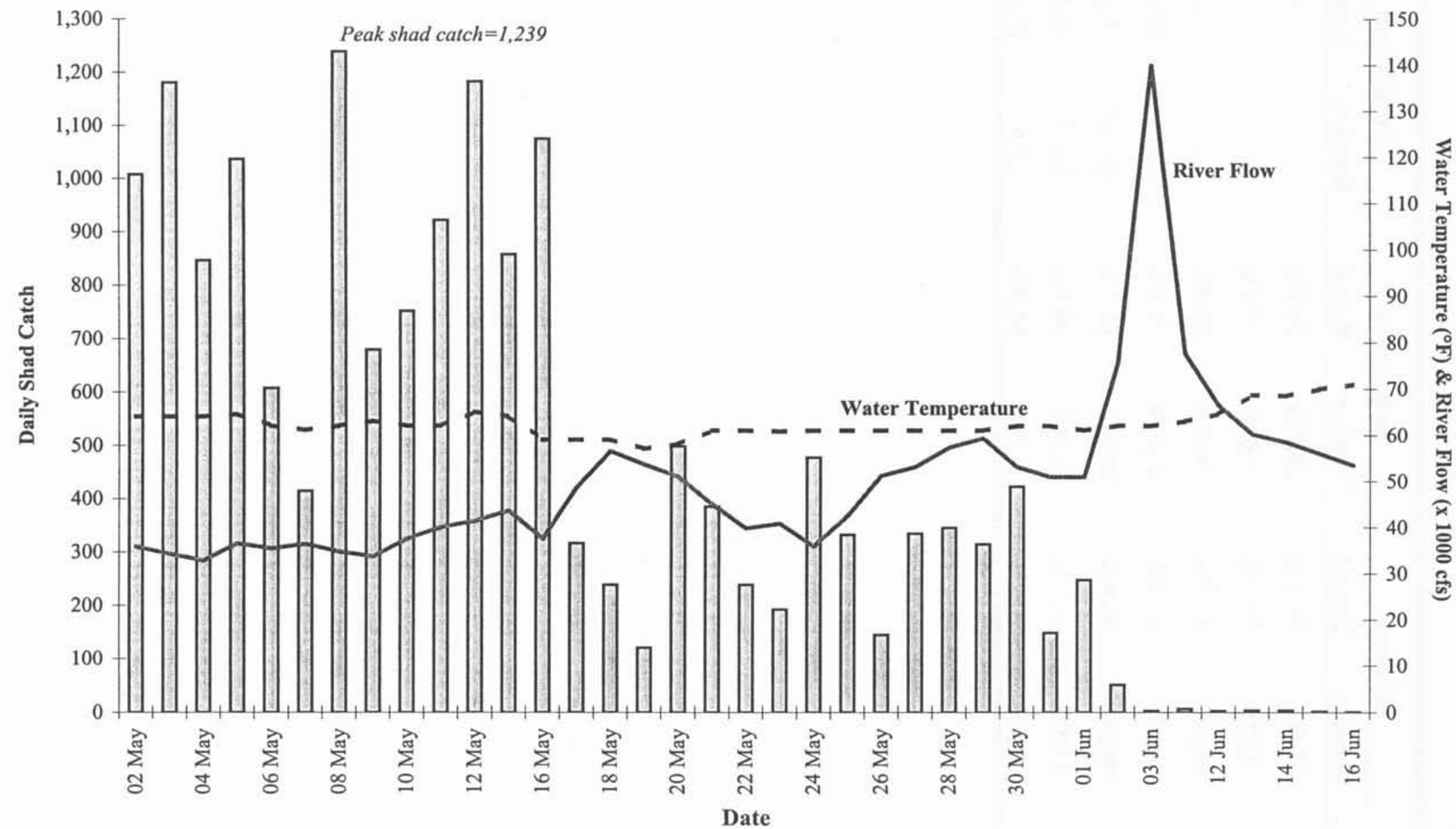


Figure 1

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Safe Harbor fish passage facility, spring 2003. No operation on May 14-15 and June 4-10.

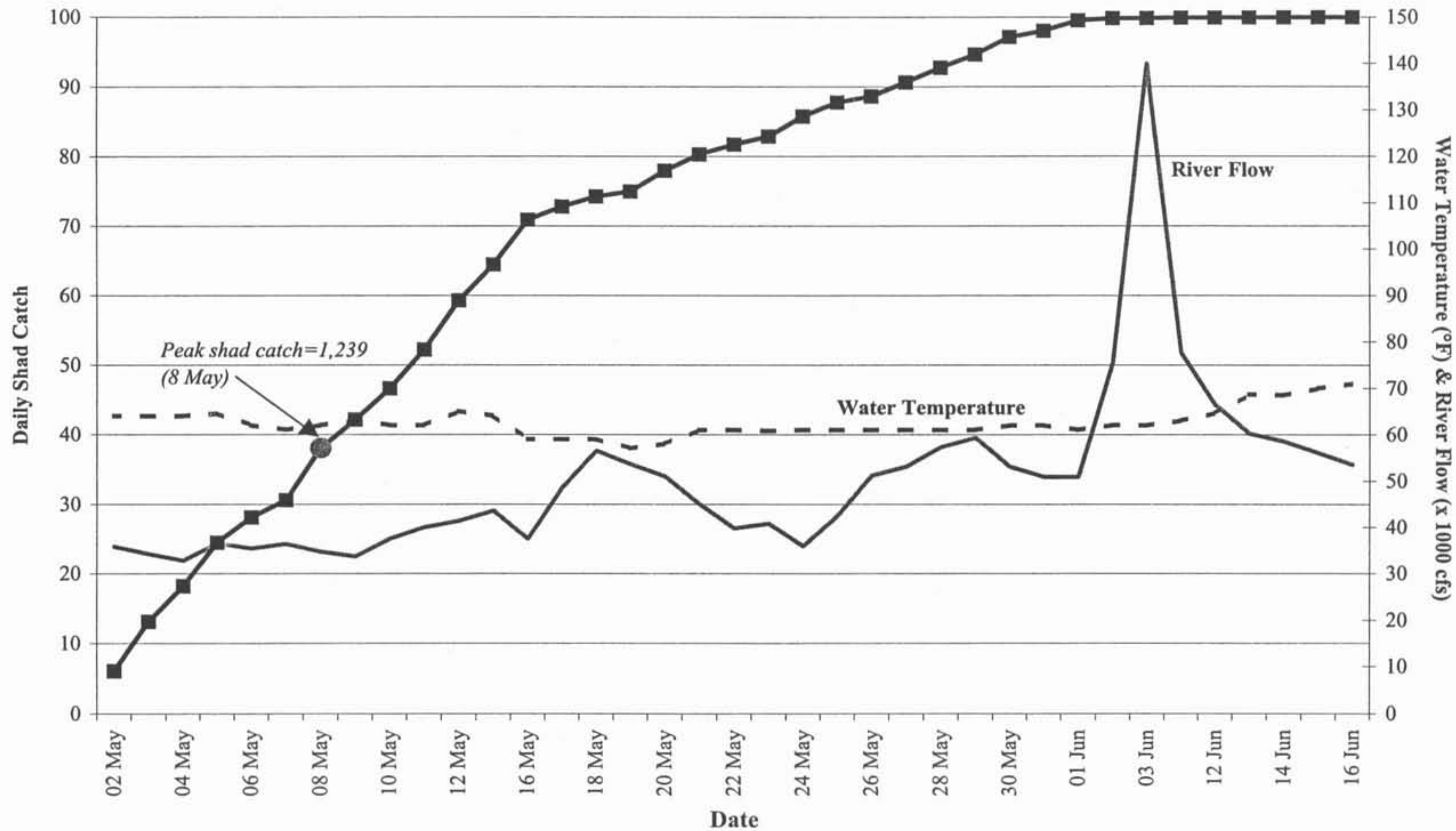


Figure 2

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American shad catch at the Safe Harbor fish passage facility, spring 2003. No operation on May 14-15 and June 4-10.

FirstEnergy

Job I - Part 5

SUMMARY OF UPSTREAM AND DOWNSTREAM FISH PASSAGE AT THEYORK HAVEN HYDROELECTRIC PROJECT IN 2003

PREPARED FOR:

York Haven Power Company
Middletown, Pennsylvania 17057

PREPARED BY:

Kleinschmidt
2 East Main Street
Strasburg, Pennsylvania 17579

January 2004

INTRODUCTION

In 1993, York Haven Power Company (YHPC), the licensees of the Safe Harbor and Holtwood Projects, the U.S. Department of the Interior represented by the Fish and Wildlife Service ("USFWS"), the Susquehanna River Basin Commission ("SRBC"), the states of Maryland and Pennsylvania and their involved agencies – Maryland Department of Natural Resources ("MDNR"), Pennsylvania Fish and Boat Commission ("PFBC") and Pennsylvania Department of Environmental Resources ("PADEP"), and two other parties signed the Susquehanna River Fish Passage Settlement Agreement.

This agreement established for each project a Fish Passage Technical Advisory Committee ("FPTAC") comprised of representatives of the affected licensee, USFWS, PFBC and MDNR. Each FPTAC is responsible for reviewing and monitoring the design, construction, maintenance and operation of the fish passage facilities at the respective project, preparing an annual report, and recommending studies and/or modifications to improve upstream and downstream passage.

Following discussions at the 18 April, 2003 FPTAC meeting, a consensus was reached on the operation of the York Haven Fishway (Fishway) for the spring migration season. As in 2002, YHPC also agreed to make periodic observations for adults in the forebay and would open the trash gate if/when large numbers of adults were observed. They also planned to the implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC.

YORK HAVEN FISHWAY OPERATIONS

The installation and operation of the Fishway are part of a cooperative private, state and federal effort to restore American shad (*Alosa sapidissima*) and other migratory fish to the Susquehanna River. In 1997, YHPC and the resource agencies reached a new settlement agreement to revise the type and location of the York Haven fish passage facility. The Fishway is located in Dauphin County, PA at the Three Mile Island end of the East Channel Dam at the York Haven Hydroelectric Project (FERC No. 1888). The Fishway was placed in service by YHPC in April 2000.

Operation in 2003, the fourth year of Fishway operation, was to incorporate experience gained during the first three seasons, along with FPTAC recommendations from the April 18, 2003 meeting. Objectives of 2003 operation were to monitor passage of migratory and resident fishes through the Fishway and continue to assess operation, including improvements to the Fishway and modifications to springtime minimum flow releases. Specific recommendations concerning minimum flows included in the 2003 Fishway Operation Procedure included:

- If/when River flow was less than 23,000 cfs, spill over the Main Dam was to be maintained at a nominal minimum spill of 1,000 cfs during daily Fishway operation.
- If/when low flow conditions occurred, the Station was to reduce Main Dam spill to 4,000 cfs, allowing a temporary staff gauge to be installed in the ponded area immediately downstream of the Fish Passage out fall (Tailrace). A baseline measurement was to be recorded once river conditions stabilized.

- Main Dam spill was to be reduced by an additional 1,000 cfs each day (pending river conditions). Prior to proceeding to the next level of flow reduction a Fish Passage Tailrace level reading needed to be recorded.
- When Main Dam spill reached 1,000 cfs, a final Tailrace level was to be recorded and evaluated prior to continuous operation at this flow condition.
    - A significant reduction in tailrace level could indicate a reduction in the volume of East Channel Flow, which could reduce attraction to the Fishway. Therefore any significant decrease in Tailrace Level was to be reviewed with the FPTAC.
    - If a significant reduction was not noted, continuous operation would be permitted for the remainder of the Fish Passage season that occurred during low flow periods.
    - During this low flow operation spill over the Main Dam was to be reduced to 500 cfs for one day to allow for observation of pooling at the tailrace of the Main Dam and for aerial photography of the river under this condition depending upon TMI airspace restrictions.

Project Operation

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

Fishway Design

Fishway design incorporated numerous criteria established by the USFWS and the other resource agencies. The Fishway has an operating limit of 150,000 cfs River flow (East Channel flow limit of approximately 22,000 cfs). The Fishway includes two sections; a "weir cut" and a vertical notch fish ladder. Figure 2 provides the general arrangement of the Fishway. A detailed description of the Fishway and its major components is located in 2000 and 2001 summary reports (Kleinschmidt 2000 & 2002).

Fishway Operation

All preseason preparations to the Fishway were completed prior to 1 April. The Fishway was opened on 6 May, 4 days after the Safe Harbor Fish Lift was placed into service. Between 6 May and 19 June; fish were counted and allowed to pass upstream on 39 days. The Fishway was opened daily between 6 May and 3 June. High River flows that peaked at 131,000 cfs on 3 June coupled with decreased shad passage resulted in the cancellation of Fishway operation until 6 June. High flows and limited shad passage resulted in the alternate day operation of the Fishway between 6 and 10 June. Although daily operation resumed on 11 June and continued through 16 June, shad passage during this period was limited. As it was very late in the season and passage was limited the Fishway stop gate was left open after viewing was curtailed on 16 June. Following 4 hours of viewing on 19 June the Fishway was shutdown for the season. The decision to shut the Fishway down for the season was mutually agreed to by members of the FPTAC

Two people opened the Fishway. First, the attraction flow through the "weir cut" was released by opening both 20-ft wide fixed wheel gates. Next, the downstream entrance gate and the upstream "exit gate" of the ladder were opened. Then the "diffuser gate" was opened. These five gates remained opened the entire season. The entrance gate was the only gate that was adjusted throughout the season. This gate was adjusted manually throughout the season maintaining a 0.5-ft differential between the surface water elevation downstream of the entrance and the water elevation in the diffuser area of the fish ladder. This setting resulted in an average velocity of 6 ft/sec at the entrance to the ladder. The 7-ft wide stop gate, located between the weir and the fish ladder entrance, remained closed during the entire period of operation.

Excluding the first and last day of operation, which involved opening and closing the Fishway, the Fishway was typically manned by one person. This person, a biologist or technician, adjusted the position of the entrance gate, counted and recorded the number of fish that passed through the ladder hourly, removed debris from the exit of the ladder, made visual observations of fish activity and movement in and through the ladder, and made observations once each day below the Main Dam. This individual also recorded water elevations several times each day on staff gauges located throughout the fishway.

Fish Counts

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

Fish passage by the viewing window was controlled by opening or closing an aluminum grating gate with an electric hoist that was controlled from inside the viewing room. Normally, this gate was closed nightly between 1500 and 1900 hrs based on shad passage. Daily operation was extended hourly between 1500 and 1900 hrs as long as 5 shad passed hourly. The stop gate was usually opened each morning the Fishway was manned at 0800 hrs. Occasionally, it was closed for brief periods of time as needed each day to enable the person manning the fishway to conduct other activities. Prior to operation in 2003, the FPTAC agreed that during the weeks of May 18, May 25 and June 1 the counting process was to start at 0600 in lieu of the normal time of 0800 for 3 of the 7 days of those weeks. Additionally, fish counting during one day in each of those weeks (other then the 3 days mentioned) was to continue for a complete 24 hour period. Fish counts during the last tow weeks of May included two 24 hour periods and started at 0600 hrs on six days. The modified operation and counting procedure was cancelled for early June due to high water. In an effort to improve viewing, the adjustable crowder screen, modified prior to the start of operation, was adjusted as needed to allow all fish that passed to be observed. Gate settings varied from 8 in to 24 in depending on river conditions.

As in previous seasons, fish passage data was entered on a field data sheet and uploaded into a computer. Files were uploaded each evening, checked and corrected as necessary. Data reporting was PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheets. Passage data and operational conditions were supplied electronically to YHPC's on-site coordinator/manager and other appropriate YHPC and GPU personnel on a daily basis. In addition, weekly passage information was supplied electronically to YHPC and GPU personnel and members of the FPTAC.

Each day a permanent record (video tape) of daily fish passage was made. The video system was the same system used in 2000 and it was set-up identical to that reported in Kleinschmidt (2000). Fish passage was recorded in 12 hour time-lapse mode. During recording, the recorder imprinted the time and date on each frame of video tape, providing a record for fish that passed the viewing window. No tape review of 2003 passage was conducted, as hourly shad passage never reached the minimum passage requirement of 1,000 shad/hr.

RESULTS

Relative Abundance

The number of fish that passed through the York Haven fish ladder is presented in Table 1. Some 146,420 fish of 25 taxa were enumerated as they passed upstream into Lake Frederic. Gizzard shad (113,513) was the dominant fish species passed and comprised nearly 78% of the fish passed. Some 2.536 American shad were counted as they passed through the ladder. Other predominant fishes passed included walleye (8,132), channel catfish (6,866), quillback (6,324), shorthead redhorse (4,208), and smallmouth bass (2,242). Peak passage occurred on 20 May when some 12,580 fish, or 8.6% of the season total, were passed.

American Shad Passage

A total of 2,536 American shad passed upstream through the ladder in 2003 (Table 1). Passage of shad varied daily, in May, over 100 American shad passed through the ladder on 12 days; on four of the days over 150 shad passed. Peak shad passage occurred on 30 May when

227 shad were passed. Most shad (97.0%; 2,460) passed before a high flow event that occurred in early June and peaked at 131,000 cfs on June 3.

American shad were collected and passed at water temperatures of 52.0° F to 71.0° F, River flows of 29,200 cfs to 131,000 cfs and East Channel flows of 3,000 cfs and 20,500 cfs (Tables 2 and 3, Figures 3 and 4). American shad passage through the ladder occurred in three waves or pulses. Peak passage occurred between 7 and 12 May. During this period 850 American shad passed the ladder at water temperatures that varied from 60.0° F to 63.3° F and at River flows that varied from 29,400 cfs to 38,300 cfs. East channel flows during this period varied from 3,000 cfs to 6,500 cfs. Some 618 shad passed the ladder from 19 to 22 May at water temperatures that varied from 59.0° F to 62.80° F and at River flows that decreased from 51,017 cfs to 37,600 cfs. East channel flows during this period decreased from 6,400 cfs to 4,700 cfs. Between 26 May and 1 June, 678 shad passed at water temperatures that varied from 62.0° F to 67.2° F and River flows from 44,100 cfs to 51,017 cfs. East channel flows during this period varied from 5,300 cfs to 6,500 cfs. Only 92 shad passed between 2 to 19 June, the last 12 days of Fishway operation. During this period River flows peaked at 131,000 cfs on 3 June and water temperatures increased from a low 59.0° F to a season high of 72.1° F on 19 June while East channel flows varied from 4,500 cfs to 20,500 cfs.

The hourly passage of American shad through the fish ladder is given in Table 3. Generally, daily shad passage was highest before 1300 hours, it declined and leveled off during early afternoon and continued to decline during the last several hours of viewing. Peak hourly passage of shad (48) occurred on 31 May between 0800 hrs and 0859 hrs. Over 66% of the shad passed prior to 1300 hours, some 562 shad passed during the first three hours (0600 hrs to 0859 hrs), 531 shad passed between 0900 hrs and 1059 hrs, and 605 shad passed between 1100 hrs and 1259 hrs. Total hourly passage from 1300 hrs to 1459 hrs, although similar, varied from 167 shad to 206 shad per hour. Total hourly passage between 1600 hrs and 1900 hrs declined from mid-day levels and varied from 121 to 65 shad per hour.

On a trial basis, the Fishway remained open all night twice between 1900 hrs and 0800 hrs; it remained open overnight on 22/23 May and 28/29 May. A total of seven shad passed overnight; 4 shad passed between 1900 hrs and 2059 hrs and 3 shad passed between 0400 hrs and 0559 hrs (Table 5).

The Fishway was also opened 6 mornings between 18 May and 1 June from 0600 hrs and 0759 hrs. Shad passage during this two hour period varied from 3 to 46 shad (Table 5). Including the two overnight periods, passage between 0600 hrs and 0759 hrs on 18, 24, 25, and 29 May varied from three to eight shad. Passage during this same two hour period on 20, 23 and 30 May and 1 June varied from 13 shad to 46 shad. Hourly shad passage between 0600 hrs and 0659 hrs varied from 2 to 22 shad and comprised from 5.1% and 26.8% of the passage each day. Passage during the first hour of operation on days the Fishway was opened at 0800 hrs during this period varied from 5 to 49 shad and comprised 3.9% to 50% of the daily shad passage. Although the hourly and daily shad passage statistics generally show that opening the Fishway early (0600 hrs) reduced the build up off shad associated with opening the fishway at 0800 hrs, opening early did not appear to increase the number of shad that passed through the Fishway daily.

Other Alosines and Observations

Although no other alosines (alewife, blueback herring and hickory shad) were observed passing through the ladder some 25 striped bass did pass through the ladder (Table 1). Once each day visual observations of fish activity were made on a random basis below the Main Dam. On several occasions several carp, quillback and gizzard shad were observed trying to swim over the Main Dam. No shad or other alosines were observed below the Main Dam.

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

SUMMARY

The spring 2003 York Haven Fishway operating season was considered a success. Survival of fish that utilized the Fishway was considered excellent as no mortalities were observed. Some 2,536 American shad used the Fishway to pass upstream. Although the impact high River flows had on upstream movement of shad in the River in 2003 is unknown, it is likely this factor resulted in reduced passage at York Haven and the other three downstream dam fishways.

Combining proposed recommendations with operating experience gained since 2000 will enable all those involved with the Susquehanna River Shad Restoration partnership to gain a better understanding of fish passage at the York Haven Project.

RECOMMENDATIONS FOR 2004 OPERATION

As River flows were high again this season, YHPC plans to:

1. Continue working with the FPTAC over the next several seasons to determine the minimum spill at the Main Dam and the attraction flow in the East Channel necessary to optimize fish passage and generation at the Project;

2. Continue the collection and evaluation of seasonal passage statistics evaluating fishway effectiveness; and,

3. Start daily operation of the fishway at 0800 hrs as shad passage in 2003 and overnight was limited and opening the Fishway early (0600 hrs and 0759 hrs) did not appear to increase the number of shad passed daily. In 2004, the Fishway will be operated daily between 0800 hrs and 1500 hrs, River conditions permitting. If five shad pass during the last hour, daily operation will be extended hourly between 1500 hrs and 1900 hrs. Daily Fishway operation will cease nightly based on the hourly shad passage and end no later than 1900 hrs.

DOWNSTREAM FISH PASSAGE

As in 2002, YHPC agreed to make periodic observations for adults in the forebay and open the trash gate if/when large numbers of adults were observed. They also planned to implement the juvenile Downstream Passage Protocol that was developed in concert with the FPTAC.

Adult Passage

Station Personnel made periodic observations of the forebay area from June through August, 2003. No observations of post-spawned adult shad were noted. This observation process will continue in 2004.

Juvenile Passage

The Juvenile Downstream Passage Protocol provides for:

- Monitoring the forebay to determine when outmigrating juveniles arrive at the project
- Starting "Downstream Operation" when juveniles arrive at York Haven; Downstream Operation begins each evening at sunset and continue until about 11:30 p.m. Downstream Operation includes:
    - Turning on temporary lighting at the trash sluiceway and opening the sluiceway
    - Operating only Units 1-6 when river flow is insufficient for operation of any of the remaining units
    - Operating Units 7-20 only when river flow exceeds the hydraulic capacity of available Units 1-6; the operating priority for Units 7-20 is Unit 7, Unit 8, Unit 9 etc.
- Monitoring and sampling in the forebay as river water temperatures drop and/or River flows increase to determine when the juvenile shad emigration has ended for the season
- Ceasing "Downstream Operation" at the end of the run, in consultation with members of the FPTAC.

Since observations of juvenile shad and other clupeids were non-existent in the York Haven forebay during the fall of 2003 "Downstream Operation" was not implemented. In accordance with the protocol, monitoring of the York Haven forebay for the presence of fish began in early September and continued through October when river flow peaked at 116,167 cfs. Throughout the entire period, detection of fish activity was generally non-existent and/or extremely light by station personnel that monitored the forebay nightly for fish activity. Cast netting, conducted on four nights in October (7, 17, 25, and 31) confirmed that fish activity in the forebay was non-existent and/or extremely limited. Only a few common shiners and YOY gizzard shad were collected; shiners were more abundant than YOY gizzard shad.

Rain fall was above average in September and October which resulted in River flows that were high. During this two month period, River flows always exceeded station hydraulic capacity and peaked near or above 100,000 cfs on three occasions (Figure 5). River flows almost reached 100,000 cfs on 5 and 24 September. Between 30 September and 14 October River flows declined from 78,983 cfs to 20,150 cfs. Flows varied between 15 and 27 October from 22,833 cfs and 43,133 cfs. Heavy rain in late October caused River flows to increase a third time; flow peaked at 116,167 cfs on 31 October.

As no juvenile shad were observed on or before 31 October and water temperatures had fallen below 48.0° F it was apparent that any juvenile shad that had used the nursery habitat upstream of the Project had passed downstream undetected. Although unsubstantiated, it is highly likely that the downstream movement of juvenile shad occurred quickly during one and/or all three high flow events. Based on this information and limited passage at downstream projects YHPC and the SRAFRC coordinator jointly agreed that there was no need to continue making nightly observations in the forebay.

LITERATURE CITED

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

Kleinschmidt. 2002 Summary of operation at the York Haven Fishway in 2001. Prepared for York Haven Power Company, GPU Energy/FirstEnergy by Kleinschmidt, Strasburg, Pennsylvania. 21 pp.

Kleinschmidt. 2003 Summary of operation at the York Haven Fishway in 2002. Prepared for York Haven Power Company, GPU Energy/FirstEnergy by Kleinschmidt, Strasburg, Pennsylvania. 19 pp.

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

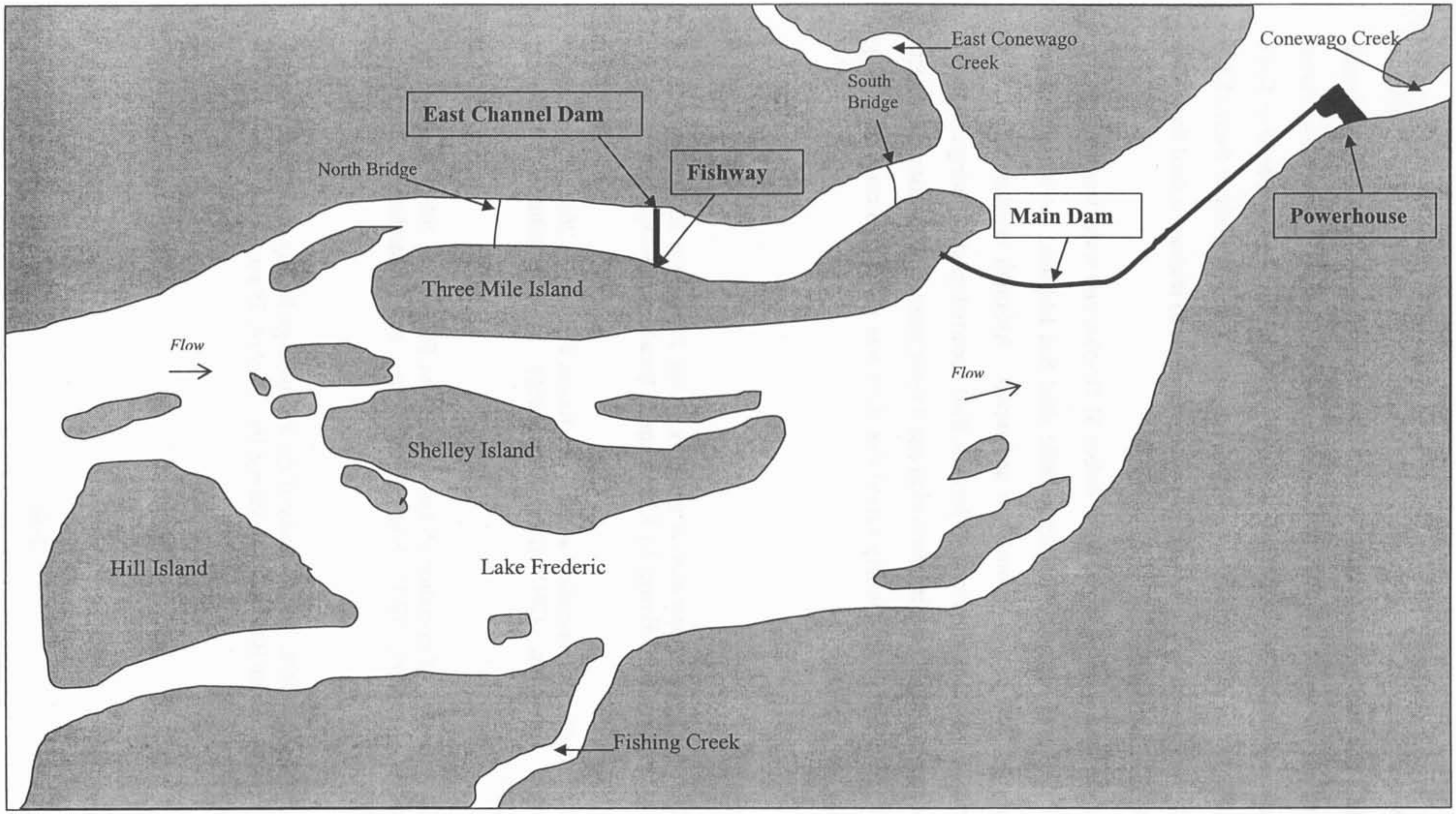
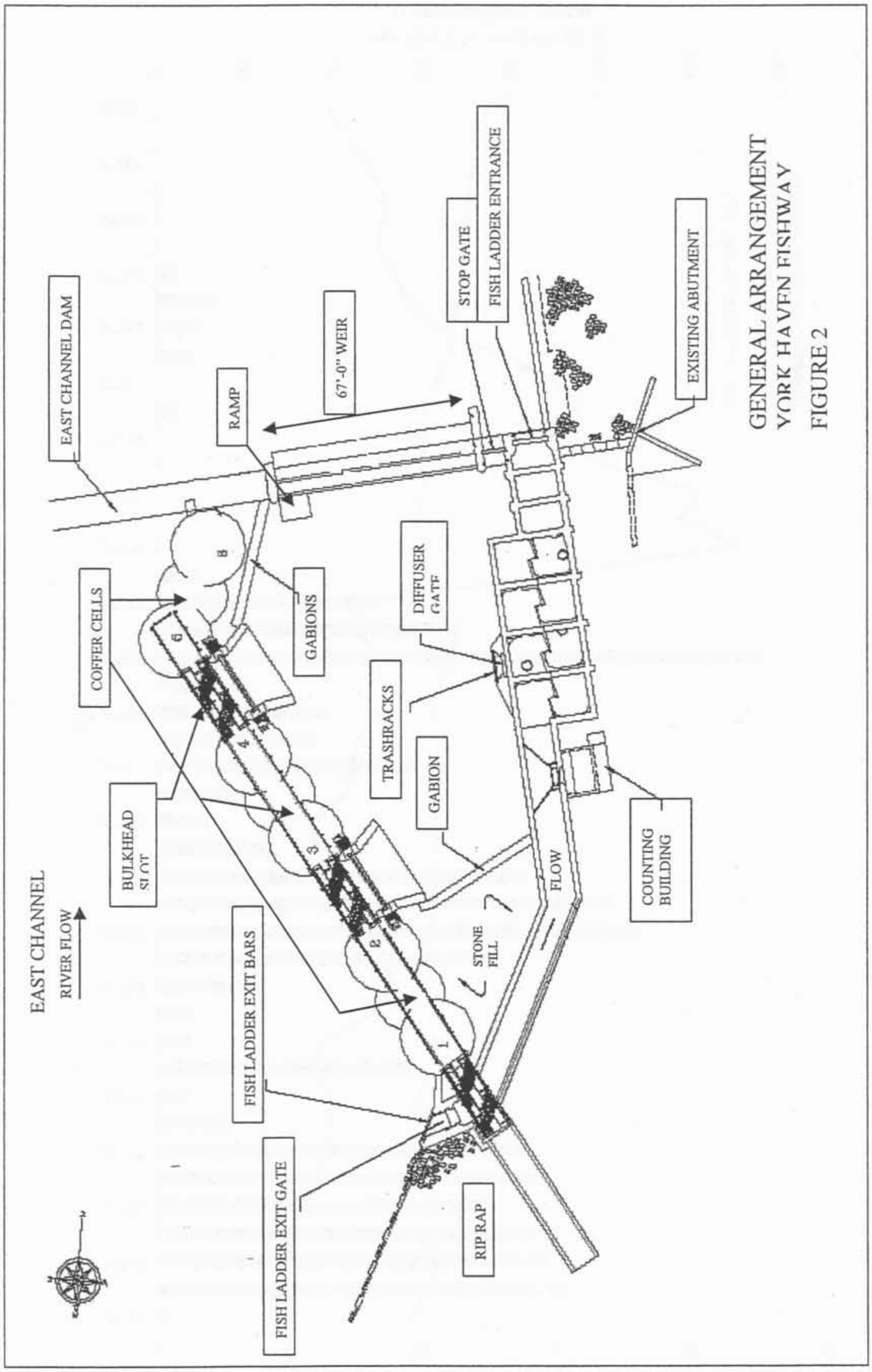


Figure 1. General Layout of the York Haven Hydroelectric Project Showing the Location of the Fishway.



GENERAL ARRANGEMENT
YORK HAVEN FISHWAY
FIGURE 2

Figure 3. Plot of River Flow (x 1000 cfs) & Water Temperature (F) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2003

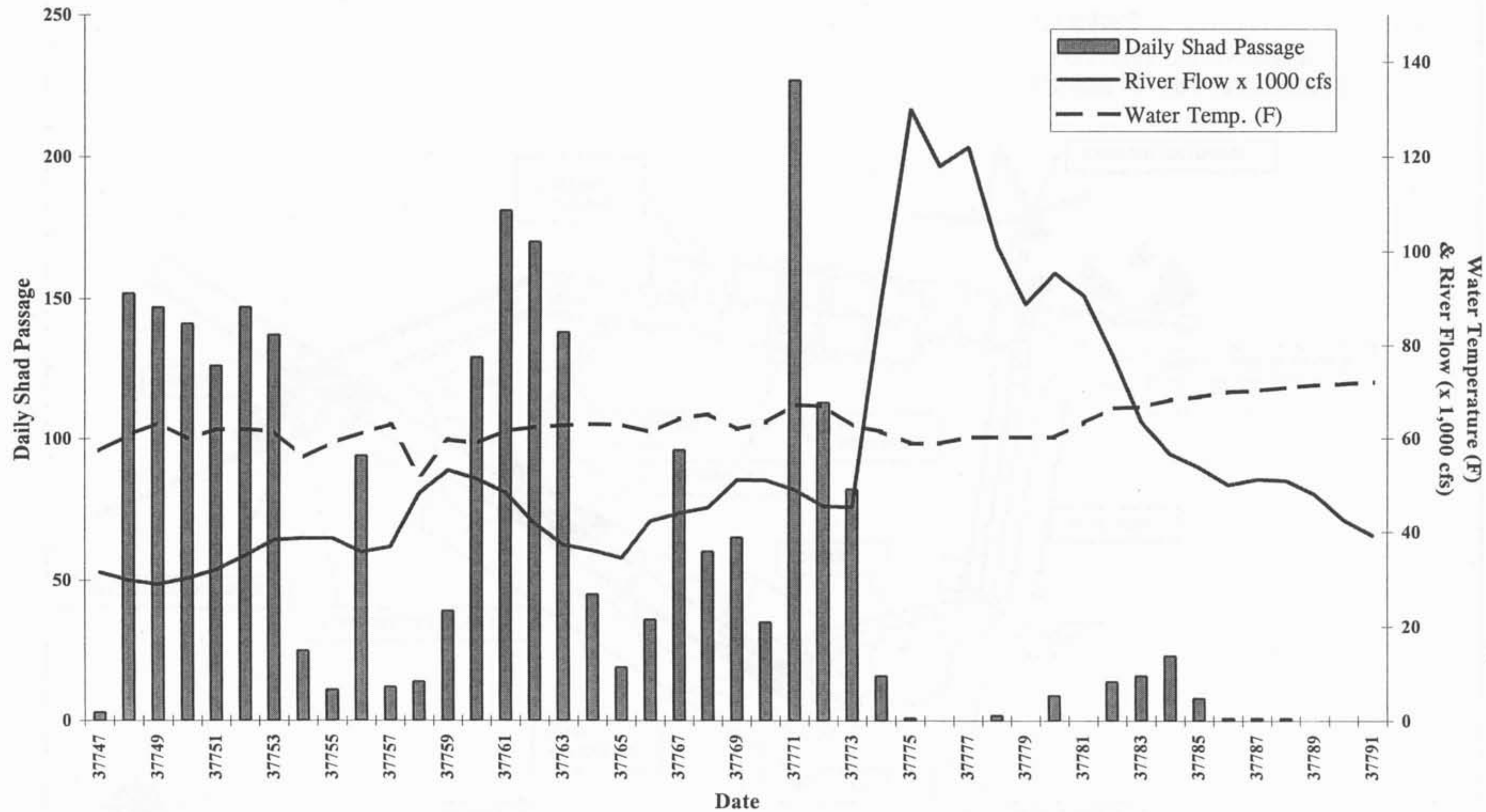


Figure 4. Plot of River Flow (x 1000 cfs) & East Channel Flow (x 1000 cfs) in Relation to the Daily American Shad Passage at the York Haven Fishway in Spring 2003

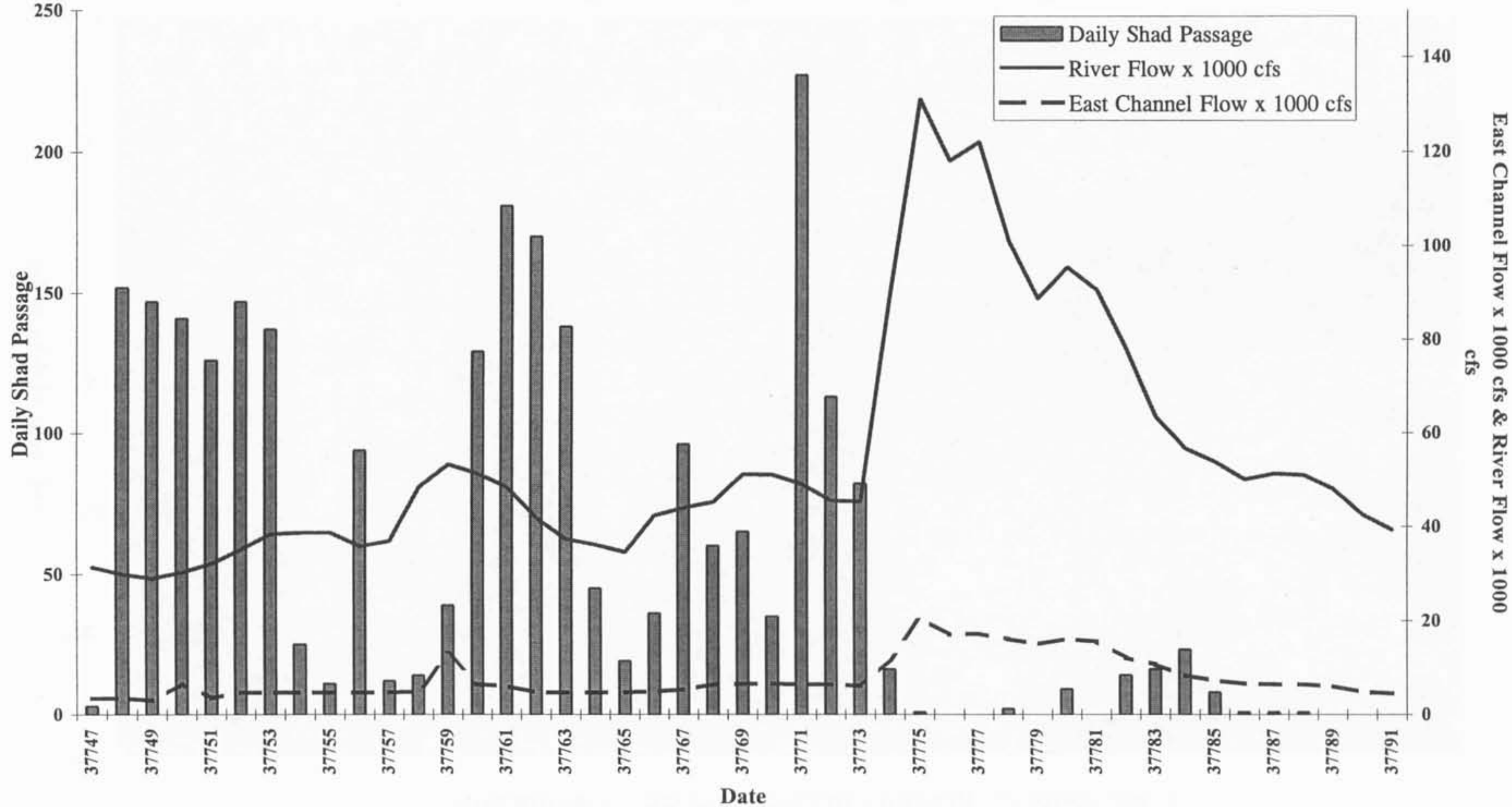


Figure 5. Plot of River Flow (x 1000 cfs),) at the USGS Harrisburg Station (#01570500) on the Susquehanna River, September through October, 2003.

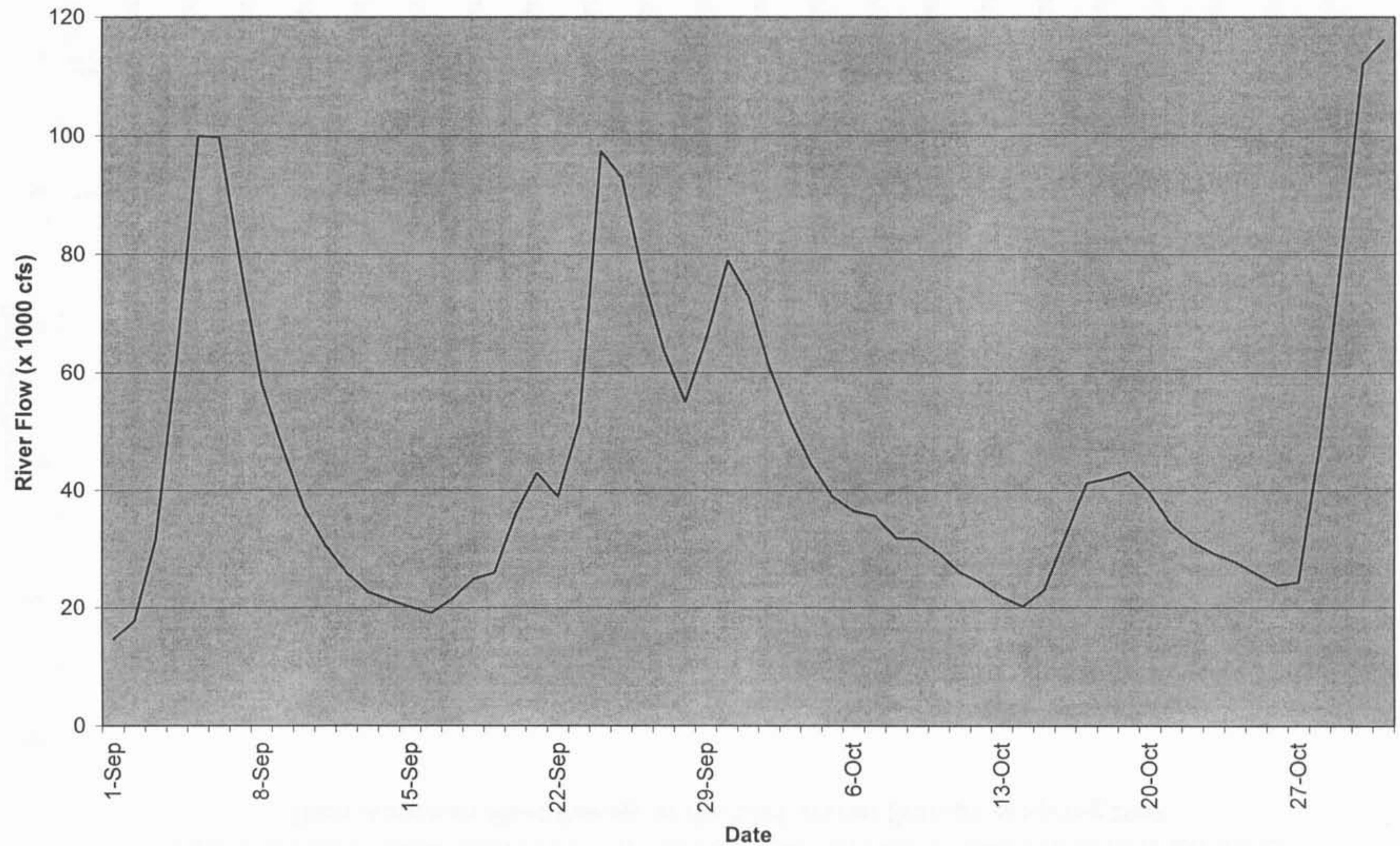


Table 1. Summary of the daily number of fish that passed by the York Haven Hydroelectric Project through the serpentine vertical notch ladder at the East Channel Dam in 2003.

Date	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May
Observation Time	6.5	10.0	10.0	10.0	10.0	8.5	10.2	6.8	6.1	8.5
Water Temperature (°F)	57.5	60.8	63.3	60.0	62.0	62.0	61.5	56.0	59.1	61.2
AMERICAN SHAD	3	152	147	141	126	147	137	25	11	94
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	2091	6345	4,388	4,126	3,868	2,725	5,651	2,438	1,804	3,176
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	1	1	3	2	2	0	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	3	0	0	0	1	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	1	0
MUSKELLUNGE	0	0	1	0	0	1	0	0	0	0
CARP	18	423	297	103	71	92	96	22	0	20
QUILLBACK	10	191	1,272	207	235	238	339	8	4	135
WHITE SUCKER	20	94	74	63	37	17	33	4	5	6
SHORTHEAD REDHORSE	43	460	563	481	502	368	197	62	25	134
WHITE CATFISH	0	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	1	0	0	0	0	0	0	0
CHANNEL CATFISH	2	529	248	227	373	379	255	64	23	33
ROCK BASS	0	0	0	0	1	0	0	0	0	0
REDBREAST SUNFISH	0	0	0	0	0	0	0	0	0	0
GREEN SUNFISH	0	0	0	1	1	1	1	0	0	0
BLUEGILL	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	7	17	245	210	70	107	152	22	5	38
LARGEMOUTH BASS	0	0	2	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	2	63	265	579	310	339	502	180	87	233
NORTHERN HOGSUCKER	0	0	4	5	2	0	4	0	0	0
FALLFISH	0	0	14	0	0	0	0	0	0	0
Total	2,196	8,274	7,522	6,147	5,599	4,416	7,369	2,826	1,965	3,869

Table 1. Continued

Date	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May
Observation Time	6.5	6.5	12.5	10.5	11.5	8.0	15.8	14.5	8.5	9.0
Water Temperature (°F)	63.0	52.0	59.7	59.0	61.6	62.4	62.8	63.1	62.9	61.3
AMERICAN SHAD	12	14	39	129	181	170	138	45	19	36
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	1,370	1,025	1,246	3,004	10,353	5,942	5951	1,167	1,735	784
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	0	1	0	1	0	2	1	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	1	0	0	1	0	0	1
MUSKELLUNGE	0	0	0	1	0	0	1	0	0	0
CARP	2	3	7	14	50	26	32	14	3	0
QUILLBACK	12	6	21	30	273	608	129	25	17	60
WHITE SUCKER	2	5	6	13	37	26	23	9	7	3
SHORTHEAD REDHORSE	16	36	108	92	203	130	166	68	8	24
WHITE CATFISH	0	0	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	0	0	3	22	2	0	0	0	0
CHANNEL CATFISH	0	10	83	153	573	262	363	121	26	50
ROCK BASS	0	1	0	0	0	0	0	0	0	0
REDBREAST SUNFISH	0	0	0	0	0	2	0	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0	2	0
BLUEGILL	1	0	0	0	0	4	3	0	1	0
SMALLMOUTH BASS	14	5	3	23	202	211	124	22	19	3
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0
BLACK CRAPPIE	0	0	0	0	0	2	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	1	0	0	0
WALLEYE	152	69	80	260	685	634	413	198	174	90
NORTHERN HOGSUCKER	0	0	0	0	0	1	0	0	0	0
FALLFISH	0	0	0	0	0	0	0	0	0	0
Total	1,581	1,174	1,594	3,723	12,580	8,020	7,347	1,670	2,011	1,051

Table 1. Continued

Date	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun	6-Jun
Observation Time	8.5	7.0	16.0	15.0	12.5	8.0	8.5	7.0	7.0	6.0
Water Temperature (°F)	64.3	65.2	62.0	63.5	67.2	67.0	62.8	61.5	59.0	60.3
AMERICAN SHAD	96	60	65	35	227	113	82	16	1	2
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	737	1,921	1,559	1,054	5,301	4,433	2,268	1,101	470	5,959
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	0	1	0	0	2	1	4	1	0	0
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	0	0	0	0	0	0	0
BROWN TROUT	0	0	0	0	0	0	0	0	0	0
MUSKELLUNGE	1	0	1	0	1	0	0	0	0	0
CARP	16	3	5	6	34	20	14	0	1	0
QUILLBACK	196	18	145	22	295	491	127	19	1	4
WHITE SUCKER	22	24	28	4	33	18	32	6	0	1
SHORTHEAD REDHORSE	13	25	59	43	120	68	43	24	3	9
WHITE CATFISH	0	3	0	0	0	0	0	0	0	0
BROWN BULLHEAD	0	2	29	20	8	19	14	7	2	0
CHANNEL CATFISH	619	284	167	198	466	202	123	198	132	11
ROCK BASS	1	1	0	0	6	1	2	0	0	0
REDBREAST SUNFISH	0	0	0	0	0	0	1	0	0	0
GREEN SUNFISH	0	0	0	0	0	0	0	0	0	0
BLUEGILL	1	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	24	11	22	3	111	62	24	2	0	6
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	0	0	0	0	0	0	0	0	0	0
WALLEYE	210	107	106	40	294	322	246	40	2	23
NORTHERN HOGSUCKER	0	0	1	0	0	0	1	0	0	0
FALLFISH	0	0	0	0	0	0	0	0	0	0
Total	1,936	2,460	2,187	1,425	6,898	5,750	2,981	1,414	612	6,015

Table 1. Continued

Date	8-Jun	10-Jun	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	19-Jun	Total
Observation Time	6.5	6.6	7.0	7.0	7.0	4.0	4.0	4.0	4.0	319.4
Water Temperature (°F)	60.3	66.5	66.8	68.3	69.0	70.0	70.3	71.0	72.1	
AMERICAN SHAD	9	14	16	23	8	1	1	1	0	2,536
ALEWIFE	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	3,811	3,989	3,675	2,826	2,329	368	1,010	1,436	77	113,513
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	2	0	1	0	0	0	0	0	0	26
WHITE PERCH	0	0	0	0	0	0	0	0	0	0
AMERICAN EEL	0	0	0	0	0	0	0	0	0	0
RAINBOW TROUT	0	0	0	1	0	0	0	0	0	5
BROWN TROUT	1	1	0	0	0	0	0	0	0	6
MUSKELLUNGE	0	0	0	0	0	0	0	0	0	7
CARP	16	8	16	14	28	2	7	7	0	1,490
QUILLBACK	188	11	95	376	320	11	33	139	13	6,324
WHITE SUCKER	10	8	32	60	33	5	3	14	0	817
SHORTHEAD REDHORSE	41	2	17	16	20	4	5	10	0	4,208
WHITE CATFISH	0	0	0	0	0	0	0	0	0	3
BROWN BULLHEAD	0	1	4	5	2	2	0	0	0	143
CHANNEL CATFISH	42	16	84	139	159	108	60	72	12	6,866
ROCK BASS	2	1	16	3	3	1	1	3	0	43
REDBREAST SUNFISH	0	0	0	0	0	0	0	0	0	3
GREEN SUNFISH	0	0	0	0	0	0	0	0	0	6
BLUEGILL	0	1	0	0	0	0	0	0	0	11
SMALLMOUTH BASS	12	54	148	106	110	13	8	27	0	2,242
LARGEMOUTH BASS	0	0	0	0	0	0	0	0	0	2
WHITE CRAPPIE	0	1	0	1	0	0	0	0	0	2
BLACK CRAPPIE	0	0	0	0	0	0	0	0	0	2
YELLOW PERCH	0	0	0	0	0	0	0	0	0	1
WALLEYE	22	19	382	384	183	60	88	250	39	8,132
NORTHERN HOGSUCKER	0	0	0	0	0	0	0	0	0	18
FALLFISH	0	0	0	0	0	0	0	0	0	14
Total	4,156	4,126	4,486	3,954	3,195	575	1,216	1,959	141	146,420

Table 2. Summary of daily average river flow (USGS, Harrisburg Gage), average flow in the East channel, sum of average flow from power station and main dam, water temperature, secchi, stop log gate position, and East channel and fishway water elevations during operation of the York Haven fishway complex in 2003.

	River	East	Main Dam	Water				Stop	Elevation (ft)					
	Flow	Channel	Flow	Temp.	Secchi (in)			log	Head Pond			Tailwater		
Date	(cfs)	Flow (cfs)	(cfs)	(^{o}F)	Avg.	Min.	Max.	Gate	Avg.	Min.	Max.	Avg	Min.	Max.
6-May	31,700	3,500	28,200	57.5	15.0	15.0	15.0	Closed	279.5	279.5	279.6	274.5	274.4	274.6
7-May	30,767	3,500	27,267	60.8	15.0	15.0	15.0	Closed	279.5	279.5	279.5	274.5	274.5	274.5
8-May	29,400	3,000	26,400	63.3	12.0	12.0	12.0	Closed	279.4	279.4	279.4	274.5	274.5	274.5
9-May	30,300	6,500	23,800	60.0	24.0	24.0	24.0	Closed	280.3	280.2	280.5	274.5	274.5	274.6
10-May	31,967	3,500	28,467	62.0	19.2	12.0	24.0	Closed	279.5	279.5	279.5	274.7	274.7	274.8
11-May	35,067	4,700	30,367	62.0	24.0	24.0	24.0	Closed	279.8	279.8	279.8	274.8	274.8	274.8
12-May	38,300	4,700	33,600	61.5	18.0	18.0	18.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
13-May	38,767	4,700	34,067	56.0	18.0	18.0	18.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
14-May	38,833	4,700	34,133	59.1	16.3	15.0	18.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
15-May	36,317	4,700	31,617	61.2	24.0	24.0	24.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
16-May	36,383	4,700	31,683	63.0	18.0	18.0	18.0	Closed	279.8	279.8	279.8	275.0	274.9	275.0
17-May	49,533	4,900	44,633	52.0	17.1	16.0	18.0	Closed	279.9	279.8	280.0	275.5	275.2	276.0
18-May	53,467	13,000	40,467	59.7	12.0	12.0	12.0	Closed	281.3	281.3	281.3	276.0	276.0	276.0
19-May	51,917	6,400	45,517	59.0	15.1	14.0	18.0	Closed	280.2	280.2	280.2	275.8	275.8	275.8
20-May	48,850	6,000	42,850	61.6	16.2	14.0	18.0	Closed	280.1	280.0	280.2	275.7	275.7	275.8
21-May	42,450	4,700	37,750	62.4	16.4	16.0	18.0	Closed	279.8	279.8	279.9	275.5	275.4	275.6
22-May	37,600	4,700	32,900	62.8	18.0	18.0	18.0	Closed	279.8	279.8	279.8	275.0	275.1	275.0
23-May	36,683	4,700	31,983	63.1	14.3	12.0	18.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
24-May	34,533	4,700	29,833	62.9	12.0	12.0	12.0	Closed	279.8	279.8	279.8	275.0	275.0	275.0
25-May	41,700	4,900	36,800	61.3	14.0	12.0	16.0	Closed	279.9	279.9	279.9	275.3	275.3	275.3
26-May	44,100	5,300	38,800	64.3	16.0	16.0	16.0	Closed	280.0	279.9	280.0	275.6	275.5	275.6
27-May	44,817	6,400	38,417	65.2	16.0	16.0	16.0	Closed	280.2	280.2	280.2	275.5	275.5	275.5
28-May	50,650	6,500	44,150	62.0	14.4	12.0	16.0	Closed	280.3	280.2	280.3	275.9	275.9	276.0
29-May	51,017	6,500	44,517	63.5	12.4	12.0	14.0	Closed	280.3	280.3	280.3	275.9	275.9	276.0
30-May	49,500	6,400	43,100	67.2	17.4	16.0	18.0	Closed	280.2	280.2	280.2	275.7	275.7	275.7
31-May	46,050	6,400	39,650	67.0	12.0	12.0	12.0	Closed	280.2	280.2	280.2	275.5	275.5	275.5
1-Jun	47,250	6,000	41,250	62.8	12.0	12.0	12.0	Closed	280.1	280.1	280.1	275.5	275.5	275.5
2-Jun	105,575	11,600	93,975	61.5	11.0	8.0	12.0	Closed	281.0	280.8	281.3	277.4	277.1	278.0
3-Jun	131,000	20,500	110,500	59.0	10.0	10.0	10.0	Closed	282.3	282.3	282.3	279.8	279.6	280.0
6-Jun	99,275	16,000	83,275	60.3	10.0	10.0	10.0	Closed	281.7	281.6	281.7	278.8	278.7	278.9
8-Jun	95,775	16,000	79,775	60.3	10.0	10.0	10.0	Closed	281.6	281.6	281.6	278.8	278.7	278.8
10-Jun	76,450	12,000	64,450	66.5	12.0	12.0	12.0	Closed	281.1	281.0	281.2	278.8	277.7	278.8
11-Jun	63,425	10,600	52,825	66.8	14.0	14.0	14.0	Closed	280.8	280.7	280.8	277.0	276.9	277.1
12-Jun	56,075	8,250	47,825	68.3	13.1	12.0	14.0	Closed	280.5	280.5	280.5	276.3	276.3	276.4
13-Jun	53,775	7,200	46,575	69.0	10.4	6.0	12.0	Closed	280.4	280.4	280.4	276.3	276.3	276.3
14-Jun	50,625	6,500	44,125	70.0	10.0	10.0	10.0	Closed	280.3	280.3	280.3	276.0	276.0	276.0
15-Jun	51,850	6,400	45,450	70.3	8.0	8.0	8.0	Closed	280.2	280.2	280.2	275.9	275.9	275.9
16-Jun	51,000	6,400	44,600	71.0	12.0	12.0	12.0	Closed	280.2	280.2	280.2	275.3	275.3	275.3
19-Jun	39,300	4,500	34,800	72.1	14.0	14.0	14.0	Closed	279.7	279.7	279.7	275.2	275.2	275.2

Table 3. Summary of surface water elevations recorded during operation of the York Haven Fishway in 2003.

	River	Elevation (ft)																				
	Flow	Head Pond			Tailwater			Inside Fishway			Inside Weir			Above Counting Room			Below Fixed Wheel Gate			Counting Room		
Date	(cfs)	Avg.	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.	Avg	Min.	Max.
6-May	31,700	279.5	279.5	279.6	274.5	274.4	274.6	275.8	275.3	276.0	277.7	277.6	277.7	279.4	279.4	279.4	277.5	277.5	277.5	279.3	279.3	279.4
7-May	30,767	279.5	279.5	279.5	274.5	274.5	274.5	275.1	275.1	275.2	277.7	277.6	277.8	279.3	279.3	279.4	277.5	277.5	277.6	279.3	279.3	279.3
8-May	29,400	279.4	279.4	279.4	274.5	274.5	274.5	275.2	275.2	275.2	277.6	277.6	277.6	279.3	279.3	279.3	277.4	277.4	277.4	279.2	279.2	279.2
9-May	30,300	280.3	280.2	280.5	274.5	274.5	274.6	275.2	275.1	275.2	277.5	277.5	277.8	279.3	279.3	279.3	277.5	277.4	277.6	279.2	279.1	279.3
10-May	31,967	279.5	279.5	279.5	274.7	274.7	274.8	275.2	275.2	275.3	277.7	277.6	277.8	279.4	279.3	279.4	277.6	277.6	277.6	279.3	279.3	279.4
11-May	35,067	279.8	279.8	279.8	274.8	274.8	274.8	275.5	275.5	275.5	277.8	277.8	277.8	279.5	279.5	279.5	277.8	277.8	277.8	279.5	279.5	279.5
12-May	38,300	279.8	279.8	279.8	275.0	275.0	275.0	275.6	275.6	275.6	277.9	277.9	277.9	279.7	279.6	279.7	277.6	277.6	277.6	279.5	279.5	279.6
13-May	38,767	279.8	279.8	279.8	275.0	275.0	275.0	275.6	275.6	275.6	278.0	277.9	278.1	279.6	279.6	279.7	277.6	277.6	277.6	279.6	279.6	279.6
14-May	38,833	279.8	279.8	279.8	275.0	275.0	275.0	275.5	275.5	275.5	277.9	277.9	278.0	279.7	279.6	279.7	277.6	277.6	277.7	279.5	279.5	279.6
15-May	36,317	279.8	279.8	279.8	275.0	275.0	275.0	275.5	275.5	275.5	277.9	277.9	277.9	279.6	279.5	279.6	277.8	277.8	277.8	279.5	279.4	279.5
16-May	36,383	279.8	279.8	279.8	275.0	274.9	275.0	275.5	275.4	275.5	278.0	277.9	278.0	279.5	279.4	279.5	277.8	277.8	277.8	279.4	279.3	279.5
17-May	49,533	279.9	279.8	280.0	275.5	275.2	276.0	275.8	275.5	279.9	278.7	279.2	279.1	279.9	279.7	280.1	277.8	277.7	277.9	279.7	279.7	279.8
18-May	53,467	281.3	281.3	281.3	276.0	276.0	276.0	276.5	276.6	276.5	278.4	278.4	278.5	280.2	280.2	280.2	278.2	278.2	278.2	280.0	280..0	280.2
19-May	51,917	280.2	280.2	280.2	275.8	275.8	275.8	276.3	276.3	276.3	278.3	278.2	278.3	280.1	280.1	280.1	277.0	277.9	280.0	279.9	279.9	279.9
20-May	48,850	280.1	280.0	280.2	275.7	275.7	275.8	276.2	276.2	276.3	278.2	278.2	278.3	280.1	280.0	280.1	278.0	277.9	280.0	279.8	279.7	279.8
21-May	42,450	279.8	279.8	279.9	275.5	275.4	275.6	276.0	275.9	276.1	278.1	278.1	278.1	279.8	279.8	279.9	277.8	277.8	277.8	279.6	279.5	279.8
22-May	37,600	279.8	279.8	279.8	275.0	275.1	275.0	275.6	275.6	275.6	278.0	278.0	278.0	279.6	279.6	279.6	277.8	277.8	277.8	279.3	279.3	279.3
23-May	36,683	279.8	279.8	279.8	275.0	275.0	275.0	275.6	275.6	275.7	278.0	278.0	278.0	279.6	279.6	279.6	277.8	277.7	277.8	279.3	279.3	279.3
24-May	34,533	279.8	279.8	279.8	275.0	275.0	275.0	275.5	275.4	275.6	278.0	278.0	278.0	279.4	279.4	279.4	277.6	277.6	277.6	279.3	279.3	279.3
25-May	41,700	279.9	279.9	279.9	275.3	275.3	275.3	275.8	275.8	275.9	278.0	277.9	278.0	279.8	279.7	279.8	277.8	277.7	277.8	275.5	275.5	275.5
26-May	44,100	280.0	279.9	280.0	275.6	275.5	275.6	276.1	276.0	276.1	278.1	278.1	278.1	279.9	279.9	278.0	277.9	277.9	277.9	279.7	279.7	279.9
27-May	44,817	280.2	280.2	280.2	275.5	275.5	275.5	276.0	276.0	276.0	278.2	278.2	278.2	280.0	280.0	280.0	278.0	278.0	278.0	279.6	279.6	279.8
28-May	50,650	280.3	280.2	280.3	275.9	275.9	276.0	276.4	276.4	276.5	278.4	278.3	278.4	280.1	280.1	280.1	278.0	278.0	278.1	280.0	280.0	280.1
29-May	51,017	280.3	280.3	280.3	275.9	275.9	276.0	276.4	276.4	276.5	278.3	278.3	278.4	280.1	280.1	280.1	278.0	278.0	278.0	280.0	280.0	280.0
30-May	49,500	280.2	280.2	280.2	275.7	275.7	275.7	276.2	276.2	276.2	278.3	278.3	278.3	280.1	280.1	280.1	278.0	278.0	278.0	279.9	279.9	280.0
31-May	46,050	280.2	280.2	280.2	275.5	275.5	275.5	276.0	276.0	276.0	278.2	278.2	278.2	280.0	280.0	280.0	278.0	278.0	278.0	279.9	279.9	279.9
1-Jun	47,250	280.1	280.1	280.1	275.5	275.5	275.5	276.0	276.0	276.0	278.0	278.0	278.0	280.0	280.0	280.0	278.0	278.0	278.0	279.9	279.9	279.9
2-Jun	105,575	281.0	280.8	281.3	277.4	277.1	278.0	276.0	276.0	276.0	278.0	278.0	278.0	280.0	280.0	280.0	278.0	278.0	278.0	279.9	279.9	279.9
3-Jun	131,000	282.3	282.3	282.3	279.8	279.6	280.0	277.9	277.6	278.5	279.3	278.7	280.2	280.7	280.5	281.1	278.8	278.5	279.5	280.7	280.5	281.0
6-Jun	99,275	281.7	281.6	281.7	278.8	278.7	278.9	280.2	280.0	280.5	279.7	279.7	279.7	282.2	282.2	282.2	280.3	280.2	280.4	282.1	282.1	282.1
8-Jun	95,775	281.6	281.6	281.6	278.8	278.7	278.8	279.3	279.2	279.3	279.6	279.6	279.6	281.5	281.5	281.5	279.4	279.3	279.4	281.4	281.4	281.4
10-Jun	76,450	281.1	281.0	281.2	278.8	277.7	278.8	278.3	278.2	278.4	279.0	278.9	279.0	281.0	280.9	281.1	278.7	278.6	278.7	280.9	280.9	280.9
11-Jun	63,425	280.8	280.7	280.8	277.0	276.9	277.1	277.5	277.4	277.6	278.4	278.3	278.5	280.6	280.6	280.6	278.3	278.3	278.3	280.6	280.5	280.6
12-Jun	56,075	280.5	280.5	280.5	276.3	276.3	276.4	276.8	276.8	276.9	278.4	278.4	278.4	280.3	280.3	280.3	278.0	278.0	278.1	280.2	280.2	280.3
13-Jun	53,775	280.4	280.4	280.4	276.3	276.3	276.3	276.8	276.8	276.9	278.4	278.4	278.4	280.3	280.3	280.3	278.0	278.0	278.0	280.2	280.2	280.2
14-Jun	50,625	280.3	280.3	280.3	276.0	276.0	276.0	276.5	276.5	276.5	278.2	278.2	278.2	280.1	280.1	280.2	280.3	280.3	280.3	280.0	280.0	280.0
15-Jun	51,850	280.2	280.2	280.2	275.9	275.9	275.9	276.4	276.4	276.4	278.0	278.0	278.0	280.2	280.2	280.2	278.0	278.0	278.0	279.9	279.9	279.9
16-Jun	51,000	280.2	280.2	280.2	275.3	275.3	275.3	275.9	275.9	275.9	278.4	278.4	278.4	280.0	280.0	280.0	278.0	278.0	278.0	280.0	280.0	280.0
19-Jun	39,300	279.7	279.7	279.7	275.2	275.2	275.2	275.7	275.7	275.7	278.0	278.0	278.0	279.6	279.6	279.6	277.7	277.7	277.7	279.6	279.6	279.6

Table 4. Hourly summary of American shad passage through the sepentine vertical notch fish ladder at the York Haven Hydroelectric Project in 2003.

Date	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May
Observation Time (Start)	0901	0801	0800	0815	0801	0815	0801	0815	0813	0800
Observation Time (End)	1500	1900	1900	1800	1800	1700	1900	1500	1500	1700
Military Time (HRS)										
0000 - 0059										
0100 - 0159										
0200- 0259										
0300 - 0359										
0400 - 0459										
0500 - 0559										
0600 - 0659										
0700 - 0759										
0800 - 0859		3	11	21	10	41	19	2	-	12
0900 - 0959	-	-	23	18	11	19	17	5	1	9
1000 - 1059	2	-	16	15	8	12	11	3	2	16
1100 - 1159	1	10	15	33	18	26	11	3	-	19
1200 - 1259	-	19	21	15	13	17	27	4	1	7
1300 - 1359	-	5	15	13	11	6	11	5	3	1
1400 - 1459	-	14	6	10	18	15	17	3	4	15
1500 - 1559		33	6	6	21	7	5			13
1600 - 1659		28	20	6	12	4	6			2
1700 - 1759		25	8	4	4		5			
1800 - 1859		15	6				8			
1900 - 1959										
2000 - 2059										
2100 - 2159										
2200 - 2259										
2300 - 2359										
Total Catch	**3**	**152**	**147**	**141**	**126**	**147**	**137**	**25**	**11**	**94**

Table 4. Continued

Date	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May
Observation Time (Start)	0810	0801	0601	0801	0600	0800	0800	0000	0625	0801
Observation Time (End)	1500	1500	1900	1900	1800	1700	2400	1500	1500	1500
Military Time (HRS)										
0000 - 0059								-		
0100 - 0159								-		
0200- 0259								-		
0300 - 0359								-		
0400 - 0459								1		
0500 - 0559								2		
0600 - 0659			2		27			6	6	3
0700 - 0759			1		19			7	2	3
0800 - 0859	4	1	-	5	23	33	49	2	1	2
0900 - 0959	-	1	-	7	18	17	22	4	-	5
1000 - 1059	3	6	2	5	31	15	21	6	-	10
1100 - 1159	4	2	4	8	24	31	15	3	2	7
1200 - 1259	-	2	6	19	9	19	5	5	5	1
1300 - 1359	-	-	2	16	6	26	9	6	1	1
1400 - 1459	1	2	-	5	4	19	1	3	2	4
1500 - 1559			8	18	11	6	8			
1600 - 1659			5	15	7	4	4			
1700 - 1759			5	10	2		-			
1800 - 1859			4	21			2			
1900 - 1959							1			
2000 - 2059							1			
2100 - 2159							-			
2200 - 2259							-			
2300 - 2359							-			
Total Catch	12	14	39	129	181	170	138	45	19	36

Table 4. Continued

Date	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	3-Jun	6-Jun
Observation Time (Start)	0800	0900	0800	0000	0600	0800	0605	0800	0800	0900
Observation Time (End)	1700	1600	2400	1500	1900	1600	1500	1500	1500	1500
Military Time (HRS)										
0000 - 0059				-						
0100 - 0159				-						
0200- 0259				-						
0300 - 0359				-						
0400 - 0459				-						
0500 - 0559				-						
0600 - 0659				2	38		22			
0700 - 0759				4	6		5			
0800 - 0859	18		19	1	36	48	4	8	-	-
0900 - 0959	6	22	5	5	29	14	3	1	1	-
1000 - 1059	4	6	4	2	31	6	13	-	-	2
1100 - 1159	12	4	9	5	23	15	5	5	-	-
1200 - 1259	13	15	5	10	24	4	16	1	-	-
1300 - 1359	15	3	8	2	4	16	11	1	-	-
1400 - 1459	17	9	4	4	11	8	3	-	-	-
1500 - 1559	8	1	7		7	2				
1600 - 1659	3		-		5					
1700 - 1759			1		5					
1800 - 1859			1		8					
1900 - 1959			2							
2000 - 2059			-							
2100 - 2159			-							
2200 - 2259			-							
2300 - 2359			-							
Total Catch	**96**	**60**	**65**	**35**	**227**	**113**	**82**	**16**	**1**	**2**

Table 4. Continued

Date	8-Jun	10-Jun	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	19-Jun	
Observation Time (Start)	0835	0822	0800	0800	0800	0800	0800	0800	0800	
Observation Time (End)	1500	1500	1500	1500	1200	1200	1200	1200	1200	TOTAL
Military Time (HRS)										
0000 - 0059										0
0100 - 0159										0
0200- 0259										0
0300 - 0359										0
0400 - 0459										1
0500 - 0559										2
0600 - 0659										106
0700 - 0759										47
0800 - 0859	2	1	8	16	7	1	-	1	-	409
0900 - 0959	3	-	1	1	1	-	1	-	-	270
1000 - 1059	1	4	1	3	-	-	-	-	-	261
1100 - 1159	-	1	1	1	-	-	-	-	-	317
1200 - 1259	1	3	1	-	-					288
1300 - 1359	1	3	1	1						203
1400 - 1459	1	2	3	1						206
1500 - 1559										167
1600 - 1659										121
1700 - 1759										69
1800 - 1859										65
1900 - 1959										3
2000 - 2059										1
2100 - 2159										0
2200 - 2259										0
2300 - 2359										0
										0
Total Catch	9	14	16	23	8	1	1	1	0	2536

Table 5. Hourly summary (number and percentage) of American shad passage through the serpentine vertical notch fish ladder at the York Haven Hydroelectric Project, 18 May through 3 June, 2003.

Date	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May	1-Jun	2-Jun	TOTAL	
Observation Time (Start)	0601	0801	0600	0800	0800	0000	0625	0801	0800	0900	0800	0000	0600	0800	0605	0800		
Observation Time (End)	1900	1900	1800	1700	2400	1500	1500	1500	1700	1600	2400	1500	1900	1600	1500	1500	#	%
Military Time (HRS)																		
0000 - 0059						(0.0%)						(0.0%)					0	0.0%
0100 - 0159						(0.0%)						(0.0%)					0	0.0%
0200- 0259						(0.0%)						(0.0%)					0	0.0%
0300 - 0359						(0.0%)						(0.0%)					0	0.0%
0400 - 0459						1 (2.2%)						(0.0%)					1	0.1%
0500 - 0559						2 (4.4%)						(0.0%)					2	0.1%
0600 - 0659	2 (5.1%)		27 (14.9%)			6 (13.3%)	6 (31.6%)	3 (8.3%)				2 (5.7%)	38 (16.7%)		22 (26.8%)		106	7.6%
0700 - 0759	1 (2.6%)		19 (10.5%)			7 (15.6%)	2 (10.5%)	3 (8.3%)				4 (11.4%)	6 (2.6%)		5 (6.1%)		47	3.4%
0800 - 0859	(0.0%)	5 (3.9%)	23 (12.7%)	33 (19.4%)	49 (35.5%)	2 (4.4%)	1 (5.3%)	2 (5.6%)	18 (18.8%)		19 (29.2%)	1 (2.9%)	36 (15.9%)	48 (42.5%)	4 (4.9%)	8 (50.0%)	249	17.9%
0900 - 0959	(0.0%)	7 (5.4%)	18 (9.9%)	17 (10.0%)	22 (15.9%)	4 (8.9%)	(0.0%)	5 (13.9%)	6 (6.3%)	22 (36.7%)	5 (7.7%)	5 (14.3%)	29 (12.8%)	14 (12.4%)	3 (3.7%)	1 (6.3%)	136	9.8%
1000 - 1059	2 (5.1%)	5 (3.9%)	31 (17.1%)	15 (8.8%)	21 (15.2%)	6 (13.3%)	(0.0%)	10 (27.8%)	4 (4.2%)	6 (10.0%)	4 (6.2%)	2 (5.7%)	31 (13.7%)	6 (5.3%)	13 (15.9%)	(0.0%)	150	10.8%
1100 - 1159	4 (10.3%)	8 (6.2%)	24 (13.3%)	31 (18.2%)	15 (10.9%)	3 (6.7%)	2 (10.5%)	7 (19.4%)	12 (12.5%)	4 (6.7%)	9 (13.8%)	5 (14.3%)	23 (10.1%)	15 (13.3%)	5 (6.1%)	5 31.3%)	168	12.1%
1200 - 1259	6 (15.4%)	19 (14.7%)	9 (5.0%)	19 (11.2%)	5 (3.6%)	5 (11.1%)	5 (26.3%)	1 (2.8%)	13 (13.5)	15 (25.0%)	5 (7.7%)	10 (28.6%)	24 (10.6%)	4 (3.5%)	16 (19.5%)	1 (6.3%)	142	10.2%
1300 - 1359	2 (5.1%)	16 (12.4%)	6 (3.3%)	26 (15.3%)	9 (6.5%)	6 (13.3%)	1 (5.3%)	1 (2.8%)	15 (15.6%)	3 (5.0%)	8 (12.3%)	2 (5.7%)	4 (1.8%)	16 (14.2%)	11 (13.4%)	1 (6.3%)	124	8.9%
1400 - 1459	(0.0%)	5 (3.9%)	4 (2.2%)	19 (11.2%)	1 (0.7%)	3 (6.7%)	2 (10.5%)	4 (11.1%)	17 (17.7%)	9 (15.0%)	4 (6.2%)	4 (11.4%)	11 (4.8%)	8 (7.1%)	3 (3.7%)	(0.0%)	85	6.1%
1500 - 1559	8 (20.5%)	18 (14.0%)	11 (6.1%)	6 (3.5%)	8 (5.8%)				8 (8.3%)	1 (1.7%)	7 (10.8%)		7 (3.1%)	2 (1.8%)			75	5.4%
1600 - 1659	5 (12.8%)	15 (11.6%)	7 (3.9%)	4 (2.4%)	4 (2.9%)				3 (3.1%)		(0.0%)		5 (2.2%)				43	3.1%
1700 - 1759	5 (12.8%)	10 (7.8%)	2 (1.1%)		(0.0%)						1 (1.5%)		5 (2.2%)				23	1.7%
1800 - 1859	4 (10.3%)	21 (16.3%)			2 (1.4%)						1 (1.5%)		8 (3.5%)				36	2.6%
1900 - 1959					1 (0.7%)						2 (3.1%)						3	0.2%
2000 - 2059					1 (0.7%)						(0.0%)						1	0.1%
2100 - 2159					(0.0%)						(0.0%)						0	0.0%
2200 - 2259					(0.0%)						(0.0%)						0	0.0%
2300 - 2359					(0.0%)						(0.0%)						0	0.0%
																	0	0.0%
Total Catch	39	129	181	170	138	45	19	36	96	60	65	35	227	113	82	16	1391	100.0%

Job II - Part 1

THE AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 2003

THE WYATT GROUP, INC.
1853 William Penn Way
P.O. Box 4423
Lancaster, PA 17604
(717) 569-6440

INTRODUCTION

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

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. is contracted to capture ripe adult shad on the spawning grounds during spawning activity, artificially fertilize the eggs, and deliver them to the hatchery. The objective in 2003 was to deliver 10 to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Since the early 1970's more than 500 million eggs have been obtained as part of the Susquehanna River anadromous fish restoration program. Annual production has ranged from 11 to 52 million eggs per year. The highest production was from the Columbia River, Oregon, which was discontinued in 1989. All subsequent egg collection efforts have been made on the East Coast. Since 1989, the primary rivers used have been the Delaware and Hudson rivers (Table 1).

COLLECTING METHODS AND SCHEDULES

Each collecting crew was assigned to a boat equipped with gill nets and the gear required for artificial fertilization and packing of shad eggs. When warranted, they fished simultaneously. Monofilament gill nets were of 4.0 to 5.5 inch meshes, up to 600 feet long and 8 feet deep. Nets with larger mesh size were used primarily to capture female shad while the smaller mesh nets were used to capture male shad. Each crew set some 900 to 1200 feet of net. Gill nets were mainly anchored at a site and tended regularly after being set, or occasionally drifted and tended after an approximately 30-45 minute drift. Fishing commenced just before dusk and continued until ripe shad were no longer caught. Generally, this was from about 7:00 PM to 1:00 AM. The only collection site in 2003 was Coxsackie.

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

All netting is done in tidal areas. The impact of tidal conditions, although mostly affecting netting efficiency at certain sites, influences the availability of ripe shad. On the Hudson River spawning shad are especially vulnerable to gill netting on the flats and along the shore during the period when the tide changes from ebb to flood. Tide tables were used to decide when gill netting would be most effective at selected sites. At Cheviot and Glasco the depth at the shoreline prevents the setting of gill nets at ebb tide. At Coxsackie the water depth is variable (4-10 feet) and gill nets could be set at any tide stage.

PROCESSING AND DELIVERY OF SHAD EGGS

The proper handling of shad and eggs in the field is crucial to egg viability. All processing was done on board the boat and only running ripe females were used. Eggs from 4-6 ripe shad were gently squeezed into a dry collecting pan. Sperm was taken only when eggs were ready to be fertilized. Eggs were fertilized with sperm from up to six males; but preferably, a ratio of one male to three female shad was used in the fertilization process. Eggs and sperm were taken from fewer fish, if the preferred number was not available, to assure that only live fish were used.

Sperm and eggs were dry mixed for about one minute followed by addition of a small amount of water to activate the sperm and ensure fertilization. After several minutes, eggs were washed repeatedly to remove excess sperm, unfertilized and broken eggs, scales, and blood. Eggs were then placed in large plastic buckets with at least 10 gallons of clean river water and allowed to harden for at least two hours before packaging. Hardened eggs were filtered into doubled plastic bags, five liters of eggs with five liters of clean river water. At least 2 liters of pure oxygen was injected into the bag, which were then secured with castrating rings. When ready for shipment, the bags were placed into coolers and labeled with river location, date of collection, quantity of eggs and water temperature.

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

RESULTS AND DISCUSSION

The first crew began sampling on May 5. Both crews sampled beginning on May 6. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on May 31 when water temperature reached 61°F. Sampling occurred on 23 dates during this period including 44 boat-days of gill netting. Haul seining was not used during the 2003 shad-fishing season.

A total of 17.1 million eggs were shipped to the Van Dyke Hatchery (Table 2). Hudson River Egg collection in 2003 did not exceed that of 1999 when 21.1 million eggs was taken. The goal of 60-70% viability was exceeded with an average of 68.5% and a range from 13.6% to 86.3% in individual shipments. Weather conditions did not have any impact on egg collection in 2003 despite record rainfall during the month of May. Water temperature increased gradually contributing, in part, to consistent collection of eggs.

SUMMARY

A total of 17.1 million American shad eggs were collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 2003. The number of eggs collected was slightly less than 2002 when 18.3 million eggs were taken. This success is attributed in part to favorable weather and water temperature conditions over an extended period of time. The use of two independent boat crews increased the probability of capturing sufficient bucks to fertilize the eggs obtained by the combined effort. Egg viability averaged 68.5%, exceeding the goal of 60-70% established by the PFBC.

TABLE 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson Rivers and delivered to the Van Dyke Hatchery, 1983-2003.

Year	Delaware	Hudson	Totals
1983	2.40	1.17	3.57
1984	2.64	-	2.64
1985	6.16	-	6.16
1986	5.86	-	5.86
1987	5.01	-	5.01
1988	2.91	-	2.91
1989	5.96	11.18	17.14
1990	13.15	14.53	27.68
1991	10.74	17.66	28.40
1992	9.60	3.00	12.60
1993	9.30	2.97	12.27
1994	10.27	6.29	16.56
1995	10.75	11.85	22.60
1996	8.31	5.69	14.00
1997	11.76	11.08	22.84
1998	10.34	15.72	26.06
1999	5.49	21.00	26.49
2000	3.83	16.40	20.23
2001	6.35	3.90	10.25
2002	2.04	18.51	20.55
2003	3.61	17.12	20.74
Totals	146.48	178.07	324.56

TABLE 2. Collection data for American shad eggs, Hudson River, 2003.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability
5-May	Coxsackie	14.6	366,852	8	56	13.6
6-May	Coxsackie	44.9	1,196,141	10	56	62.6
7-May	Coxsackie	24.5	601,180	11	56	56.1
8-May	Coxsackie	56.8	1,495,698	13	56	62.4
10-May	Coxsackie	82.6	2,075,476	15	56	59.3
11-May	Coxsackie	41.2	1,229,676	16	55	58.6
12-May	Coxsackie	46.5	1,326,866	18	56	73.0
13-May	Coxsackie	30.0	780,831	21	56	69.5
14-May	Coxsackie	38.9	954,526	24	56	70.5
15-May	Coxsackie	4.5	126,958	26	56	78.6
17-May	Coxsackie	27.9	726,173	29	56	78.5
18-May	Coxsackie	35.3	908,095	31	57	74.4
19-May	Coxsackie	20.7	570,835	34	57	85.0
20-May	Coxsackie	19.1	526,713	37	57	85.3
21-May	Coxsackie	33.6	874,531	40	59	72.3
22-May	Coxsackie	14.3	394,345	43	59	78.9
24-May	Coxsackie	32.9	856,312	45	59	74.9
25-May	Coxsackie	23.2	603,843	46	59	75.2
26-May	Coxsackie	7.9	243,764	47	60	80.4
27-May	Coxsackie	17.0	548,041	49	60	82.4
28-May	Coxsackie	14.4	401,667	53	60	84.3
29-May	Coxsackie	8.8	259,731	55	60	68.2
31-May	Coxsackie	1.6	52,710	58	62	86.3
Totals		645.3	17,120,964	23	57.6	68.5

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 2003

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

Introduction

A key element in the restoration of American shad to areas above dams in the Susquehanna, Lehigh and Schuylkill Rivers is the stocking of hatchery-reared larvae. These larvae imprint to the tributary/river reach in which they are stocked and return to spawn 3 to 6 years later. Hatchery production of larvae is dependant upon reliable sources of good quality eggs. Cost-effective collection of eggs requires intensive sampling efforts in well documented spawning areas where ripe brood fish are abundant.

The Delaware River was first used as a source of American shad eggs in 1973. Between 1973 and 1975, some 1.6 million eggs were collected from the Delaware River and stocked (as eggs) into the Schuylkill River. In 1976, the Lehigh and Schuylkill Rivers each received 80,000 eggs from the Delaware source. The Susquehanna River received its first fry from the Delaware River in 1976 when the surviving larvae from 1.5 million eggs were stocked. Collections of shad eggs from the Delaware River were discontinued from 1977 to 1982. In 1983, egg collection resumed, and has continued annually to the present. The goal of this activity in 2003, as in past years, was to collect and ship up to 15 million American shad eggs.

Methods

Brood fish were captured in gill nets set in the Delaware River at Martins Creek (RM 194) or Smithfield Beach (RM 218). In past years, Ecology III of Berwick, PA provided a boat, equipment and labor support to assist the PFBC Area Fisheries Manager and his staff stationed at Bushkill, PA. In 2000 through 2003, however, the Ecology III contract was not renewed (due to termination of funding) and the PFBC Area Fisheries Manager and his staff completed egg collection without the assistance of Ecology III. Six to fourteen 200-foot gill nets were set per night with mesh sizes ranging from 4.5 to 6.0 inches (stretch). Nets were anchored on the upstream end and allowed to fish parallel to shore in a concentrated array. Netting began at dusk and, on a typical evening; shad were picked from the nets two or three times before retrieving them at midnight. Both male and female shad were placed into water-filled tubs and returned to shore. Eggs were stripped from ripe female shad and fertilized in dry pans with sperm from ripe males. Once gametes were mixed, a small amount of fresh water was added to activate the sperm and they were allowed to stand for five minutes, followed by several washings. Cleaned fertilized eggs were then placed into floating boxes with fine mesh sides and bottom. Directional fins were added to the mesh areas to further promote a continuous flushing with fresh river water. Eggs were water-hardened for about one hour.

Water- hardened shad eggs were removed from the floating boxes and placed into buckets where excess water was decanted. Eggs were then gently scooped into large, double-lined plastic bags – about 3 liters of eggs and 3 to 5 liters of fresh water. Medical-grade oxygen was bubbled into the bags to super-saturation and they were sealed with rubber castration rings. Bags were then placed into coolers and transported by truck 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

After spawning the shad, catch data was recorded for all shad including gillnet mesh size, sex, length (total and fork) and weight. Representative samples of each night's catch of both sexes were collected for scale and otolith analysis. Ovaries from females in various stages of development (immature to spawned-out) were also removed and weighed. Most adult shad did not survive the rigors of netting and artificial spawning and it was necessary to properly dispose of the carcasses. The National Park Service provided a disposal pit on park property and shad carcasses were delivered there each night and covered with hydrated lime.

Results and Discussion

Table 1 summarizes daily Delaware River shad egg collections during May 2003. American shad spawning operations commenced on May 8, when river flow was 6,050 cfs (USGS gauge at Montague, NJ), and river temperature was 15.5° C (59.9° F). Egg take ended on May 29, when river flow was 5,260 cfs and temperature was 16.4° C (61.5° F). The 2003 egg-take operation was conducted during a window of moderate flow and temperature conditions (Figure 1, Table 1). After relatively good collecting conditions on May 28 and 29, a rain event resulted in peaking flow conditions on June 1 and 2 and operations were terminated for the year. All of the successful egg collections occurred when flow was near or below 62-year median flows (Figure 1). Water temperature remained in the ideal range for shad spawning for the entire collection period.

Nets were set on 14 nights with 12-14 nets set on each night except for the first night at Martins Creek, when only 6 nets were set. The usual number of nets set per mesh size (stretch, inch) each night was: 4.50- 2-3 each; 4.75- 1 each; 5.00- 5 each; 5.25- 1 each; 5.50- 1 each; 5.75- 1 each; and 6.00- 2 each. On May 8, number of nets set per mesh size (stretch, inch) was: 4.50- 2 each; 5.00- 2 each; 5.50- 1 each; 5.75- 1 each.

A total of 569 adult American shad were caught (Table 1). Nightly catches ranged from 9 to 85 shad. Sex ratio (male to female) was 0.87:1. From 1983 to 2003, 143 million American shad eggs were collected from the Delaware River. From those eggs, some 29 million larvae have been stocked in the Susquehanna River, 14.2 million in the Lehigh River and 3.8 million in the Schuylkill River.

Summary

Shad eggs were collected and shipped on 13 of the 14 nights that were fished from 8 May through 29 May 2003. During this time, 569 adult shad were captured and 118 liters of eggs were shipped for a hatchery count of 3.6 million eggs. Overall, the percent viability of eggs was 62%.

References

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

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

Hendricks, M. L. 2001. Collection of American shad eggs from the Delaware River, 2000. Pp. 2-9 to 2-15 *IN* Restoration of American shad to the Susquehanna River, 2000 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2001).

Hendricks, M. L. 2002. Collection of American shad eggs from the Delaware River, 2001. Pp. 2-9 to 2-15 *IN* Restoration of American shad to the Susquehanna River, 2001 Annual

Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2002).

Hendricks, M. L. and D. A Arnold. 2003. Collection of American shad eggs from the Delaware River, 2002. Pp. 2-8 to 2-13 *IN* Restoration of American shad to the Susquehanna River, 2002 Annual Progress Report, Susquehanna River Anadromous Fish Restoration Committee, Harrisburg, PA (February, 2003).

Figure 1. American shad egg collections and flow, Delaware River, 2003.

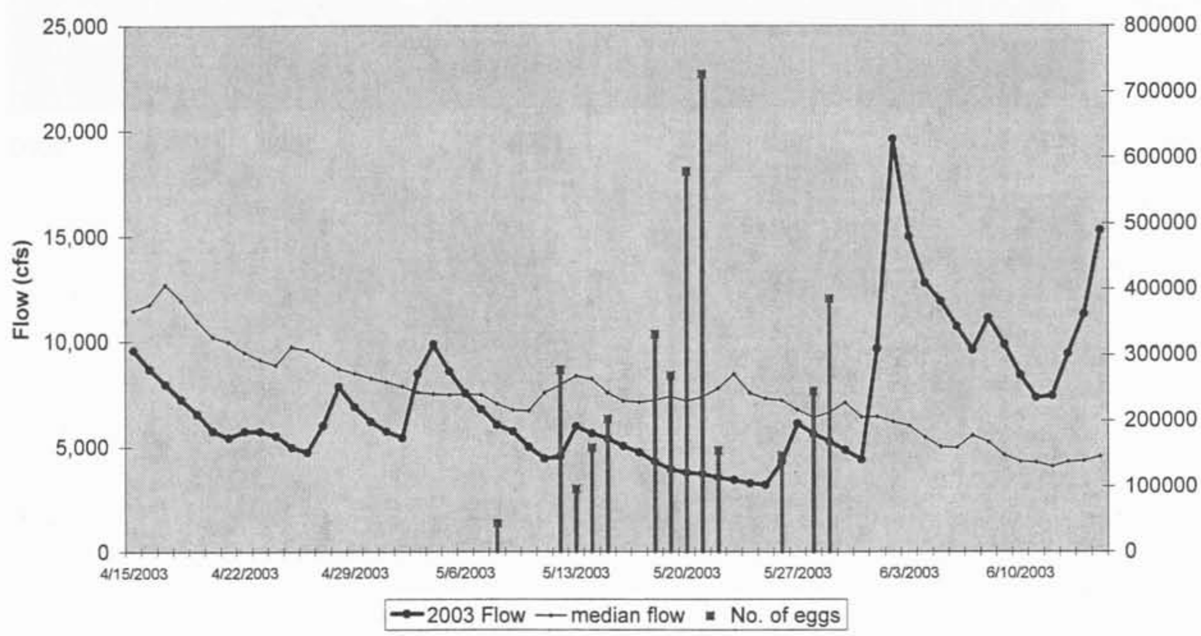


Figure 2. American shad eggs collected from the Delaware River, 1983-2003.

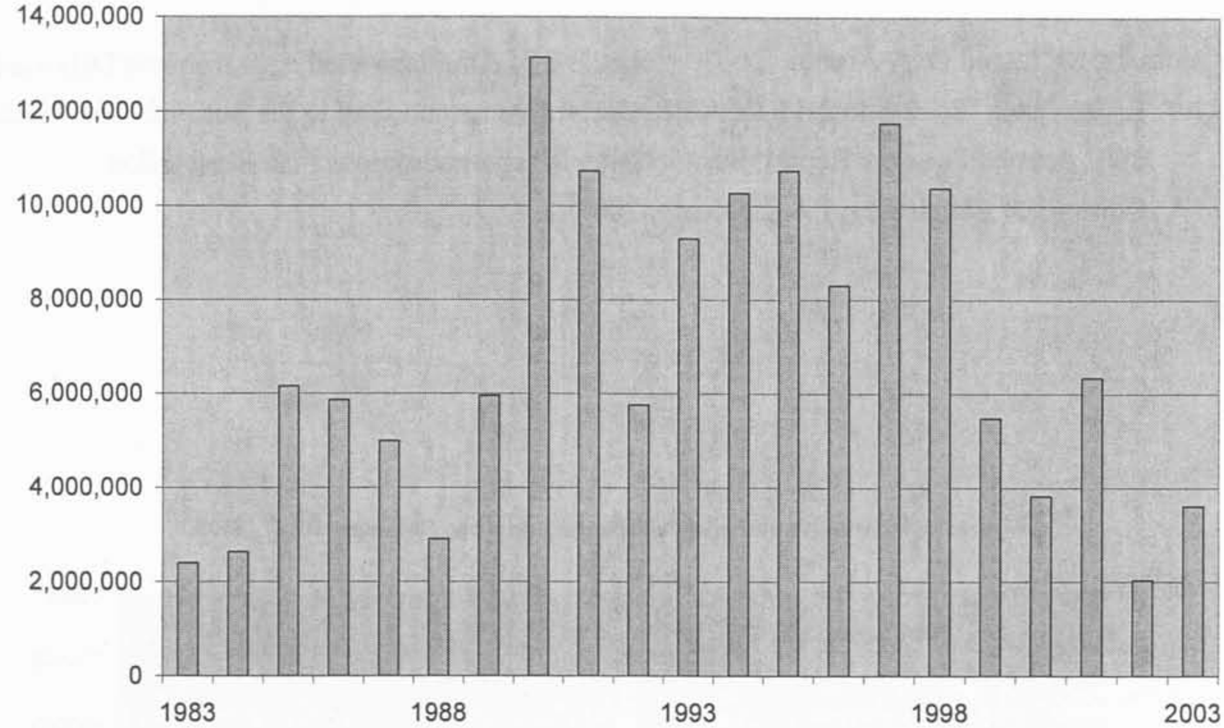


Table 1. Delaware River American shad egg collection data, 2003.

Month	Day	Year	Location	No. of Nets	Water Temp C	No. of shad captured	Vol. Of eggs shipped (L)	No. of eggs shipped	No. of viable eggs shipped	Percent Viability
5	8	2003	Martins Cr.	6	15.5	14	1.3	43,758	21,643	49.5%
5	12	2003	Smithfield Beach	12	14.8	76	8.6	277,244	191,820	69.2%
5	13	2003	Smithfield Beach	12	13.9	18	2.7	95,837	0	0.0%
5	14	2003	Smithfield Beach	12	13.8	27	4.0	159,064	99,475	62.5%
5	15	2003	Smithfield Beach	14	13.6	34	7.5	202,124	89,095	44.1%
5	18	2003	Smithfield Beach	13	15.3	48	13.0	330,522	146,114	44.2%
5	19	2003	Smithfield Beach	14	16.7	40	9.0	268,619	213,185	79.4%
5	20	2003	Smithfield Beach	14	17.8	59	16.3	578,574	426,113	73.6%
5	21	2003	Smithfield Beach	14	17	85	24.9	726,724	444,557	61.2%
5	22	2003	Smithfield Beach	14	15.7	43	4.6	154,835	56,655	36.6%
5	26	2003	Smithfield Beach	14	14	32	4.1	147,068	91,028	61.9%
5	27	2003	Smithfield Beach	13	14.9	9	No shipment			
5	28	2003	Smithfield Beach	13	15.9	38	9.3	244,894	163,216	66.6%
5	29	2003	Smithfield Beach	14	16.4	46	12.9	385,020	290,065	75.3%
					Totals	569	118.2	3,614,283	2,232,965	61.8%

JOB II – PART 3
REPORT ON HORMONE-INDUCED SPAWNING TRIALS WITH AMERICAN AND HICKORY SHAD AT CONOWINGO DAM, SPRING 2003

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

BACKGROUND

For over a decade, the Pennsylvania Fish and Boat Commission Van Dyke Hatchery has utilized strip spawned American shad eggs from Hudson and Delaware River broodstock to produce and stock over 130 million shad larvae in the Susquehanna River. The importance of these hatchery releases is evidenced by the high percentage (75-90%) of hatchery origin shad in the Susquehanna River spawning runs in the early to mid 1990's. Since the mid 1990's Susquehanna River shad stocks have continued their growth and the contribution of hatchery fish has ranged from 30 to 60%.

The removal of up to 15 million shad eggs from the Delaware River and up to 20 million eggs from the Hudson River has become controversial or questioned by state agencies. In an effort to reduce the costs and controversy of out of basin egg shipments, three options were proposed for the Annual Work Plan in 2001. Option 1 was the strip spawning of adult broodfish collected from known spawning areas in the Lower Susquehanna River. Option 2 was the hormone-induced spawning of shad broodfish on site at the Conowingo Dam West Fish Lift and Option 3 was the combination of Options 1 and 2. Option 2 was selected for the Annual Work Plan in 2001 and with modifications, this plan was continued in 2002. Option 3 was selected for the Annual Work Plan in 2003 with the further addition of hormone induced spawning of hickory shad.

INTRODUCTION

The Conowingo Dam West Fish Lift was built in 1972 and has been operated annually during the months of April, May and early June. Initially it was an integral part of the anadromous fish restoration effort, which combined the operation of the West Fish Lift, hand sorting of target species and a fleet of transport trucks to carry American shad and other Alosids to upriver release sites. Since the completion of permanent fish lifts at Conowingo Dam (1991), Holtwood and Safe Harbor Dam (1997), and a fish ladder at York Haven Dam (2000), the Conowingo West Fish Lift is now operated under contract as (1) a source of fishes for special on-site spawning studies and studies conducted by the Maryland Department of Natural Resources at the Manning Hatchery and (2) collection of biological information from American shad. In past years, the West Fish lift has also provided pre spawn American shad for spawning studies at the USFWS Northeast Fishery Center at Lamar, PA and adult herring for the Pennsylvania Fish and Boat Commission's tributary stocking program.

The West Fish Lift when operated daily from11 AM to 7 PM from late April through early June typically captures 10,000 adult American shad. The majority of these fish are in a pre-spawn condition and based on results at Lamar and Manning, many of these fish could be induced to spawn in two to three days with hormone implants. The advantage of conducting spawning studies on site at Conowingo Dam rather than at a distant hatchery is the elimination of the stress associated with lengthy transport times. The West Fish lift captures few, if any, hickory shad in a typical year. Anglers however are quite successful in catching hickories at Shures Landing in Conowingo Fisherman's Park and at the mouth of Deer Creek. Cooperating anglers at these sites provided the source for pre spawn hickory shad for the 2003 trials.

METHODS AND MATERIALS

The hickory shad spawning trials began on 15 April to coincide with the 15 April start up date for the Van Dyke Hatchery. Normandeau personnel cooperated with DNR biologists to obtain pre spawned hickory shad broodstock for the Conowingo trials and DNR's trials at Manning Hatchery. Hickory shad caught at the mouth of Deer Creek were transported to the Conowingo West Lift holding tanks by DNR and PFBC tank trucks.

All broodstock for the American shad trials between 28 April and 5 June was collected from the Conowingo West Fish lift. The 2003 American shad trials were patterned after similar trials conducted by USFWS at Lamar in previous years and on the trials conducted at Conowingo Dam in 2001 and 2002. Most of the equipment and supplies needed to conduct the spawning trials was provided by the Lamar Hatchery.

The 10 ft and 12 ft diameter fiberglass tanks used for spawning trials in 2003 were the same tanks that were used in 2002.These tanks were assembled on-site at the West Fish Lift in early April and plumbed in a configuration similar to that used last year (Figure 1). Both tanks were supplied with 25-40 gpm of river water through a wall mounted 2-inch fitting. A screened 4-inch PVC drainpipe in the bottom of each tank provided the only exit for the demersal shad eggs and water from the tank. The water level in both spawning tanks was maintained by an external standpipe that also provided a source of water for the rectangular 72 by 36 by 16 inch raised egg collection tank. The calculated volumes for the small and large and tanks were 6,400 and 9,200 liters respectively. An egg sock fastened to the discharge from the standpipe prevented the shad eggs from entering the internal standpipe drain that maintained the water level in the egg tank.

The stocking rate for hickory shad was 60 and 100 fish for the small and large tanks respectively with a 3:2 (M/F) sex ratio if available. The stocking rate for the larger American shad was 50 and 75 fish for the small and large tanks with the same 3:2 sex ratio as hickory shad. All on-site spawning trials in 2003 were conducted with Lutenizing Hormone Releasing Hormone (LHRH) which was purchased in powder form (25 mg vials) from Syndel Labs, Vancouver BC. A portion of the powdered LHRH was converted to 50 and 150 ug cholesterol based pellets by the PFBC. The remaining powder was used to make an injectable saline solution that contained 50 ug/ml for hickory shad trials or 150 ug/ml for American shad trials. The injectable solution was prepared just before use due to its short shelf life. Both sexes within each species received equal dosages of LHRH. Within each trial, all fish received an implant or a liquid injection. Each fish was injected with a pelletized implant or liquid in the thick muscles of the shoulder area. Fish were not anesthetized prior to injection.

The egg sock was examined daily during each spawning trial. If eggs were present, they were transferred into a framed nylon net, sieved to remove scales and measured for volume in a graduated 2 liter measuring cup. The packaging of eggs for shipment followed well-established techniques. Up to five liters of water hardened eggs were mixed with 5 liters of river water in double plastic bags. Pure oxygen was introduced into the inner bag before being sealed with tape. The bags were placed into marked insulated shipping containers and driven to the PFBC Van Dyke facility by PFBC or Normandeau personnel. Eggs collected from an overnight or morning pulse were driven to Van Dyke on the same day. Eggs collected during afternoon hours were packaged for shipment, held overnight in an air conditioned room and transported the next day. When less than 1 liter of hickory shad eggs was collected in a 24 hr period, they were measured for volume and released in the river below Conowingo Dam. In past trials with American shad if less than 5.0 liters of eggs were collected in a day they were released below the dam but that did not occur in 2003. After the initial egg pulse, that occurred 24 to 48 hours following injection with LHRH the tanks were drained, mortalities, if any, recorded and the fish were buried at an off-site location. No attempts were made to hand strip shad following the egg pulse.

RESULTS

Hormone induced spawning trials with hickory shad at Conowingo Dam began on April 15 and concluded on April 27 2003. During this interval, 5 spawning trials (2 pellet and 3 liquid LHRH) were conducted with 381 adult hickory shad (Appendix Table A-1). Three of the trials were conducted in the 10 ft tank and two in the 12 ft tank. Each trial ran from two to four days but the largest pulse of eggs was produced on the second day. A total of 30.2 liters of eggs was collected from all five hickory shad trials and shipped to the Van Dyke Hatchery (Table 1). An additional 0.85 liter was released into the river below Conowingo Dam. The overall viability of the hickory shad eggs sent to the Van Dyke Hatchery was 44% (Mike Hendricks, personal communication). The volume of eggs produced by hickory shad that received pellet implants (6.2 liters/trial) was slightly higher than the volume produced by fish that received liquid injections (5.9 liters/trial); this difference could have resulted from the use of low potency liquid hormone for one of the liquid trials. The average viability of hickory shad eggs produced by implants (56%) was higher than the viability of eggs produced by liquid injection (39%). Water temperature in the spawning tanks ranged from 11.3 to 14.4°C and dissolved oxygen levels ranged from 10.7 to 12.3 ppm. Adult mortality rate for hickory shad during the spawning trials was 14%.

A total of 12 on-site pawning trials with 1504 American shad followed the hickory shad trials and produced 234 liters of eggs (Table 2 and Appendix Table A-2). The first American shad trial began on April 28 and the last trial finished on June 5. Four of the trials were conducted with liquid injections and eight with pelletized implants. Each trial, except Trial 7, consisted of 125 American shad split 75/50 between the large and small tank. Four extra males were added to the 10-ft tank in trial 7. The goal for both tanks was a sex ratio of 3:2 in favor of males. This goal was met for all trials except trial 9 when the 10-ft tank was stocked with a 1:1 sex ratio. Both sexes received an identical dosage of LHRH (150 ug). The total volume of eggs produced per female in individual 2003 trials (0.2-0.58 liters) was similar to the 2001 trials but lower than the 2002 trials (Figure 2). When adjusted for viability, the volume of viable eggs produced per female in the 2003 trials was generally lower than the 2001 and 2002 egg volumes (Figure 3). Water temperatures and oxygen levels in the spawning tanks were monitored daily and ranged from 14.8 to 18.8°C and 5.7 to 11.8 ppm. Cooler than normal weather conditions in May and elevated river flows helped keep safe oxygen levels (above 5.0 ppm) in the spawning tanks without supplemental aeration. River temperature remained below 18°C during the 2003 trials compared to 23 to 25°C temperatures reached in 2001 and 2002 trials. As with hickory shad, the largest pulse of eggs was collected 48 h after hormone treatment. Of the 234 liters of eggs collected during the American shad spawning trials, 229 liters were transported to the Van Dyke Hatchery. A 5.0 liter shipment was sent to the University of Memphis for genetic studies. The overall estimated viability of the eggs shipped to VanDyke was 17.7% (Mike Hendricks, personal communication). The viability of eggs produced by pelletized implants was 18.4% compared to the 13% viability for eggs produced by liquid hormone. The mean volume of eggs produced per trial by shad injected with pelletized implants was 20 liters versus 18 liters for trials injected by liquid hormone. Mortality rate for adult American shad averaged 2.0% during the 2003 trials. In previous trials mortality ranged from 3.6 to 6.0%.

SUMMARY

The results of the hickory shad hormone-induced spawning trials at Conowingo Dam in 2003 show that a 50 ug dose per fish of liquid or pelletized LHRH is effective in inducing spawning in hickory shad at stocking densities of up to one fish per 92 liters of water. The estimated overall egg viability of 44% is higher than the 10 to 33% viability estimates for on-site spawning trials with American shad since 2001. Hickory shad trials with pelletized LHRH had a slightly higher mean volume of eggs and a higher mean viability.

This was the third year of hormone induced American shad spawning trials at the Conowingo West Fish Lift but the first time that liquid injections were tested. The results of liquid hormone trials with American shad were similar to the hickory shad trials in that trials with pelletized hormone produced a higher average volume of eggs per female (0.40 versus 0.35 liters) and a higher average viability (18.4 versus 13.0%) as well. Liquid injections however do have some advantages; they are easier to prepare and easier to administer in rainy or windy field conditions. The production of 234 total liters of American shad eggs at Conowingo in 2003 is a new volume record for egg production but the total number of viable eggs produced in the 2001 trials (2,159,135) still remains to be surpassed (Table 3). This was primarily due to the higher estimated viability (33.2%) and smaller size (63,140 eggs per liter) of 2001 eggs.

Table 1

Summary of egg production data for hormone (LHRH)-induced spawning trials conducted with hickory shad at Conowingo Dam, spring 2003.

Trial Number	Liquid/ Pellet	Tank	Start/Stop Date	M/F	Egg Vol. (Liters)	Number of Eggs	Proportion Viable	Number Viable
1	L	12 ft	4/15-4/18	38/48	15.6	8,825,520	0.383	3,376,384
2	P	10 ft	4/17-4/21	22/47	5.1	2,106,944	0.356	749,962
3	L	10 ft	4/22-4/25	41/21	0.9	319,726	0.825	263,795
4	P	12 ft	4/25-4/27	60/40	7.3	2,598,464	0.718	1,865,274
5	L	10 ft	4/25-4/27	39/25	1.3	573,075	0.185	106,239
Totals				**200/181**	**30.2**	**14,423,729**	**44.1**	**6,361,654**

Mean egg volume/trial, all trials = 6.0 liters
Mean volume/trial for Liq. = 5.9 liters
Mean volume/trial for Pellet. = 6.2 liters

Mean Egg Viability (All Trials) = 44.1%
Mean Egg Viability (Liquid Trials) = 38.6%
Mean Egg Viability (Pellet Trials) = 55.6 %

Mean number of eggs/liter = 477,607

Mean number of Eggs/Female (All Trials) = 79,689
Mean number of Eggs/Female (Liquid Trials) = 103,386
Mean number of Eggs/Female (Pellet Trials) = 54,085

Mean number of Viable Eggs/ Female (All Trials) = 35,147
Mean number of Viable Eggs/ Female (Liquid Trials) = 39,856
Mean number of Viable Eggs/ Female (Pellet Trials) = 30,060

Table 2

Summary of American shad egg production data for hormone-induced spawning trials conducted in a 10 and 12 ft diameter tank at Conowingo Dam, spring 2003.

Trial Number	Liquid/ Pellet	Start/Stop Date	12 ft M/F	10 ft M/F	12 ft Liters	10 ft Liters	Total Liters	Number of Eggs	Proportion Viable	Number Viable
1	P	4/28-4/30	45/30	30/20	8.3	1.5	9.8	657,218	0.206	135,554
2	L	4/30-5/2	45/30	30/20	7.8	3.8	11.6	730,385	0.029	21,324
3	P	5/4-5/6	45/30	30/20	17.0	11.8	28.8	1,180,436	0.322	380,613
4	L	5/8-5/11	45/30	30/20	11.0	5.5	16.5	942,671	0.183	172,591
5	P	5/11-5/13	45/30	30/20	11.9	5.2	17.1	1,285,511	0.102	131,092
6	L	5/13-5/15	45/30	30/20	9.7	10.1	19.8	1,051,852	0.13	136,705
7	P	5/15-5/18	45/30	34/20	10.5	7.7	18.2	866,520	0.155	135,354
8	P	5/18-5/20	45/30	30/20	14.5	9.1	23.6*	1,174,682	0.094	110,518
9	L	5/21-5/23	45/30	25/25	16.1	8.2	24.3	1,088,667	0.151	163,937
10	P	5/26-5/28	45/30	30/20	16.5	10.6	27.1	1,479,768	0.192	283,715
11	P	5/28-6/2	45/30	30/20	10.9	10.4	21.3	918,450	0.282	259,119
12	P	6/3-6/5	45/30	30/20	10.4	5.5	15.9	594,604	0.113	67,451
Totals			**540/360**	**359/245**	**144.6**	**89.4**	**234***	**11,970,764**	**0.177**	**1,997,973**

*Includes 5.0 liter shippment to University of Memphis.

Total Males = 899 (295 Liquid, 604 Pellet)
Total Females = 605 (205 Liquid, 400 Pellet)
Total Fish = 1504 (500 Liquid, 1004 Pellet)

Mean vol. / trial =19.5 liters
Mean vol. / liquid trial = 18.05 liters
Mean vol. / pellet trial = 20.25 liters

Mean Egg Viability (All Trials) = 17.7%
Mean Egg Viability (Liquid Trials) = 13.0%
Mean Egg Viability (Pellet Trials) = 18.4%

Mean number of Eggs/Female (All Trials) = 19,786
Mean number of Eggs/Female (Liquid Trials) = 18,603
Mean number of Eggs/Female (Pellet Trials) = 20,393

Mean number of Viable Eggs/ Female (All Trials) = 3,302
Mean number of Viable Eggs/ Female (Liquid Trials) = 2,412
Mean number of Viable Eggs/ Female (Pellet Trials) = 3,759

Mean number of Eggs / Liter (All Trials) = 51,187

Table 3

Summary of hormone induced spawning trials with American shad at Conowingo Dam, 2001-03

Year:	2001	2002	2003
Start/Finish date	4-30/6-4	4-24/6-6	4-28/6-5
Tank diameter	12 ft	10,12 ft	10,12 ft
Tank volume	9,200 liters	15,600 liters	15,600 liters
Number of trials	10	10	12
Total fish	599	1000	1504
Males/Females per trial	36/24	66/34	75/50
Stocking density (fish/liters)	1/153	1/156	1/125
Male:Female ratio	1.5:1	2:1	3:2
Hormone injected	LHRH	SGnRHa	LHRH
Liquid, Pellet	P	P	L+P
Dose (ug) Male/Female	75/150	150/150	150/150
Eggs collected (liters)	103	146.8	234
Liters of eggs /Female	0.429	0.432	0.387
Number of eggs/liter	63,140	51,235	51,187
Total number of eggs	6,503,420	7,521,346	11,970,764
Viability (%)	33.2	10.1	17.7
Total number of viable eggs	2,159,135	760,935	2,118,852
Total liters of viable eggs	34.20	14.85	41.42
Adult mortality rate (%)	6.0	3.6	2.0

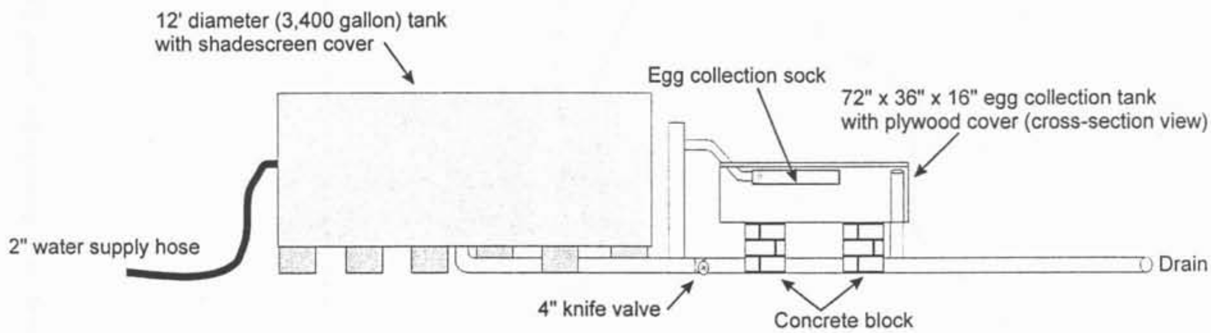


Figure 1

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

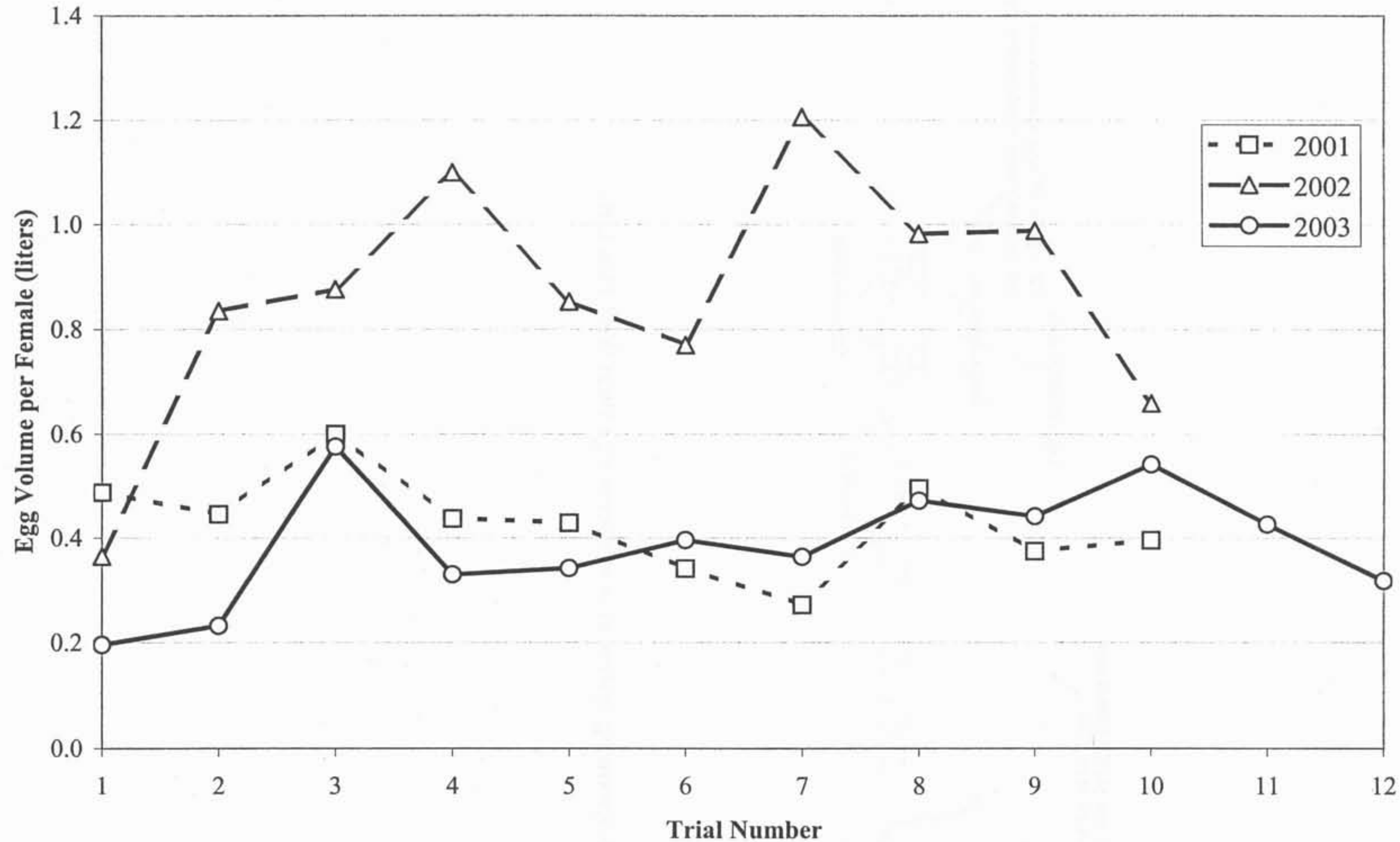


Figure 2

Comparison of American shad egg production per female by trial number and year at Conowingo Dam, 2001-2003.

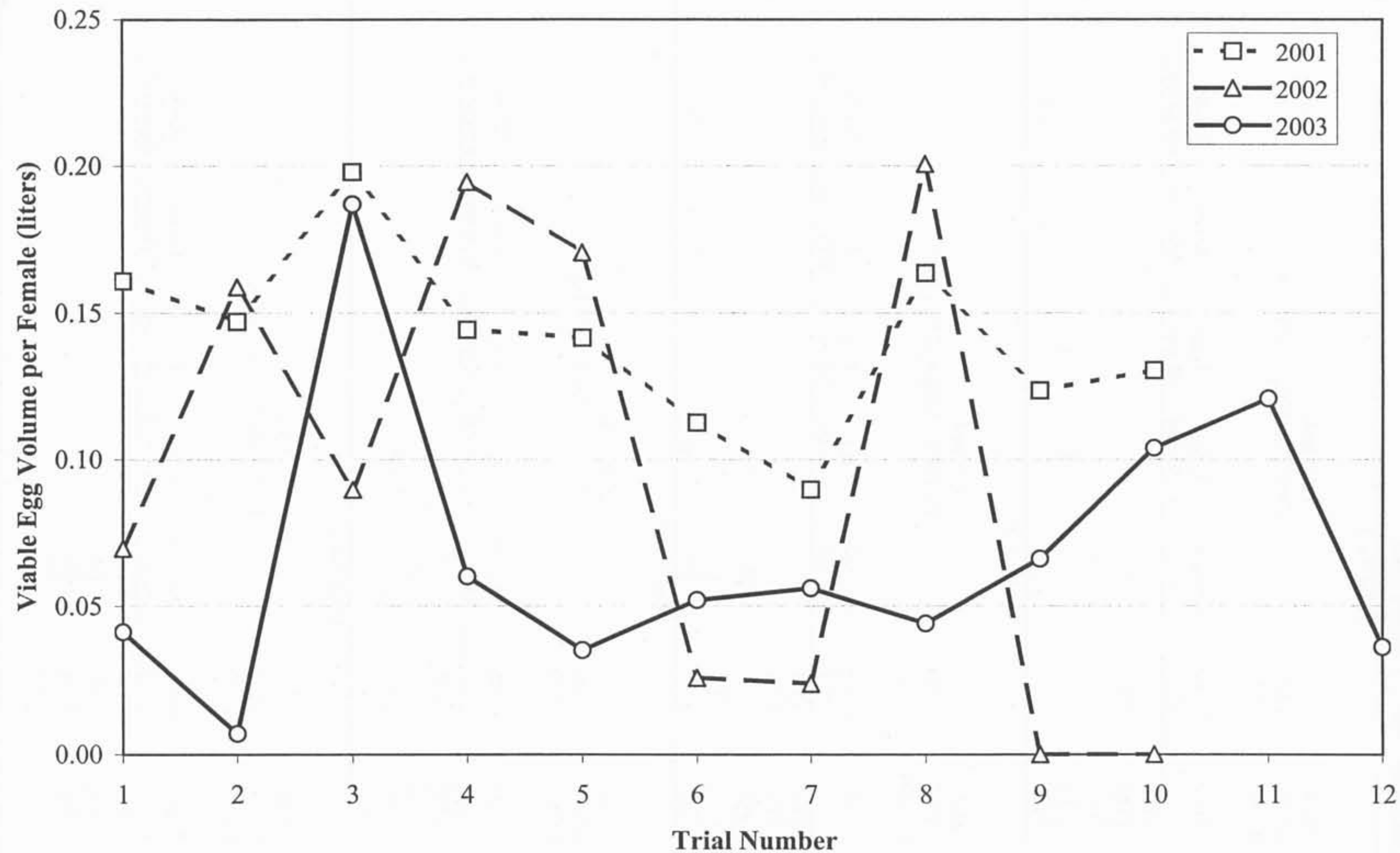


Figure 3

Comparison of viable American shad eggs produced per female by trial number and year at Conowingo Dam, 2001-2003.

Appendix Table A-1

Individual trial data collected during the hormone induced hickory shad spawning trials conducted at Conowingo Dam West Fish Lift, spring 2003.

Trial No.1

M/F Ratio	38/48		12 ft tank	
Start Date	4/15/03	1330	Dose/fish 50ug LHRH liquid	
End Date	4/18/03	0840		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/15/03	1445	11.3	12				
4/16/03	1345	12.7	10.7				
4/17/03	935		10.8				
4/17/03	1115			11	11		
4/18/03	820		11.6			0.1	14

Trial No. 2

M/F Ratio	22/47		10 ft tank	
Start Date	4/17/03	1300	Dose/fish 50ug LHRH pellet	
End Date	4/21/03	720		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/17/03	1400	13.0	10.3				
4/18/03	820	12.8	11				
4/19/03	950	12.8	10	3.5	3.5		
4/20/03	1330	13.5	11.8	0.75		0.75	
4/21/03	722	12.9	11.4	Trace		Trace	26

Trial No. 3

M/F Ratio	41/21		10 ft tank	
Start Date	4/22/03	1400	Dose/fish 50ug LHRH liquid	
End Date	4/25/03	0900		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/22/03	1405	13.6	11.5				
4/23/03	1222	13.1	12.0				
4/24/03	1620	13.5	12.3	0.6	0.6		
4/25/03	845	13.2	11.3				14

Trial No. 4

M/F Ratio	60/40		12 ft Tank	
Start Date	4/25/03	1115	Dose/fish 50ug LHRH pellet	
End Date	4/27/03	1030		

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/03	1238	13.8	11.4				
	1430	14	11.6				
4/26/03	1240	13.8	11.8				
4/27/03	1000	14.4	11.2				
	1030			5.5	5.5		

Appendix Table A-1

Continued.

Trial No. 5

M/F Ratio	39/25			10 ft Tank			
Start Date	4/25/03	1230		Dose/fish 50ug LHRH liquid			
End Date	4/27/03	1030					

Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/25/03	1238	14	11.8				
	1427	14	11.6				
4/26/03	1240	13.8	11.8				
4/27/03	1000	14.4	11.5				
	1100			1.0	1.0		

Appendix Table A-2

Individual trial data for hormone induced American shad spawning trials conducted at Conowingo Dam West Fish Lift, spring 2003.

Trial No.1

M/F	30/20	10 ft tank		LHRH 150ug Pellets			
Start Date	4/28/03						
End Date	4/30/03	1100					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/28/03	1230	15.2	12				
	1840	14.8	11.7				
4/29/03	829	15.2	11.1				
	1715	15.9	10				
4/30/03	1020	16	10.4				
	1100			1.5	1.5		

M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	4/28/03	1200					
End Date	4/30/03	1100					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/28/03	1200	15.2	11.8				
	1840	14.9	9.8				
4/29/03	836	15.2	10.9				
	1715	15.9	10.7				
4/30/03	1015	16	10.1				
	1100			8.3	8.3		1f

Trial No. 2

M/F	30/20	10 ft tank		LHRH 150ug Liquid			
Start Date	4/30/03	1300					
End Date	5/2/03	1230					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/30/03	1620	16.4	10.0				
5/1/03	1615	17	8.6				
5/2/03	1046	17	8.6				
5/2/03	1230			3.8	3.8		6f

M/F	45/30	12 ft tank		LHRH 150 ug Liquid			
Start Date	4/30/03	1400					
End Date	5/2/03	1300					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
4/30/03	1620	16.4	8.6				
5/1/03	1615	17	8.6				
5/2/03	1045	17.7	9.1				
5/2/03	1300			7.8	7.8		1f

Appendix Table A-2

Continued.

Trial No. 3

M/F	30/20	10 ft tank		LHRH 150ug Pellets			
Start Date	5/4/03	1230					
End Date	5/6/03	1200					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/03	1745	18	6.4				
5/5/03	1100	18.2	7.6				
5/6/03	1030	17.8	6.3				
5/6/03	1100			11.8	11.8		

M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	5/4/03	1315					
End Date	5/6/03	1200					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/4/03	1745	18	7.5				
5/5/03	1100	18.2	7.6				
5/6/03	1030	17.8	5.7				
5/6/03	1100			17.0	17.0		1f

Trial No. 4

M/F	30/20	10 ft tank		LHRH 150ug Liquid			
Start Date	5/8/03	1100					
End Date	5/11/03	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/03	1200	18.5	8.5				
	1638	18.6	8.9				
5/9/03	1120	18.6	7.8				
5/10/03	1007	18.2	8.9	5.5	5.5		
5/11/03	930						2f

M/F	**45/30**	12 ft tank		LHRH 150 ug Liquid			
Start Date	5/8/023	1200					
End Date	5/11/03	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/8/03	1200	18.5	8.1				
	1640	18.8	7.8				
5/9/03	1121	18.8	8.5				
5/10/03	1010	18.2	8.4	11	11		
5/11/03	930						1m,3f

Appendix Table A-2

Continued.

Trial No. 5

M/F	30/20	10 ft tank	LHRH 150ug Pellets				
Start Date	5/11/03	1200					
End Date	5/13/03						
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/11/03	1530	18.3	6.9				
5/12/03	1003	18.4	7.1				
5/13/03	1000	18.4	7.4	5.2	5.2		1f

M/F	45/30	12 ft tank	LHRH 150 ug pellets				
Start Date	5/11/03	1300					
End Date	5/13/03	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/11/03	1530	18.3	7.9				
5/12/03	1003	18.4	7.8				
5/13/03	1000	18.4	7.4	11.9	11.9		

Trial No. 6

M/F	30/20	10 ft tank	LHRH 150ug Liquid				
Start Date	5/13/03	1200					
End Date	5/15/03	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/13/03	1900	17.9	6.5				
5/14/03	838	17.8	7.4				
	1715		7.9				
5/15/03	1030	18.2	8.5	10.1	10.1		2f

M/F	45/30	12 ft tank	LHRH 150 ug Liquid				
Start Date	5/13/03	1130					
End Date	5/15/03	1100					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/13/03	1900	17.9	6.7				
5/14/03	840	17.8	7.1				
	1715		7.2				
5/15/03	1100	18.2	8.2	9.7	9.7		3f

Appendix Table A-2

Continued.

			Trial No. 7				
M/F	30/20	10 ft tank		LHRH 150ug Pellets			
Start Date	5/15/03	1100					
End Date	5/18/03	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/15/03	1430	18.2	8.2				
	1710	18.2	8.6				
5/16/03	1000	17.5	7.5				
	1720	17	7.4				
5/17/03	1025	16.8	8.3	5.7	5.7		
5/18/03	930	16	8.4	2	2		4f
M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	5/15/03	1200					
End Date	5/18/03	930					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/15/03	1430	18.2	7.8				
	1710	18.2	8.6				
5/16/03	1000	17.5	7.5				
	1720	17	6.8				
5/17/03	1025	16.8	8				
5/17/03	1100			7.3	7.3		
5/18/03	930	15.8	7.7	3.2	3.2		

			Trial No. 8				
M/F	30/20	10 ft tank		LHRH 150ug Pellets			
Start Date	5/18/03	1200					
End Date	5/20/03	1200					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/18/03	1550	15.8	8.1				
5/20/03	1145	16.1	11.7	9.1	4.1 V.D. 5.0 TNN		
M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	5/18/03	1300					
End Date	5/20/03	1130					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/18/03	1550	15.9	8.6				
5/20/03	1100			14.5	14.5		1f

Appendix Table A-2

Continued.

Trial No. 9

M/F	34/20	10 ft tank		LHRH 150ug Liquid			
Start Date	5/21/03	1130					
End Date	5/23/03	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/21/03	1524	15.8	9.2				
5/22/03	1550	16.1	6.6				
5/23/03	1015	16.3	8.7				
5/23/03	1030			8.2	8.2		

M/F	45/30	12 ft tank		LHRH 150 ug Liquid			
Start Date	5/21/03	1100					
End Date	5/23/03	1130					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/21/03	1524	15.8	9.5				
5/22/03	1550	16.1	6.9				
5/23/03	1015	16.3	8.5				
5/23/03	1130			16.1	16.1		2f

Trial No. 10

M/F	30/20	10 ft tank		LHRH 150 ug pellets			
Start Date	5/26/03	1100					
End Date	5/28/03	1030					
Date	Time	Temp. (°C)	Oxygen ((ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/26/03	1245	16.9	8.4				
	1535	16.8	8.9				
5/27/03	1140	16.7	8				
5/28/03	900	16.9	8.9				
	1030			10.6	10.6		

M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	5/26/03	1015					
End Date	5/28/03	1000					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/26/03	1245	16.9	8.2				
	1535	16.8	8.5				
5/27/03	1139	16.7	8.2				
5/28/03	900	16.9	9.2				
	1000			16.5	16.5		

Appendix Table A-2

Continued.

Trial No. 11

M/F	25/25	10 ft tank		LHRH 150 ug pellets			
Start Date	5/28/03	1200					
End Date	5/30/03	1035					
Date	Time	Temp. (°C)	Oxygen ((ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/28/03	1400	17	8.1				
	1750	17.2	8.2				
5/29/03	856	17.1	8				
	1643	17.5	6.2				
5/30/03	1020	18.4	7.5	10.4	10.4		

M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	5/29/03	1030					
End Date	6/2/03	1030					
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
5/29/03	1200	17.5	7.1				
	1642	17.5	7.6				
5/30/03	1015	18.3	7.6				
5/31/03	1000	18.1	8.2	10.9	10.9		

Trial No. 12

M/F	30/20	10 ft tank		LHRH 100-150 ug pellets			
Start Date	6/3/03	1115		(all f 3x50 ug, 20 m 3x50 ug, 10 m 2x50 ug)			
End Date	6/5/03						
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/3/03	1240	18	8.1				
	1435	17.9	8.6				
6/4/03	835	16.6	8.7				
6/5/03	807	15	9.5				
	930			5.5	5.5		1m

M/F	45/30	12 ft tank		LHRH 150 ug pellets			
Start Date	6/3/03	1030		(18 f 150ug, 12 f 3x50 ug, all males 3x50 ug)			
End Date	6/5/03						
Date	Time	Temp. (°C)	Oxygen (ppm)	Eggs Collected	Eggs Shipped	River Releases	Morts Removed
6/3/03	1240	18	7.8				
	1430	17.9	8.2				
6/4/03	835	16.6	8.2				
6/5/03	807	15	9.2				
	900			10.4	10.4		1f

Job II - Part 4

American Shad Egg Collection from the Lower Susquehanna River

Richard St. Pierre
U. S. Fish and Wildlife Service
P. O. Box 67000
Harrisburg, PA 17106-7000

INTRODUCTION

For many years, the hatchery component of the Susquehanna River shad restoration program has relied on delivery of fertile shad eggs taken by strip-spawning of broodfish from the Hudson and Delaware rivers. Although Hudson River shad eggs have been extremely beneficial to the program with large numbers and very good viability, this is a costly project which involves hiring a private contractor and maintaining two netting crews over at least a 30-day period each spring. Since the Susquehanna River adult shad population has grown substantially in recent years, SRAFRC is interested in using this egg source to eventually replace that of the Hudson River. This will reduce overall cost of egg collections while providing a genetically superior strain - fish with a demonstrated urge to return to the Susquehanna to spawn.

From the 1890s through about 1920, tens of millions of shad eggs were collected by commercial fishermen and delivered to U. S. Fish Commission culture operations at the head of the Chesapeake Bay near Havre de Grace, MD. Newly hatched larvae were released into nearby and distant waters but it was eventually determined that these stockings were not enhancing shad populations. In fact, Chesapeake Bay shad harvest levels declined sharply from the mid-1890's until about 1910. Maryland harvest stabilized at 1-2 million pounds per year during the 1920s through the early 1970s followed by a precipitous decline which led to Maryland's closure of all Bay fisheries in 1980.

Immediately prior to the recent crash of shad fisheries in the upper Bay, shad eggs were once again collected from the lower Susquehanna River near Lapidum, MD. In 1971-1973, over 20 million eggs were taken from this area and released into hatching boxes upstream of all

Susquehanna dams. This was replaced by other sources, including the Mattaponi, Pamunkey, Potomac, James and Columbia rivers which supplied eggs to the Susquehanna program through the early 1980s. The Hudson and Delaware rivers have been the program's primary egg producers since 1990.

The purpose of this effort in 2003 was to reinvestigate the possibility of taking large numbers of shad eggs from the lower Susquehanna River in the hopes of eventually replacing costly distant waters collections. The U. S. Fish and Wildlife Service (Harrisburg, PA and Annapolis, MD) assumed responsibility for this work.

METHODS

With the help of Maryland's SRAFRC Technical Committee representative Dale Weinrich, a commercial fisherman was located with gear and knowledge of the shad fishery in the lower Susquehanna River. Gary "Rooster" Potter from Perryville, MD agreed to enter a contract on a daily rate basis, and to supply his nets, storage facility and boat docks for the Service vessel. The USFWS Maryland Fishery Resources Office supplied a boat and 2-3 man crew and the Susquehanna River Coordinator provided most minor equipment (buckets, tubs, coolers, etc.) and directed daily operations. Since this was an experimental effort, the plan called for netting shad three nights per week for 3-4 weeks during May, with eggs being delivered to Conowingo Dam nightly. Normandeau Associates, under separate contract to operate the tank spawning system at the dam, was responsible for delivery of eggs to Van Dyke. Normandeau also provided bottled oxygen from their supply at the dam.

Gear and Location

The primary gear employed for this effort included two multi-filament nets (mono is not allowed in MD) approximately 700-ft. and 500-ft. in length, both 12-ft depth and with 5 ½" mesh. This is the same gear that Mr. Potter and his father used for commercial shad fishing during the 1970s. Back-up nets included several hundred feet of experimental gill net with various mesh sizes down to 4 ½" (USFWS) and a length of net provided by Maryland DNR with 5 1/4" mesh.

Most netting attempts were initiated adjacent to the Lapidum boat landing in 12-15-ft of water approximately on the Harford-Cecil county line (Fig. 1). Length of drift time was limited by natural river flow, Conowingo operation, and placement of anchored catfish pots which had to be avoided to reduce gear damage. Sets at this primary location typically lasted for about 30 minutes, covered 1.0-1.4 km, and terminated off St. Catherine Island. A secondary site adjacent to the marina at Port Deposit, MD was fished on three occasions, and one attempt was made to locate spawning shad on the Susquehanna Flats near the Veterans Administration Hospital at Perry Point. Smaller mesh nets were not used in 2003.

Effort

Netting and spawning operations occurred on only seven nights between May 13 and June 10 with each weekly foray being terminated early due to persistent low water temperature, high flows, and lack of spawners. Spring 2003 was characterized as being unusually cool with frequent (near record) rainfall. Fifteen net sets (1-3 per night) were completed during this period (Table 1). Typically, first sets each evening were laid out about 8:15 - 8:30 pm, fished for about 30 minutes, and reset. Operations usually ceased by about 11 pm.

Egg Processing

Male and female shad pulled from the net were placed into separate wash tubs. Egg take proceeded immediately following capture using the dry pan method described by Wyatt Group and successfully employed in their Hudson River operation. After all eggs were taken from each individual set, sperm was squeezed from one to several ripe males, gametes were gently stirred and allowed to sit for 1-2 minutes. Clean river water was added to initiate fertilization. After a few minutes, the eggs were washed with clean water and placed into a large water-filled container to harden. Water-hardening lasted at least one hour.

Hardened eggs were strained through cheesecloth and packaged into double plastic bags, 5 liters of eggs with 5 liters of clean water, injected with pure oxygen and secured with rubber bands. Bags were placed into coolers and dropped off at Conowingo Dam for next day delivery to Van Dyke hatchery.

RESULTS

A total of 219 American shad were netted on seven nights including 35 bucks (mostly ripe), and 184 roe shad. Of the latter, 114 were green (hard roe), 9 were fully spent and the remaining 61 fish were ripe or partially spent (Table 1). All but 25 shad were taken at the Lapidum site and only one shad was collected on the Flats. Other fish in collections included 360 gizzard shad (all locations), 10 striped bass (mostly from the Flats), 20 channel catfish, and a few blueback herring, hickory shad and carp.

Shad eggs were collected on four occasions including 5.5 liters on May 13, 1.5 liters on May 14 (dumped), 7.5 liters on May 20, and 2.6 liters on May 21. All later trials (May 27-28 and June 10) produced a total of only three bucks, one ripe female, 13 hard and 6 spent females. Viability was very high for the first two egg shipments (88.7% and 77.5%) but very low on the third shipment (8.4%). Egg size was comparable to other rivers and averaged 35,600 eggs/liter. Total egg count at Van Dyke was 555,265 of which 375,576 were viable. Surviving larvae were specially marked and stocked (see Job III).

DISCUSSION

May 2003 was one of the rainiest on record with above average flows and cooler than normal water temperatures. Temperature was 63°F on May 13-14 but decreased to 59-61° as the season progressed. The first night's operation was terminated after only one net set due to lack of sufficient on-board lighting. USFWS staff and Mr. Potter corrected this problem. Multiple sets were made all other nights until June 10, when it was apparent that shad were very scarce and netting operation was impeded by heavy recreational boat traffic related to the opening of the rockfish season.

Concern over the potential high by-catch of striped bass was unfounded as few were netted and only one died in the net. Gizzard shad were abundant as expected, but catfish were much more difficult to handle during extraction. Having an experienced commercial fisherman aboard each night was invaluable. His knowledge of the river and netting skills saved considerable time and effort in locating American shad. In fact, shad were collected in every one of the 15 net sets during this operation.

Roe to buck ratio for the season using 5½" mesh net was 5.2:1, just as predicted by Mr. Potter from his earlier experience in the 1970s. This would be sufficient for quality egg collection, but abundance of buck shad varied greatly throughout the season. They were plentiful (1:3 ratio) on May 13 and May 20 when most eggs were taken and delivered, but poorly represented in the catch (1:10 to 1:50) on all other dates. Poor viability measured for the May 21 collection (2.5L at 8.4%) most likely related to the absence of buck shad, with only one male available to fertilize the spawn from three net sets. Oddly, the day before (5/20), buck numbers exceeded that of ripe females (16 to 14) and many were returned to the river unneeded. Nevertheless, it seems that a smaller mesh net (perhaps 5") will be required to ensure future buck collections and enhance egg production.

The Port Deposit site produced 24 shad in three sets but included only one male. Gizzard shad were very common here - about 30 per set. The single set on the Flats off Perry Point could not be used as an indicator of future potential, however striped bass were most plentiful here. Lapidum appears to be the most useful of areas examined (as was the case in 1971-73) producing an average of 19 American shad per 30-minute set during May.

Using Fish and Wildlife Service labor and boat, and contracting with an experienced fisherman, was a cost effective way to examine the possibility of taking quality shad eggs from spawners in the lower Susquehanna River. Shad catch and egg production was seriously hampered by weather in 2003. Under "normal" May conditions, it is likely that 5-10 liters of eggs could be shipped each night. Total cost of this operation to SRAFRC in 2003 was less than $3,800.

RECOMMENDATIONS

1. This effort should be expanded in 2004 to include at least 15-20 nights of netting. Weekends should be avoided due to heavy recreational boating use in the area around Lapidum.

2. A commercial fisherman should be contracted to assist as in 2003. Ideally that person will also supply properly hung shad nets, storage and boat dock space.

3. Lapidum should be the primary netting site, but new areas such as between the I-95 and US 40 bridges and the Susquehanna Flats (north and south channel) should be more thoroughly investigated.

4. In addition to the 5½" roe net, purchase and rig at least 200-300-ft. of 5" net to enhance collection of buck shad.

5. Continue using the dry method of fertilization as well as traditional water-hardening and packaging techniques.

6. Deliver shad eggs nightly to Conowingo for later delivery to Van Dyke. If this is not viable (e.g., if Normandeau discontinued tank spawning), arrange for separate nightly egg delivery.

ACKNOWLEDGMENTS

Appreciation is extended to Dale Weinrich (DNR) who helped with logistics and field work, and the entire crew from USFWS Maryland Fishery Resources Office. Mike, Tina, Clif and Sheila put in 12-16 hour days in adding this nighttime work to their already busy day schedules. A special thanks is given to Rooster Potter for his congenial and helpful attitude and especially for repeatedly putting us onto fish, rigging boat lights, and mending torn nets.

Table 1. Lower Susquehanna River Shad Egg Collections - 2003

Date	No. sets	Location - gear	water temp. (°F)	shad catch males	ripe roe	hard roe	spent	eggs taken
May 13	1	Lapidum - 700'	63	12	20	13	2	5.5 liters
May 14	3	Lapidum - 700' (1)						
		Pt. Deposit - 500' (2)	63	3	12	17	0	1.5 L (dumped)
May 20	3	Lapidum - 700'	59	16	14	36	0	7.5 liters
May 21	3	Lapidum - 700'	59	1	14	35	1	2.6 liters
May 27	2	Lapidum - 500'						
		Pt. Deposit - 500'	60	1	0	8	4	-
May 28	2	Susq. Flats - 500'						
		Lapidum - 500'	60	2	0	5	2	-
June 10	1	Lapidum-500'	61	0	1	0	0	-
Totals	15			35	61	114	9	17.1 liters

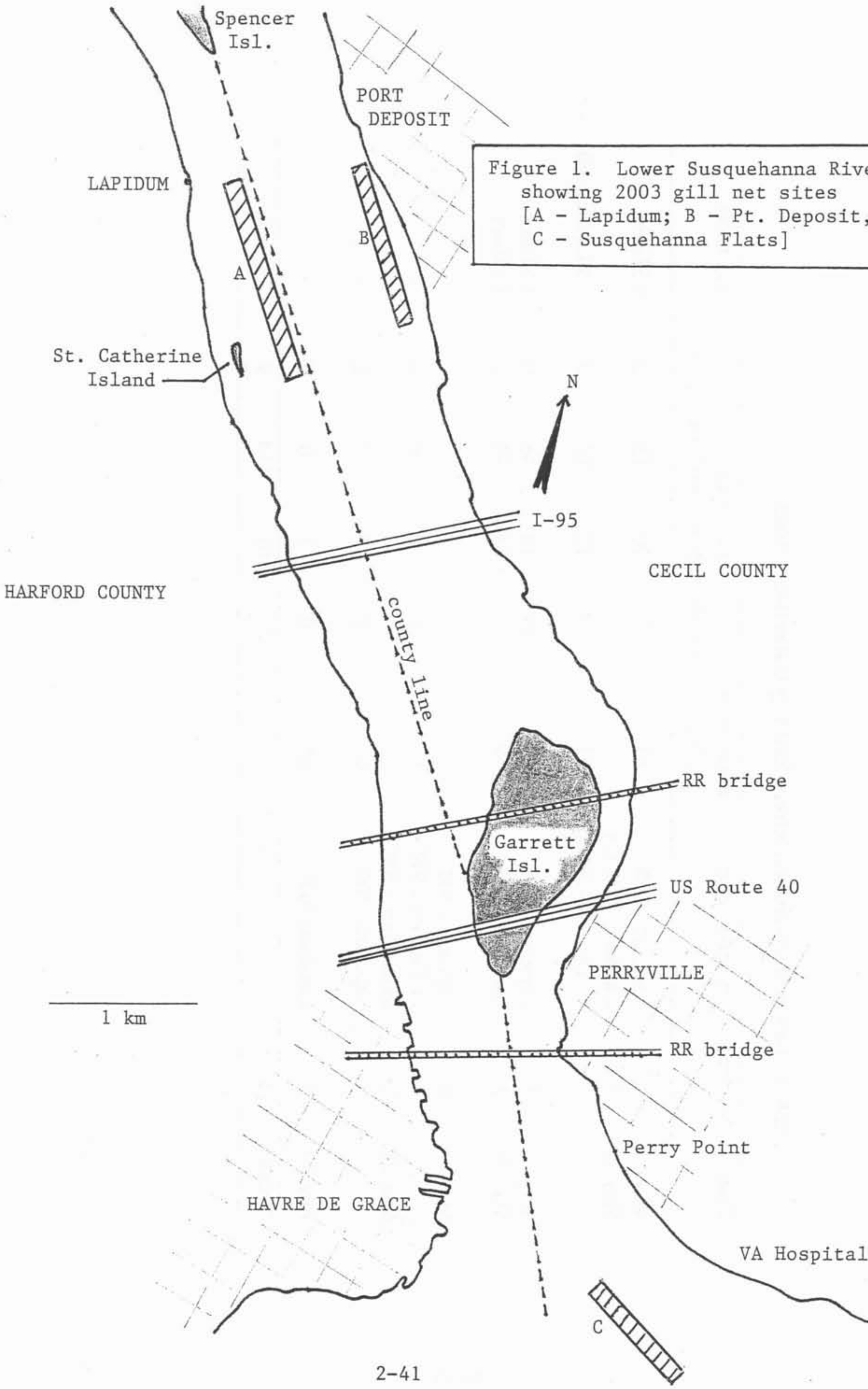


Figure 1. Lower Susquehanna River showing 2003 gill net sites [A - Lapidum; B - Pt. Deposit, C - Susquehanna Flats]

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 2003

M. L. Hendricks

Pennsylvania Fish and Boat Commission

Benner Spring Fish Research Station

State College, PA

INTRODUCTION

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

In 2003, a new effort in migratory fish restoration was undertaken. Adult hickory shad (*Alosa mediocris*) were collected and tank-spawned as part of the initial efforts to culture, release and restore runs of hickory shad to the Susquehanna and Delaware River basins. As in previous years, production goals for American shad for 2003 were to stock 10-20 million larvae. All Van Dyke hatchery-reared American and hickory shad larvae were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by natural spawning. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

EGG SHIPMENTS

Hickory shad

A total of 14.4 million hickory shad eggs (30.0 L) were received in five shipments from tank-spawning operations at Conowingo Dam (Table 1). Some 6.3 million (44.1%) of the hickory shad eggs were viable.

American shad

A total of 33.0 million American shad eggs (944 L) were received in 54 shipments in 2003 (Table 1). This was the fourth-highest quantity of eggs received since the program began in 1976 (Table 2). Overall American shad egg viability (which we define as the percentage which ultimately hatches) was 49.4%. Increased egg viability, compared to 2002, was due to the high viability of eggs received from strip-spawning operations on the Delaware River (61.8%), and increased egg viability from tank-spawn operations at Conowingo Dam (17.7%).

Hudson River egg shipments were received from May 6 to June 1, 2003. Hudson River eggs were collected only from the site at Coxsackie, where water depths permit gill netting at all stages of the tide. Twenty-three shipments (17.1 million eggs) were delivered with an overall viability of 68.5%.

Delaware River shipments were received from May 9 to May 30. A total of 13 shipments of eggs were received from the Delaware River (3.6 million eggs) with a viability of 61.8%.

The U.S. Fish and Wildlife Service obtained eggs by strip-spawning ripe adult shad collected by gill net in the lower Susquehanna River near Lapidum MD. Three shipments were received (15.6L) between May 14 and May 22. A total of 555 thousand eggs were received with a viability of 67.6%.

Normandeau Associates, under contract with the PFBC, obtained eggs by strip-spawning ripe adult shad collected by gill net in the upper portion of Conowingo Reservoir. One shipment of 0.6L (23 thousand eggs) was received on May 28. Viability was 18.2%.

American shad eggs were also obtained from a tank-spawning operation at Conowingo Dam, operated by Normandeau Associates. Pre-spawn adult American shad were obtained from the West Fish Lift at Conowingo Dam, injected with hormones and allowed to spawn naturally. Some 11.7 million eggs, in 14 shipments, were delivered to the Van Dyke Hatchery. Viability of Conowingo tank-spawned eggs, delivered to Van Dyke for incubation was 17.7%.

SURVIVAL

Overall survival of American shad larvae was 78% compared to a range of 19% to 94% for the period 1984 through 2002. The high survival is in stark contrast to 19% survival in 2002, believed to be due to toxicity associated with fire retardants in the foam bottom screen used on Van Dyke incubation jars.

Survival of individual tanks followed four patterns (Figure 1). The majority of tanks (42 tanks) exhibited 20-d survival averaging 85%. This is typical of survival patterns experienced in the past. Five tanks exhibited slightly lower survival, and were held longer due to high flow conditions at the stocking sites, exhibiting 26-d survival of 67%. Two tanks exhibited comparatively high mortalities early and again after 20d of age, for an overall 26-d survival of 55%. One tank suffered high mortality (25% mortality) on day one as a result of larvae laying on the bottom of the tank and smothering each other. The mortality problems experienced in 2002 were not repeated in 2003. New foam bottom screens were purchased, specifying no fire retardants or additives. Additional discussion of larval survival, as it relates to foam bottom screens, can be found in Appendix 1.

LARVAL PRODUCTION

One million hickory shad larvae were stocked in the lower Susquehanna River (Conowingo Reservoir) at Muddy Creek Access and 2.9 million were stocked in Ridley Cr., Chester County, a tributary to the Delaware River.

Production and stocking of American shad larvae, summarized in Tables 2, 3 and 4, totaled 12.7 million. A total of 4.0 million was released in the Juniata River, 492 thousand in the North Branch Susquehanna River in New York, 414 thousand in the Chemung River in New York, 800 thousand in the North Branch Susquehanna River in Pennsylvania, and 592 thousand in the West Branch Susquehanna River. American shad larvae were also stocked in tributaries: 168 thousand in Conodoguinet Creek, 158 thousand in the Conestoga River, 293 thousand in West Conewago Creek and 108 thousand in Swatara Creek. In addition, 783 thousand larvae were stocked in the Lehigh

River and 1.0 million were stocked in the Schuylkill River to support restoration efforts there.

TETRACYCLINE MARKING

All American and hickory shad larvae produced at Van Dyke received marks produced by immersion in tetracycline (Table 5). Immersion marks were administered by bath treatments in 256-ppm oxytetracycline hydrochloride for 4h duration. All hickory shad larvae were marked with a single mark on day 1, while all American shad larvae were marked according to stocking site and/or egg source. American shad larvae from the Susquehanna River egg source, and stocked in the Juniata River or Susquehanna River near Montgomery Ferry were given a triple mark at 3, 6, and 9 days of age. Larvae from out-of-basin egg sources and stocked in the Juniata River or Susquehanna River near Montgomery Ferry were marked at 3 days of age. Larvae stocked in the Conodoguinet Creek were given a quadruple mark at 3, 6, 12 and 15 days of age. Larvae stocked in the Conestoga River were given a quadruple mark at 3, 9, 12, and 15 days of age. Larvae stocked in Swatara Creek were given a quintuple mark at 3, 6, 9, 15, and 18 days of age. Larvae stocked in West Conewago Cr. were given a triple mark at 3, 6 and 12 days of age. Larvae stocked in the North Branch Susquehanna River (NY) were given a quintuple mark at 3, 6, 9, 12, and 18 days of age. Larvae stocked in the Chemung River (NY) were given a triple mark at 3, 12 and 15 days of age. Larvae stocked in the North Branch Susquehanna River (PA) were given a quintuple mark at 3, 6, 12, 15 and 18 days of age. Larvae stocked in the Lehigh River were given a triple mark at 9, 12, and 15 days of age. Larvae stocked in the Schuylkill River were given a quadruple mark at 3, 6, 9, and 12 days of age.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways and examining otolith samples collected later. Otoliths were extracted and mounted in Permount on microscope slides. A thin section was produced by grinding the otolith on both sides. Otolith sections were examined for marks with an epi-fluorescent microscope with a UV light source. Retention of tetracycline marks for American shad was 100% for all groups analyzed (Table 5), however, some of the specimens had marks which bled together and thus appeared to be incorrectly marked. Eight of 20 shad marked on days 3, 9, and 12 (West Branch Susquehanna River) appeared to be marked on days 3, 9, and 10. One of 20 had a continuous glow from day 3 to day 9 with a brighter glow on day 9. Four of 20 shad marked on days 3, 9, 12 and 15 (Conestoga River) appeared to be marked on days 3, 9, and 10. Two of 20 had a continuous glow from day 3 to day 9 with a brighter glow on day 9. Two of 20 shad marked on days 3, 6 and 12 (W. Conewago Cr.) had the marks bled together. One of 20 had a single bright mark on day 10. All of these groups had daily increments that were very close together. This is probably a result of low tank water temperatures during marking, resulting from cold weather and high water demand. Van Dyke culture water is adjusted to achieve a median temperature of 64-65F. During the period from May 23, 2003 to June 8, 2003, when the non-typical marks were created, the average of the median water temperature was 62F (Figure 2). From June 1 to June 5 the median was below 60F. During this time the furnace was running continuously, but was unable to elevate water temperature to the desired 64-65F. Since otolith growth is correlated with metabolic rate, not somatic growth

(Gauldie and Nelson 1990), this accounts for the narrow increments and non-typical marks. Shad collected from the wild, which exhibit these atypical marks, will be difficult or impossible to assign to a stocking site.

Only 3 of 20 (15%) of the hickory shad otoliths examined exhibited marks. Of the fish that were not marked upon examination of the first otolith, an additional 3 fish had marks on the second otolith. This low marking success may be a result of attempting to apply the mark too early (one day of age). Walleye fry also exhibit poor marking success before 3 days of age (Brooks et al. 1994). In 2004, we will postpone hickory shad marking until day 3. Analysis of survival of each uniquely marked group is discussed in Appendix II.

SUMMARY

Five shipments of hickory shad eggs (14.4 million eggs) were received at Van Dyke in 2003. Egg viability was 44.1% and 2.95 million hickory shad larvae were stocked in Conowingo Reservoir and Ridley Creek (Delaware River tributary).

A total of 54 shipments of American shad eggs (33.0 million eggs) was received at Van Dyke in 2003. Total egg viability was 49% and survival of viable eggs to stocking was 78%, resulting in production of 12.7 million larvae. Larvae were stocked in the Juniata River (4.0 million), Susquehanna River near Montgomery Ferry (3.6 million), Conodoguinet Cr. (168 thousand), Conestoga River (158 thousand), Swatara Creek (108 thousand), West Conewago Cr. (293 thousand), the North Branch Susquehanna River (NY-492 thousand), the Chemung River (NY- 415 thousand), the North Branch

Susquehanna River (PA-800 thousand), the West Branch Susquehanna River (592 thousand), the Lehigh River (783 thousand), and the Schuylkill River (1.0 million).

Overall survival of larvae was 78%. Problems with mortality associated with foam bottom screens did not re-occur in 2003.

All American and hickory shad larvae cultured at Van Dyke were marked by 4-hour immersion in 256 ppm oxytetracycline. Marks for American shad were assigned based on release site and/or egg source river. Some groups of American shad exhibited atypical marks, probably related to low water temperature during marking. Hickory shad were marked on day one. Mark retention problems for hickory shad may have been related to marking too early in development.

RECOMMENDATIONS FOR 2004

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55F.
3. Routinely feed all larvae beginning at hatch.
4. Continue to hold egg jars on the incubation battery until eggs begin hatching (usually day 7), before transferring to the tanks. Transfer incubation jars to the tanks on day 7 without sunning. Sun the eggs on day 8 to force hatching.
5. Continue to siphon eggshells from the rearing tank within hours of egg hatch.
6. Continue to feed left over AP-100 only if freshly manufactured supplies run out.
7. Continue to hold Delaware River eggs until 8:00AM before processing.
8. Buy new foam bottom screens each year and specify "no-fire retardants" when ordering foam.

9. Conduct controlled experiments to determine the impact of foam bottom screens on survival of larvae after day 10 (see appendix 1).
10. Modify the egg battery to accept 12 additional MSXXX jars (total 34)
11. Construct additional aluminum bottom screens with Chapman diffusers for the existing Van Dyke jars to replace the foam bottoms if they are shown to be detrimental to larval survival after 10 days of age.
12. Develop a reference collection of scales and otoliths from known age American shad by marking according to year stocked (Table 6). Utilize larvae from the Hudson River egg source, stocked in the Juniata or Susquehanna Rivers, and uniquely marked on a three year rotating schedule.
13. Mark hickory shad at day three and stock at day four.

LITERATURE CITED

Brooks, R. C., R. C. Heidinger, and C. C. Kohler. 1994. Mass-marking otoliths of larval and juvenile walleyes by immersion in oxytetracycline, calcein or calcein blue. North American Journal of Fisheries Management 14:143-150.

Gauldie, R. W. and D. G. A. Nelson. 1990. Otolith growth in fishes. Comparative Biochemistry and Physiology 97A (2): 119-135.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Job III. American shad hatchery operations. 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, 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, 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.

Hendricks, M. L. 1999. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1998. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2001. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2000. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2002. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2001. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2003. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2002. Susquehanna River Anadromous Fish Restoration Committee.

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

Figure 1. Survival patterns for American shad larvae reared at Van Dyke, 2003.

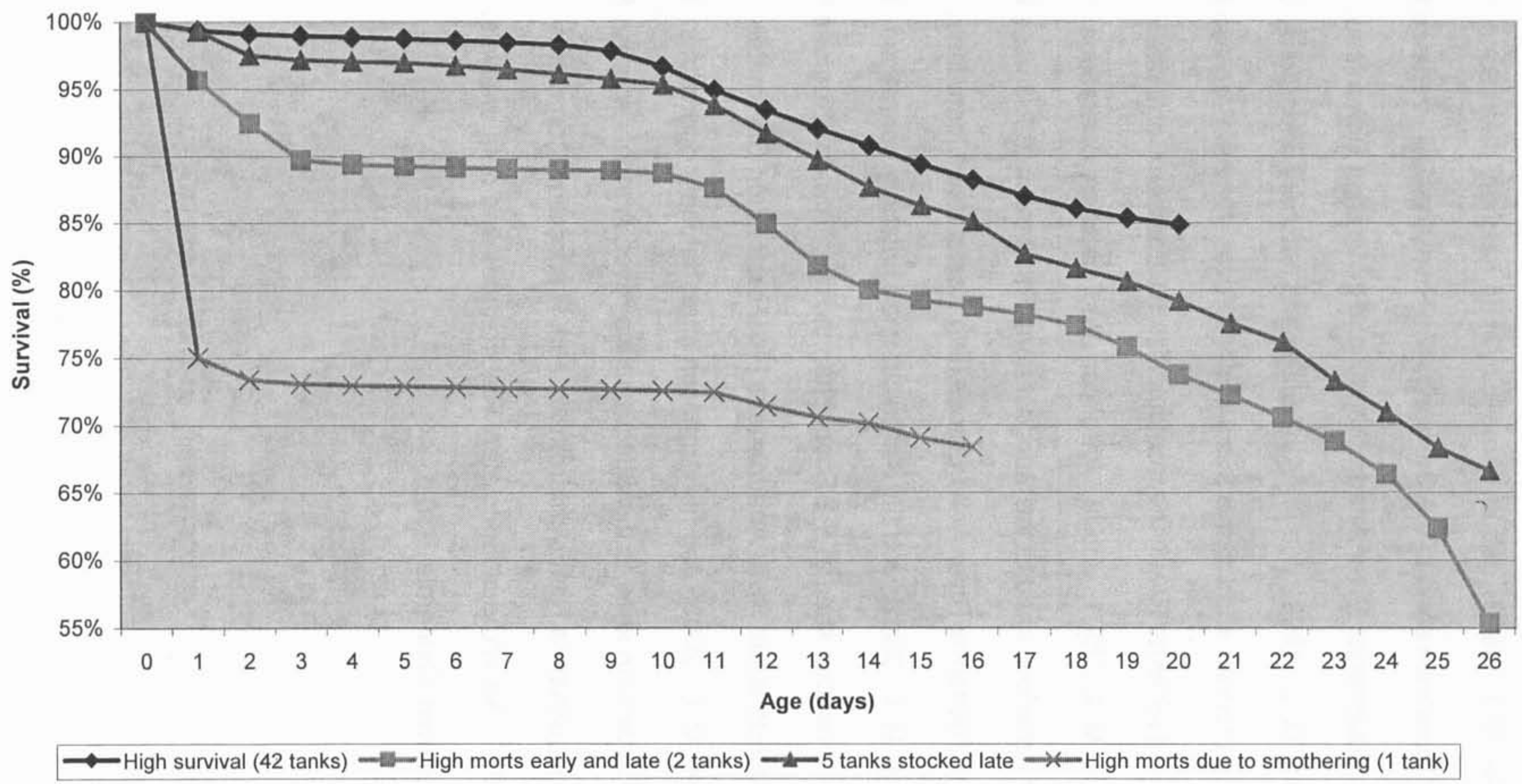


Figure 2. Maximum, minimum, and median water temperatures (F) during OTC marking of tanks that exhibited non-typical marks, Van Dyke 2003.

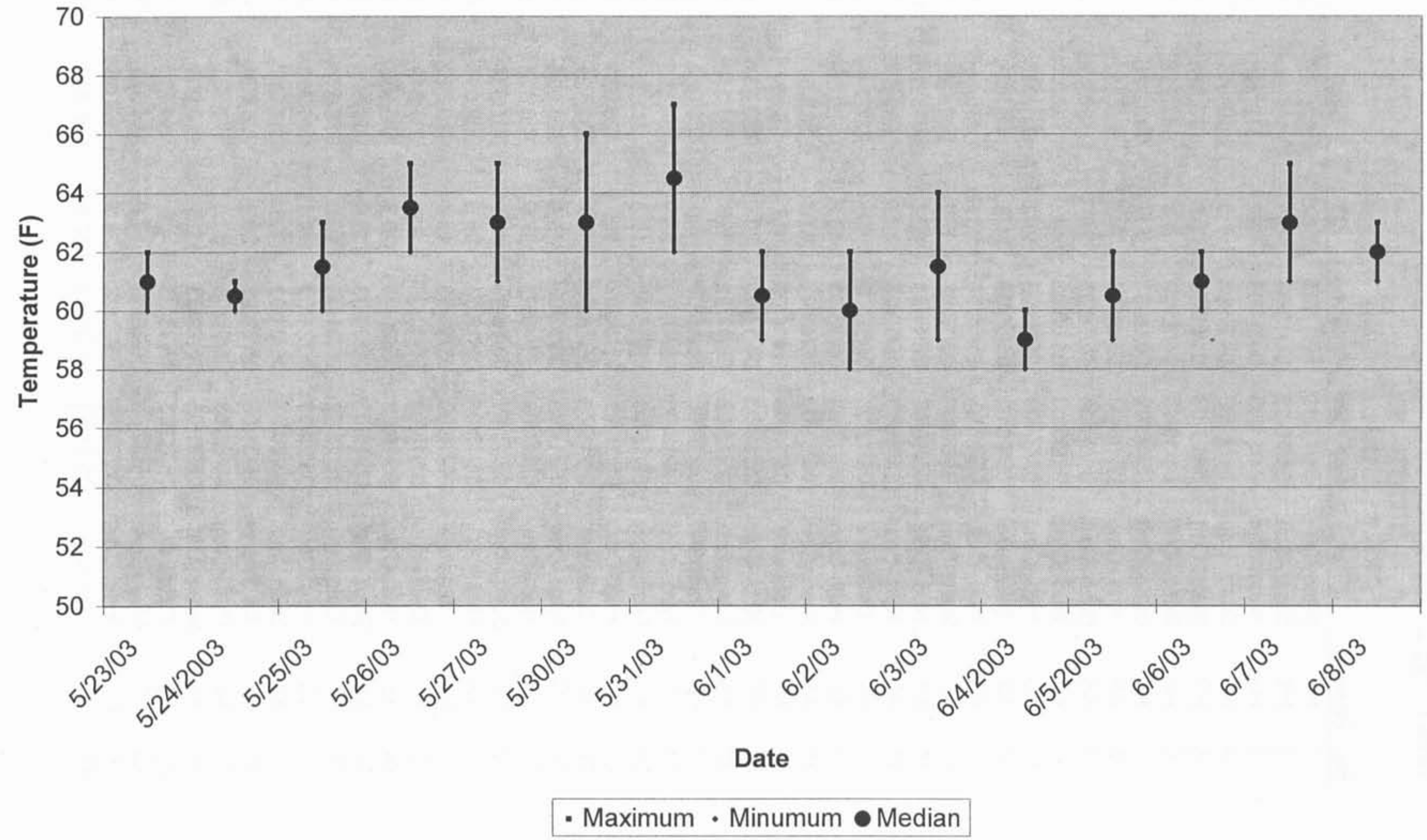


Table 1. Egg shipments received at Van Dyke, 2003.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
1	HS	Susq.-Con.	04/17/03	04/17/03	15.6	8,825,520	3,376,384	38.3%
2	HS	Susq.-Con.	04/19/03	04/19/03	5.1	2,106,944	749,962	35.6%
3	HS	Susq.-Con.	04/24/03	04/24/03	0.9	319,726	263,795	82.5%
4	HS	Susq.-Con.	04/27/03	04/27/03	7.3	2,598,464	1,865,274	71.8%
5	HS	Susq.-Con.	04/27/03	04/27/03	1.3	573,075	106,239	18.5%
6	AS	Susq.-Con.	04/30/03	04/30/03	9.8	657,218	135,554	20.6%
7	AS	Susq.-Con.	05/02/03	05/02/03	11.6	730,385	21,324	2.9%
8	AS	Hud.-Cox.	05/05/03	05/06/03	14.6	366,852	49,772	13.6%
9	AS	Susq.-Con.	05/06/03	05/06/03	28.8	1,180,436	380,613	32.2%
10	AS	Hud.-Cox.	05/06/03	05/07/03	44.9	1,196,141	748,428	62.6%
11	AS	Hud.-Cox.	05/07/03	05/08/03	24.5	601,180	337,338	56.1%
12	AS	Delaware	05/08/03	05/09/03	1.3	43,758	21,643	49.5%
13	AS	Hud.-Cox.	05/08/03	05/09/03	56.8	1,495,698	932,861	62.4%
14	AS	Susq.-Con.	05/10/03	05/10/03	16.5	942,671	172,591	18.3%
15	AS	Hud.-Cox.	05/10/03	05/11/03	82.6	2,075,476	1,231,316	59.3%
16	AS	Hud.-Cox.	05/11/03	05/12/03	41.2	1,229,676	720,927	58.6%
17	AS	Delaware	05/12/03	05/13/03	8.6	277,244	191,820	69.2%
18	AS	Hud.-Cox.	05/12/03	05/13/03	46.5	1,326,866	968,595	73.0%
19	AS	Susq.-Con.	05/13/03	05/13/03	17.1	1,285,511	131,092	10.2%
20	AS	Delaware	05/13/03	05/14/03	2.7	95,837	0	0.0%
21	AS	Hud.-Cox.	05/13/03	05/14/03	30.0	780,831	542,464	69.5%
22	AS	Susq.-Lap.	05/13/03	05/14/03	5.5	197,286	174,934	88.7%
23	AS	Delaware	05/14/03	05/15/03	4.0	159,064	99,475	62.5%
24	AS	Hud.-Cox.	05/14/03	05/15/03	38.9	954,526	672,854	70.5%
25	AS	Susq.-Con.	05/15/03	05/15/03	19.8	1,051,852	136,705	13.0%
26	AS	Hud.-Cox.	05/15/03	05/16/03	4.5	126,958	99,731	78.6%
27	AS	Delaware	05/15/03	05/16/03	7.5	202,124	89,095	44.1%
28	AS	Susq.-Con.	05/17/03	05/17/03	13.0	628,986	97,349	15.5%
29	AS	Hud.-Cox.	05/17/03	05/18/03	27.9	726,173	570,247	78.5%
30	AS	Susq.-Con.	05/18/03	05/18/03	5.2	237,534	38,005	16.0%
31	AS	Hud.-Cox.	05/18/03	05/19/03	35.3	908,095	675,498	74.4%
32	AS	Delaware	05/18/03	05/19/03	13.0	330,522	146,114	44.2%
33	AS	Delaware	05/19/03	01/00/00	9.0	268,619	213,185	79.4%
34	AS	Hud.-Cox.	05/19/03	05/20/03	20.7	570,835	485,294	85.0%
35	AS	Susq.-Con.	05/19/03	05/20/03	18.6	925,809	87,103	9.4%
36	AS	Delaware	05/20/03	05/21/03	16.3	578,574	426,113	73.6%
37	AS	Hud.-Cox.	05/20/03	05/21/03	19.1	526,713	449,386	85.3%
38	AS	Susq.-Lap.	05/20/03	05/21/03	7.5	247,077	191,370	77.5%
39	AS	Delaware	05/21/03	05/22/03	24.9	726,724	444,557	61.2%
40	AS	Hud.-Cox.	05/21/03	05/22/03	33.6	874,531	631,892	72.3%
41	AS	Susq.-Lap.	05/21/03	05/22/03	2.6	110,902	9,272	8.4%
42	AS	Delaware	05/22/03	05/23/03	4.6	154,835	56,655	36.6%
43	AS	Hud.-Cox.	05/22/03	05/23/03	14.3	394,345	310,961	78.9%
44	AS	Susq.-Con.	05/23/03	05/23/03	24.3	1,088,667	163,937	15.1%
45	AS	Hud.-Cox.	05/24/03	05/25/03	32.9	856,312	641,453	74.9%

Table 1. Continued.

No.	Species	River	Date Spawned	Date Received	Volume (L)	Eggs	Viable Eggs	Percent Viable
46	AS	Hud.-Cox.	05/25/03	05/26/03	23.2	603,843	454,003	75.2%
47	AS	Hud.-Cox.	05/26/03	05/27/03	7.9	243,764	196,090	80.4%
48	AS	Delaware	05/26/03	05/27/03	4.1	147,068	91,028	61.9%
49	AS	Hud.-Cox.	05/27/03	05/28/03	17.0	548,041	451,515	82.4%
50	AS	Susq.-MR	05/27/03	05/28/03	0.6	23,379	4,262	18.2%
51	AS	Susq.-Con.	05/27/03	05/28/03	27.1	1,479,768	283,715	19.2%
52	AS	Delaware	05/28/03	05/29/03	9.3	244,894	163,216	66.6%
53	AS	Hud.-Cox.	05/28/03	05/29/03	14.4	401,667	338,544	84.3%
54	AS	Delaware	05/29/03	05/30/03	12.9	385,020	290,065	75.3%
55	AS	Hud.-Cox.	05/29/03	05/30/03	8.8	259,731	177,092	68.2%
56	AS	Susq.-Con.	05/30/03	05/30/03	10.2	430,782	158,803	36.9%
57	AS	Susq.-Con.	05/31/03	05/31/03	11.1	487,668	100,316	20.6%
58	AS	Hud.-Cox.	05/31/03	06/01/03	1.6	52,710	45,495	86.3%
59	AS	Susq.-Con.	06/05/03	06/05/03	15.9	594,604	67,451	11.3%
Totals				No. of shipments				
American shad								
		Hudson-Coxsackie		23	641.2	17,120,964	11,731,757	68.5%
		Delaware		13	118.2	3,614,283	2,232,965	61.8%
		Susq.-Lapidum		3	15.6	555,265	375,576	67.6%
		Susq.-Muddy Run		1	0.6	23,379	4,262	18.2%
		Susq.-Conowingo		14	229.0	11,721,891	1,974,560	17.7%
		Grand total		54	1,004.6	33,035,782	16,319,121	49.4%
Hickory shad								
		Susq.-Conowingo		5	30.0	14,423,730	6,361,654	44.1%

HS- hickory shad
AS- American shad

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976-2003.

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

Table 2. (continued).

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via-bility (%)	No. of Viable Eggs (exp.6)	No. of Fry stocked (exp.3)	No. of Finglerling stocked (exp.3)	Total stocked (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1998	628	27.7	57.4	15.9	11,757	2	11,759	0.42	0.74
1999	700	26.6	59.2	15.7	14,412	-	14,412	0.54	0.92
2000	503	18.7	64.8	12.1	10,535	-	10,535	0.56	0.87
2001	423	21.1	35.0	7.4	6,524	7	6,531	0.31	0.88
2002	943	35.6	38.8	13.8	2,589	-	2,589	0.07	0.19
2003	1005	33.0	49.4	16.3	12,742	3.2	12,742	0.39	0.78
						Total	229,575		
				Total since 1985 (OTC marked)			198,178		

*Includes fry reared at Manning Hatchery.

Table 3. American shad stocking and fish transfer activities, 2003.

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age (days)	Size
4/26/03	A1 1	Hickory shad	500,000	Muddy Cr. Access	1	Susq.-Conowingo	2	Fry
4/26/03	A2 1	Hickory shad	500,000	Muddy Cr. Access	1	Susq.-Conowingo	2	Fry
4/28/03	A3 1	Hickory shad	200,000	Ridley Cr.	1	Susq.-Conowingo	2	Fry
5/3/03	A4 1	Hickory shad	250,000	Ridley Cr.	1	Susq.-Conowingo	2	Fry
5/5/03	B1 1	Hickory shad	1,500,000	Ridley Cr.	1	Susq.-Conowingo	3	Fry
5/19/03	B2 1	American shad	127,029	Montgomery Ferry	3,6,9	Susq.-Conowingo	12	Fry
5/19/03	B3 1	American shad	17,875	Montgomery Ferry	3,6,9	Susq.-Conowingo	10	Fry
5/19/03	B4 1	American shad	238,279	Montgomery Ferry	3	Hudson	6	Fry
5/23/03	C1 1	American shad	367,815	Liverpool	3,6,9	Susq.-Conowingo	10	Fry
5/29/03	C2 1	American shad	201,907	Chemung River	3,12,15	Hudson	16	Fry
5/29/03	C3 1	American shad	212,814	Chemung River	3,12,15	Hudson	16	Fry
5/23/03	C4 1	American shad	329,344	Liverpool	3	Hudson	7	Fry
6/20/03	D1 1	American shad	166,866	Schuylkill River	3,6,9,12	Delaware	30	Fry
6/5/03	D2 1	American shad	118,995	N. Br. Susq. R. (NY)	3,6,9,12,18	Hudson	19	Fry
6/5/03	D3 1	American shad	372,994	N. Br. Susq. R. (NY)	3,6,9,12,18	Hudson	19	Fry
5/23/03	D4 1	American shad	372,881	Liverpool	3	Hudson	6	Fry
6/13/03	E1 1	American shad	286,046	Montgomery Ferry	3,6,9	Susq.-Conowingo	23	Fry
5/27/03	E2 1	American shad	306,314	Warrior Ridge Dam	3	Hudson	11	Fry
5/27/03	E3 1	American shad	302,226	Warrior Ridge Dam	3	Hudson	11	Fry
5/27/03	E4 1	American shad	323,902	Warrior Ridge Dam	3	Hudson	11	Fry
5/27/03	F1 1	American shad	248,890	Tuscarora Cr.	3	Hudson	10	Fry
6/13/03	F2 1	American shad	307,932	W. Br. Susq. R.	3,9,12	Hudson	24	Fry
6/13/03	F3 1	American shad	283,626	W. Br. Susq. R.	3,9,12	Hudson	24	Fry
6/12/03	F4 1	American shad	383,512	N. Br. Susq. R.	3,6,12,15,18	Hudson	22	Fry
6/12/03	G1 1	American shad	416,618	N. Br. Susq. R.	3,6,12,15,18	Hudson	22	Fry
6/26/03	G2 1	American shad	151,355	Schuylkill River	3,6,9,12	Delaware	32	Fry
6/30/03	G3 1	American shad	107,867	Swatara Cr.	3,6,9,15,18	Hudson	38	Fry
6/18/03	G4 1	American shad	167,774	Conodoguinet Cr.	3,6,12,15	Hudson	26	Fry
6/14/03	H1 1	American shad	112,190	Montgomery Ferry	3,6,9	Susq.-Lapidum	22	Fry
6/30/03	H2 1	American shad	158,146	Conestoga R.	3,9,12,15	Hudson	37	Fry
6/18/03	H3 1	American shad	293,183	W. Conewago Cr.	3,6,12	Hudson	25	Fry
6/14/03	H4 1	American shad	236,050	Montgomery Ferry	3,6,9	Susq.-Conowingo	20	Fry

Table 3. (continued).

Date	Tank	Species	Number	Location	OTC mark (days)	Origin	Age	Size
6/15/03	I1 1	American shad	481,648	Liverpool	3	Hudson	21	Fry
6/15/03	I2 1	American shad	291,155	Liverpool	3	Hudson	20	Fry
6/16/03	I3 1	American shad	231,886	Mahantango	3	Hudson	21	Fry
6/26/03	I4 1	American shad	130,279	Schuylkill River	3,6,9,12	Delaware	29	Fry
6/20/03	I4 1	American shad	150,000	Schuylkill River	3,6,9,12	Delaware	23	Fry
6/16/03	A1 2	American shad	358,109	Mahantango	3	Hudson	19	Fry
6/17/03	A2 2	American shad	371,594	Millerstown (Greenwood)	3,6,9	Susq. Con./Lap.	19	Fry
6/19/03	A3 2	American shad	341,474	Lehigh River	9,12,15	Delaware	21	Fry
6/17/03	A4 2	American shad	309,631	Millerstown (Greenwood)	3	Hudson	17	Fry
6/19/03	B1 2	American shad	322,849	Lehigh River	9,12,15	Delaware	20	Fry
6/17/03	B2 2	American shad	290,399	Millerstown (Rt. 17)	3	Hudson	18	Fry
6/17/03	B3 2	American shad	196,864	Millerstown (Rt. 17)	3	Hudson	18	Fry
6/19/03	B4 2	American shad	118,689	Lehigh River	9,12,15	Delaware	16	Fry
6/27/03	C1 2	American shad	364,325	Huntingdon	3	Hudson	26	Fry
6/27/03	C2 2	American shad	254,543	Raritan River	3	Hudson	26	Fry
6/30/03	C3 2	American shad	171,570	Huntingdon	3	Hudson	28	Fry
6/17/03	C4 2	American shad	137,255	Millerstown (Rt. 17)	3	Hudson	12	Fry
6/21/03	D2 2	American shad	200,862	Montgomery Ferry	3	Hudson	13	Fry
6/27/03	D3 2	American shad	42,172	Huntingdon	3,6,9	Susq.-Conowingo	14	Fry
6/27/03	D4 2	American shad	337,670	Huntingdon	3	Hudson	22	Fry
6/30/03	E2 2	American shad	386,453	Huntingdon	3,6,9	Susq. Con./Lap.	25	Fry
6/26/03	E3 2	American shad	140,117	Schuylkill River	3,6,9,12	Delaware	19	Fry
6/30/03	E4 2	American shad	219,454	Huntingdon	3	Hudson	23	Fry
6/26/03	F1 2	American shad	261,831	Schuylkill River	3,6,9,12	Delaware	18	Fry

Table 4. Production and utilization of juvenile Alosids, Van Dyke, 2003.

	Site	Fry
American shad Releases	Millerstown (Greenwood)	681,226
	Millerstown (Rt. 17 Bridge)	624,517
	Huntingdon	1,521,643
	Warrior Ridge Dam	932,442
	Tuscarora Creek	248,890
	Juniata River Subtotal	4,008,719
	Montgomery Ferry	1,218,330
	Liverpool	1,842,843
	Mahantango	589,995
	Conodoguinet Creek	167,774
	Conestoga River	158,146
	Swatara Creek	107,867
	West Conewago Creek	293,183
	North Branch Susquehanna River (PA)	800,129
	West Banch Susquehanna River	591,558
	Chemung River	414,721
	North Branch Susquehanna River (NY)	491,988
	Susquehanna River Basin Subtotal	10,685,252
	Schuylkill River	1,020,169
	Lehigh River	783,013
	Raritan River	254,543
	Total American shad	**12,742,976**
Hickory shad releases	Muddy Creek Access Area- Susquehanna. River Basin	1,000,000
	Ridley Creek- Delaware river Basin	1,950,000
	Total Hickory shad	**2,950,000**

Table 5. Summary of marked Alosids stocked in Pennsylvania, 2003.

Number	Size	Immersion Mark (days)	Feed Mark Feed	Immersion Tag	Feed Tag	Immersion Mark Retention (%)	Feed Mark Retention (%)	Fry Culture	Fingerling Culture	Stocking Location	Egg Source
American shad											
5,712,662	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata/Susq. R.	Hudson
1,947,223	Fry	3,6,9	-	256ppm OTC	-	100	-	Van Dyke	-	Juniata/Susq. R.	Susquehanna
591,558	Fry	3,9,12	-	256ppm OTC	-	100 a	-	Van Dyke	-	W. Br. Susq. R.	Hudson
167,774	Fry	3,6,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Conodoguinet Cr.	Hudson
158,146	Fry	3,9,12,15	-	256ppm OTC	-	100 b	-	Van Dyke	-	Conestoga R.	Hudson
293,183	Fry	3,6,12	-	256ppm OTC	-	100 c	-	Van Dyke	-	W. Conewago Cr.	Hudson
107,867	Fry	3,6,9,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	Swatara Cr.	Hudson
800,129	Fry	3,6,12,15,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.(PA)	Hudson
491,988	Fry	3,6,9,12,18	-	256ppm OTC	-	100	-	Van Dyke	-	N. Br. Susq. R.(NY)	Hudson
414,721	Fry	3,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Chemung R. (NY)	Hudson
783,013	Fry	9,12,15	-	256ppm OTC	-	100	-	Van Dyke	-	Lehigh R.*	Delaware
1,020,169	Fry	3,6,9,12	-	256ppm OTC	-	100	-	Van Dyke	-	Schuylkill R.*	Delaware
254,543	Fry	3	-	256ppm OTC	-	100	-	Van Dyke	-	Raritan R. (NJ)	-
12,742,976	Fry	Total									
Hickory shad											
1,000,000	Fry	1		256ppm OTC	-	15.0% d	-	Van Dyke	-	Conowingo Res.	Susquehanna
1,950,000	Fry	1		256ppm OTC	-	15.0% d	-	Van Dyke	-	Ridley Cr.*	Susquehanna
2,950,000	Fry	Total									

a Daily increments very close together. Eight of 20 looked like triple tag on days 3,9,10. One of 20 had continuous glow from day 3 to day 9 with brighter glow at day 9.

b Daily increments very close together. Four of 20 looked like triple tag on days 3,9,10. Two of 20 had continuous glow from day 3 to day 9 with brighter glow at day 9.

c Daily increments are very close together. Two of 20 have day 3 and 6 tags bled together. One of 20 has one bright tag at day 10.

d Three additional specimens (15%) had tag on one otolith but not on the other.

* Tributary to the Delaware River.

Table 6. Proposed marking plan for Alosines stocked in Pennsylvania, 2004-2009.

Size	Immersion mark (days)	Immersion mark	Stocking Location	Egg Source	Years
American shad					
Fry	3	256ppm OTC	Juniata/Susq. R.	Hudson	2006, 2009
Fry	3,9,12	256ppm OTC	Juniata/Susq. R.	Hudson	2004, 2007
Fry	3,6,12	256ppm OTC	Juniata/Susq. R.	Hudson	2005, 2008
Fry	3,6,9	256ppm OTC	Juniata/Susq. R.	Susquehanna	2004-2009
Fry	3,6,9,12,15	256ppm OTC	W. Br. Susq. R.	Hudson	2004-2009
Fry	3,6,12,15	256ppm OTC	Conodoguinet Cr.	Hudson	2004-2009
Fry	3,9,12,15	256ppm OTC	Conestoga R.	Hudson	2004-2009
Fry	3,9,12,15,18	256ppm OTC	W. Conewago Cr.	Hudson	2004-2009
Fry	3,6,9,15,18	256ppm OTC	Swatara Cr.	Hudson	2004-2009
Fry	3,6,9,15	256ppm OTC	N. Br. Susq. R.(PA)	Hudson	2004-2009
Fry	3,6,9,12,18	256ppm OTC	N. Br. Susq. R.(NY)	Hudson	2004-2009
Fry	3,15,18	256ppm OTC	Chemung R. (NY)	Hudson	2004-2009
Fry	9,12,15	256ppm OTC	Lehigh R.	Delaware	2004-2009
Fry	3,6,9,12	256ppm OTC	Schuylkill R.	Delaware	2004-2009
Fry	3	256ppm OTC	Raritan R. (NJ)	Hudson	2004-2009
Hickory shad					
Fry	3	256ppm OTC	Conowingo Res.	Susquehanna	2004-2009
Fry	3	256ppm OTC	Delaware River	Susquehanna	2004-2009
Fry	3	256ppm OTC	Ridley Cr.	Susquehanna	2004-2009

Appendix I

Egg viability and survival of larvae from American shad eggs incubated in various egg jar configurations, Van Dyke, 2003

Michael L. Hendricks

Pennsylvania Fish and Boat Commission

Division of Research

Benner Spring Fish Research Station

1225 Shiloh Rd.

State College, Pa. 16801

Introduction

American shad eggs incubated at the Van Dyke Hatchery between 1976 and 1987 were incubated exclusively in May-Sloan incubation jars. In 1987, we constructed, and began testing homemade incubation jars that we named the "Van Dyke jar". Van Dyke jars were made from clear plastic jars, previously used in manufacture of batteries. Specifications of the May-Sloan and Van Dyke jars are listed in Table 1. While use of the Van Dyke jar increased egg battery capacity from 250L to 450L, problems with dead spots (areas of reduced flow) in the jar were common. Upwelling flow in the May-Sloan jar, with its 6-inch (152mm) diameter, was generally sufficient to keep all the eggs rolling, unless the flow was reduced by improper adjustment, attempts to conserve water, or an obstruction that blocked the orifice. In contrast, the larger diameter (13.5 inches, 343mm) Van Dyke jar, when fitted with a window screen bottom, experienced routine problems with dead spots in the middle of the jar, as the flow was concentrated around the perimeter. These dead spots resulted in mortality of fully developed, eyed eggs, which appeared to be dead fry in the jar.

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

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

In 2002, overall survival of larvae was 19% compared to a range of 41% to 94% for the period 1984 through 2001 (Hendricks 2003). The low survival is believed to be due to toxicity associated with fire retardants in the foam bottom screen used on Van Dyke incubation jars.

Survival of individual tanks in 2002 followed two patterns (Figure 1). Four tanks, whose eggs were incubated in May-Sloan Jars, exhibited 13-day survival averaging 89.5%. This is typical of survival patterns experienced in the past. All remaining tanks suffered high mortality beginning on days 3 and 4. These tanks experienced problems with larvae lying on the bottom of the tank and the larvae fed very poorly, if at all. All larvae in this group came from eggs incubated in Van Dyke jars, with foam bottom screens. Fourteen-day survival for these tanks averaged 15%, with 15 tanks discarded due to complete mortality.

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

A number of potential causes for the mortalities in 2002 were considered, including toxicity of leachate from treated lumber, gas super-saturation, low culture temperature, aluminum toxicity from drought followed by acid precipitation, and OTC tagging (some of the OTC used was brown in color instead of the typical yellow). In addition, gypsy moth spraying occurred in the Van Dyke drainage for the first time since 1992, filamentous algae grew in the warming pond for the first time ever, and we had a pre-season drought, followed by ample rainfall, much like the 1992 season when we also had mortality problems.

We tested the hypothesis that OTC marking was involved by rearing two tanks (E41, F11) with no OTC marking. Both tanks were discarded after suffering complete mortality. In addition, none of these scenarios explain the good survival of all eggs incubated in May-Sloan jars and the poor survival of all eggs incubated in Van Dyke jars. Hudson River shipment 50 provided definitive proof that the mortalities were related to incubation in Van Dyke jars. The shipment was divided between one Van Dyke jar and four May-Sloan jars. Tank D22 received eggs from the Van Dyke jar and had only 2,000 larvae (1%) survive to 18 days. Tank D32 received eggs from the May-Sloan jars and had 198,000 larvae (83%) survive to 18 days.

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

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

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

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

May-Sloan jars are the standard for incubation of American shad eggs, however, use of May-Sloan jars in a production facility leads to inefficiencies and other problems. May-Sloan jars have a capacity of 2.5L or approximately 85,000 eggs, compared to 12.5L and 412,500 eggs for Van Dyke jars. Modification of the ¾ egg battery to accommodate Van Dyke jars increased egg battery capacity by 80% from 250L to 450L. Incubation procedures call for enumeration and sunning of eggs for each jar. Since Van Dyke jars hold 5 times the eggs of a May-Sloan jar, they require 1/5 of the work in doing egg enumerations, taking off dead eggs and sunning the jars. May-Sloan jars are mounted inside the tank for hatch with plastic and aluminum brackets, and plumbed to the water source with "spiders" made from clear plastic tubing and a series of plastic "Y" connectors. Flow adjustments are made with a hose clamp on each section of tygon tube. At 85,000 eggs per jar with egg viability of 50%, 5 May-Sloan jars are required per tank to achieve an optimal 200,000 larvae per tank. If egg viability is lower or more larvae are put in the tank to conserve tank space, more jars are needed and more connections are required. Flow adjustment becomes problematic due to the complexity of the "spider", uncoupling of connections, air locks, etc. A single Van Dyke jar normally provides an optimal density of 200,000 larvae per tank with only one plumbing connection required. In order to maximize egg incubation and larval production, and minimize the effort needed to do that, it is imperative that we utilize egg jars with greater capacity than the standard May-Sloan jar.

This study evaluated four egg jar configurations, using eggs incubated in May-Sloan jars as a control. Test jars included: Van Dyke jars with open-cell foam bottom screens (special ordered without additives), modified Van Dyke jars with a perforated aluminum plate bottom screen and a "Chapman diffuser", triple May-Sloan jars, and five-foot tall, six-inch diameter Acrylic jars.

Materials and Methods

Incubation jars

Table 1 lists the characteristics of the egg incubation jars used in this study. Top screens of all jars used in the study were constructed from perforated aluminum. May-Sloan jars (MS) were fitted with bottom screens made of aluminum window screen, supported by a plastic frame. MS jars were mounted in the rearing tank for hatch in the manner described above.

Van Dyke jars (VD-foam) had an open-cell foam bottom screen held in place with a 1/4 inch retaining ring and cut ½ inch too large to ensure a tight fit. The bottom screen had a ¼ inch hole in the center, with a ¼ inch PVC pipe to act as a standpipe to permit air bubbles to escape. VD-foam jars were mounted in the tank for hatch with a non-toxic, epoxy painted steel holder, which was chained to the rafters. They had two ½ inch inlet ports on opposite sides of the jar and were plumbed to the water supply via ¾ inch latex tubing and a ½ inch PVC tee fitting.

The modified Van Dyke jar (VD-modified) had a perforated aluminum bottom screen which rested on top of the retaining ring. A "Chapman diffuser" was glued to the center of the screen, and consisted of a 3-inch long section of ½ inch PVC pipe, with 16 holes (jets), 5/64 inch in diameter, evenly spaced around the pipe, and drilled 3/8 inch above the surface of the screen. The jar was plumbed to the water supply with one section of ¾ inch latex tubing attached to the inlet port at the side of the jar and another section to the "Chapman diffuser". In this way, one-half the flow entered the jar from the bottom and flowed up through the bottom screen, while the other half entered through the "jets" and flowed horizontally, rolling the eggs on top of the screen and preventing dead spots. Flows to the two ports were independently adjustable by virtue of two valves. The VD-modified jar was mounted in the tank for hatch in the same manner as the VD-foam jar.

Triple May-Sloan jars (MSXXX) were 42-inch high versions of the standard MS jar, made by gluing parts from three jars together. Top screens, bottom screens, inlet ports and outlet ports were identical to those on standard MS jars. MSXXX jars were mounted in the tank for hatch by resting them on the floor of the tank. They were plumbed in the same manner as standard MS jars.

Acrylic jars were constructed at Van Dyke from 6-inch diameter, 5-foot sections of clear acrylic pipe. Inlet and outlet ports were similar to those on MS jars. Bottom screens were made of perforated aluminum. Acrylic jars were too high to be mounted in the tank for hatch. They were set on the floor of the building, outside the tank, and secured to the tank via bungee cords. Inlet plumbing was similar to MS jars. The outlet pipe was fitted with a section of ¾ inch latex tubing to direct the jar effluent and hatching larvae into the rearing tank.

Methods

Experiment 1- Larval survival of American shad eggs incubated in VD-foam jars.

Susquehanna River egg shipment 7 was incubated in one VD-foam jar (11.6L) with a non-toxic foam bottom screen. Egg enumeration and incubation were by standard methods. After 7 days of incubation, the jar was transferred to tank B31 for hatch. Larval survival and feeding was monitored to determine if the larval mortality and feeding problems from 2002 re-occurred.

Experiment 2- Viability of American shad eggs incubated in Van Dyke jars, modified Van Dyke jars, Triple May-Sloan jars and Acrylic jars, compared to May Sloan jars.

Egg shipments were split and incubated in the test and control jars with 2.5L in each MS jar, 9.0 to 13.0L in each VD-foam and VD-modified jar, 6.5- 6.8L in each MSXXX jar and 8.5L in each Acrylic jar. Four replicates were tested. Percent egg viability and percent dead fry were recorded for each lot and tested for statistical significance using Friedman Rank Sums (Hollander and Wolfe 1973). In order to optimize use of tank space, larvae from MS jars, VD-modified jars, MSXXX jars, and Acrylic jars were combined for rearing in one or more common tanks. Larvae from VD-foam jars were reared separately to permit isolation of any problems associated with the foam bottom screens.

Results and Discussion

VD-modified jars, MSXXX jars and Acrylic jars were prototypes that had never been used in egg incubation. It took very little time and experimentation to develop the ancillary equipment and procedures to deploy these new egg incubation jars. Longer siphons were quickly constructed, as were tools to aid in seating the bottom screens in the taller jars. Plumbing the VD-modified jars was easily accomplished by rotating the valve to provide necessary clearance and using a longer section of latex tubing. The egg battery was modified to accept the taller jars by removing the platform and constructing a new platform near ground level. Bungee cords were used to stabilize the taller jars while on the egg battery and in the tank.

Logistical concerns are extremely important in the efficient operation of a production hatchery. Improvements in egg viability are useless if it is impractical to implement the procedures necessary to achieve those improvements. It is important to evaluate egg jars based on subjective criteria in addition to the objective criteria of egg viability and percent dead fry. Observations were made on all aspects of the use of the experimental jars.

Layering of dead eggs. Eggs layered extremely well in the taller MSXXX and Acrylic jars, permitting us to siphon off most of the dead without siphoning live eggs as well. These jars are preferred for Delaware and Susquehanna egg shipments where lack of layering is problematic. Siphoning was more difficult in these jars and required a longer, more cumbersome siphon. Eggs in the VD-modified jar did not layer well due to the turbulence in the jar. Cutting back on the flow through the "Chapman diffuser" may have corrected this, but cutting back too much is likely to have produced dead spots. Ideally, flows on VD-modified jars would have been adjusted to prevent dead spots, but promote layering. This was judged to be a risky proposition and was not attempted.

Extracting a random sample of eggs from the incubation jar has been common practice in enumeration of eggs in jars where the eggs do not layer. Random samples were usually extracted by stirring the eggs and taking a sample from bottom to top with a small net. This was difficult in the taller jars and a siphon was used to extract the sample.

The eggs were stirred; the siphon was lowered into the bottom of the jar and the sample extracted as the siphon was lifted from the jar, collecting eggs from every level in the jar.

Dead spots. No dead spots were observed in any of the jars, nor were any "dead fry" observed. The "jets" on the VD-modified jar did not clog with debris, creating dead spots. We were careful to eliminate air bubbles under the bottom screens before putting the eggs in the jars and we observed no problems with air bubbles accumulating under the bottom screen during incubation. Air bubbles did form in the jar plumbing, particularly while the jar was on the tank for hatch. This was a problem with the MS jars more than the other jars. Constant vigilance was required to deal with this problem.

Egg jar handling. Moving the jars from the egg battery to the tank and from the tank outside for sunning was easiest for MS jars because of their small size. VD-foam and VD-modified jars were moved in their steel holders and required two persons, but the process has been done for years and no catastrophic accidents have occurred. Moving the MSXXX jars was far easier than expected and could be done by a single person. The jars were somewhat cumbersome, but with care they were moved successfully with no accidents. A stabilizer was constructed of PVC pipe and aluminum and used, with a bungee cord, to stabilize the MSXXX jar while it rested on the floor of the tank. The acrylic jars were extremely difficult to move because of their height and weight. The process involved three persons and required supporting the weight of the jar while bending, inviting back injuries. Because the acrylic jars had to be mounted outside the tank, the influent hose was not supported by the water and tended to airlock or kink. The hose connection to the jar required a hose clamp to remain in place. Continued use of this jar would eventually result in a catastrophic accident where millions of live eggs would be lost on the floor. As a result, we discontinued the use of this jar after the second trial. All three acrylic jars were cut down to the size of the MSXXX jar and used successfully for the remainder of the season.

The VD-foam and VD-modified jars are made of heavy plastic and have been used with the foam bottoms for many years without significant breakage. MS jars are made from thin, brittle plastic and have always been subject to breakage. It is assumed that MSXXX jars will be subject to breakage as well, although none broke in 2003. Two-part epoxy plastic welder glue was used to make the MSXXX jars and the glue joints appeared to be as strong as the plastic. The acrylic jars are made from sturdy 0.25 in. thick acrylic, and are expected to be more durable than MSXXX jars.

Cleaning and dis-infection of the taller jars was more difficult than with the small jars, as was seating of the bottom screen, but these were minor problems.

Hatching of eggs. Hatching larvae had to swim upward, often through a layer of eggs, to exit the incubation jar. The distance required was significantly more in the taller jars, but the larvae appeared to accomplish this with ease.

Experiment 1- Larval survival of American shad eggs incubated in VD-foam jars. The first shipment incubated in a VD-foam jar was Susquehanna River tank-spawn shipment 7. Ten-day survival for shipment 7, reared in tank B31, was 83.8%. This was considered good survival, and additional tests and production lots were incubated with foam bottom screens. Close examination of larval survival from production tanks suggested that incubation of eggs on foam screens appeared to result in lower survival for most tanks (Figure 2). This reduction in survival was not apparent until after 10 days of age. Mean 10d survival for tanks with foam was 95.0%, compared to 97.0% for tanks with no foam. Survival after 10 days appeared to decrease for tanks with foam bottom screens (Figure 3). Tanks with only foam bottom screens (15 tanks) exhibited 19d survival of 79.2% compared to 90.5% for tanks with no foam bottom screens (13 tanks). These were not controlled experiments, however, and further testing will be required to validate this result.

Experiment 2- Viability of American shad eggs incubated in Van Dyke jars, modified Van Dyke jars, Triple May-Sloan jars and Acrylic jars, compared to May Sloan jars. Experiment 2 was replicated 4 times with Hudson River shipments 10, 13, 24 and 31 (Table 2, Figure 4). Acrylic jars were tested in shipments 10 and 13, but not in shipments 24 and 31 because of the difficulty in handling them. Mean egg viability for the MS, VD-foam, VD modified and MSXXX jars were 72.4%, 70.7%, 68.4% and 61.1% respectively (Table 3). These data were subjected to a distribution free test using Friedman Rank Sums (Hollander and Wolfe 1973) and the differences were not significant ($S=3.97$, $\alpha= 0.324$). Mean egg viability for the acrylic jars was 62.8% for shipments 10 and 13.

Additional lots of Hudson River eggs were incubated for larval production, and are listed in Table 2 (Production lots). Direct comparisons of egg viability were possible for MS and VD-foam jars for shipments 40, 45 and 53 (Table 2, Figure 5). Overall mean egg viability for these shipments was 77.8% for MS jars and 76.7% for VD-foam jars, but there was no consistent pattern. Direct comparisons of egg viability were possible for MSXXX and VD-foam jars for shipments 15, 29, 40, and 49 (Table 2, Figure 6). Overall mean egg viability for these shipments was 64.1% for MSXXX jars and 76.2% for VD-foam jars, with the VD-foam jars exhibiting consistently higher viability. I believe this to be an artifact of the enumeration process, not a real difference in viability. The taller MSXXX jars layered out much better than the shorter VD or MS jars, facilitating the siphoning off of dead eggs. A thin layer of dead eggs is routinely allowed to remain on top of the live eggs after siphoning to ensure that no live eggs are siphoned off. For a given thickness, this layer contains more dead eggs in a larger diameter jar than in a smaller diameter jar. Thus, in the MSXXX jars, fewer dead eggs were left on top of the live after siphoning. In addition, because the eggs layered better, fewer dead were mixed in with the live in the MSXXX jars. In the past, as well as in 2003, we observed no developed eggs in any of the samples of dead eggs siphoned from any of the jars, suggesting that eggs that were viable upon arrival at the hatchery did not die during incubation. Thus, differences in egg viability between jars are likely to be due to the enumeration process.

Recommendations. VD-foam jars are preferred by the crew at Van Dyke because of their large capacity and ease in handling. A single Van Dyke jar provides an ideal number of larvae for the Van Dyke tanks. Questions remain about the survival of larvae, particularly after 10 days of age, after incubation in these jars. A controlled experiment should be conducted in 2004 to further explore this issue. Modified VD jar screens should be available in the event problems arise. Modified VD jars are not yet recommended for routine use because of uncertainties associated with adjusting the flows to facilitate layering. MSXXX jars provide a viable alternative to VD jars, especially for egg sources which do not layer well (Susquehanna tank spawn, Delaware). At 6.5L capacity, they are also useful for smaller quantities of eggs, saving VD jars for future large shipments. MS jars are too small and time consuming for production lots of eggs, but are useful for research purposes. Acrylic jars are too large and cumbersome for routine use.

The Van Dyke egg battery is currently set up for 25 MS jars, 22 MSXXX jars and 26 VD-foam jars. I recommend that we modify the battery to accommodate 12 more MSXXX jars and eliminate 13 MS jars. Because each jar is put on the tank for hatch for 2 to 3 days, we require extra jars as replacements to ensure the egg battery is at capacity. We currently have an inventory of 43 VD jars, 37 MS jars and 22 MSXXX jars. Thus, we will require approximately 18 additional MSXXX jars to fill the battery and provide for replacements. This will increase egg battery capacity from 517.5L to 563L.

Literature Cited

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Job III. American shad hatchery operations. 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, 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, 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. 2003. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2002. Susquehanna River Anadromous Fish Restoration Committee.

Hollander, M. and D. A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley & Sons, New York. 503 pp.

Ott, L. l977. An introduction to statistical methods and data analysis. Duxberry Press, Belmont, California 730 p.

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

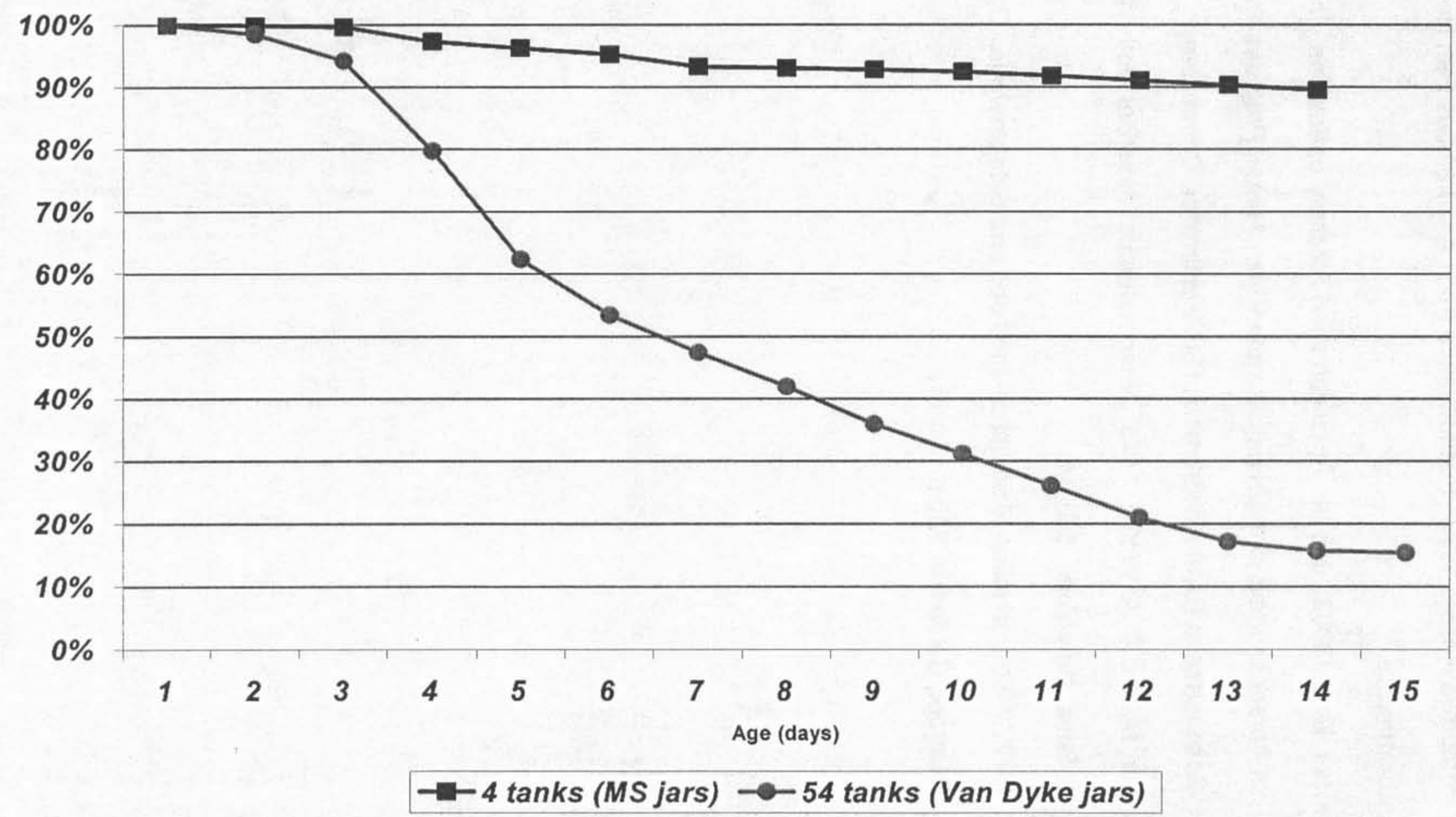


Figure 2 . Survival of larvae incubated in egg jars with foam vs no-foam, 2003.

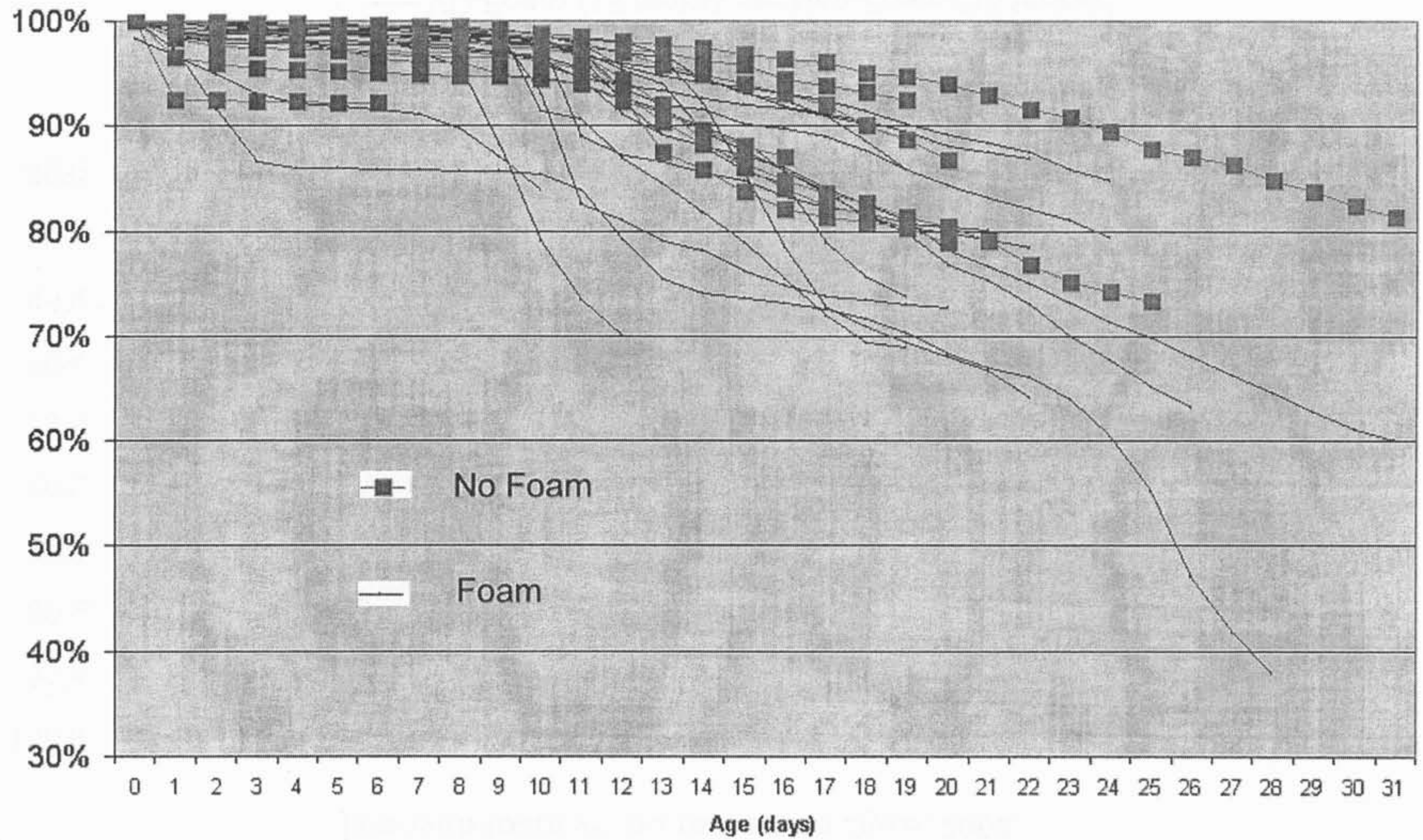


Figure 3. Mean survival for American shad larvae incubated in egg jars with foam vs. no foam, Van Dyke, 2003.

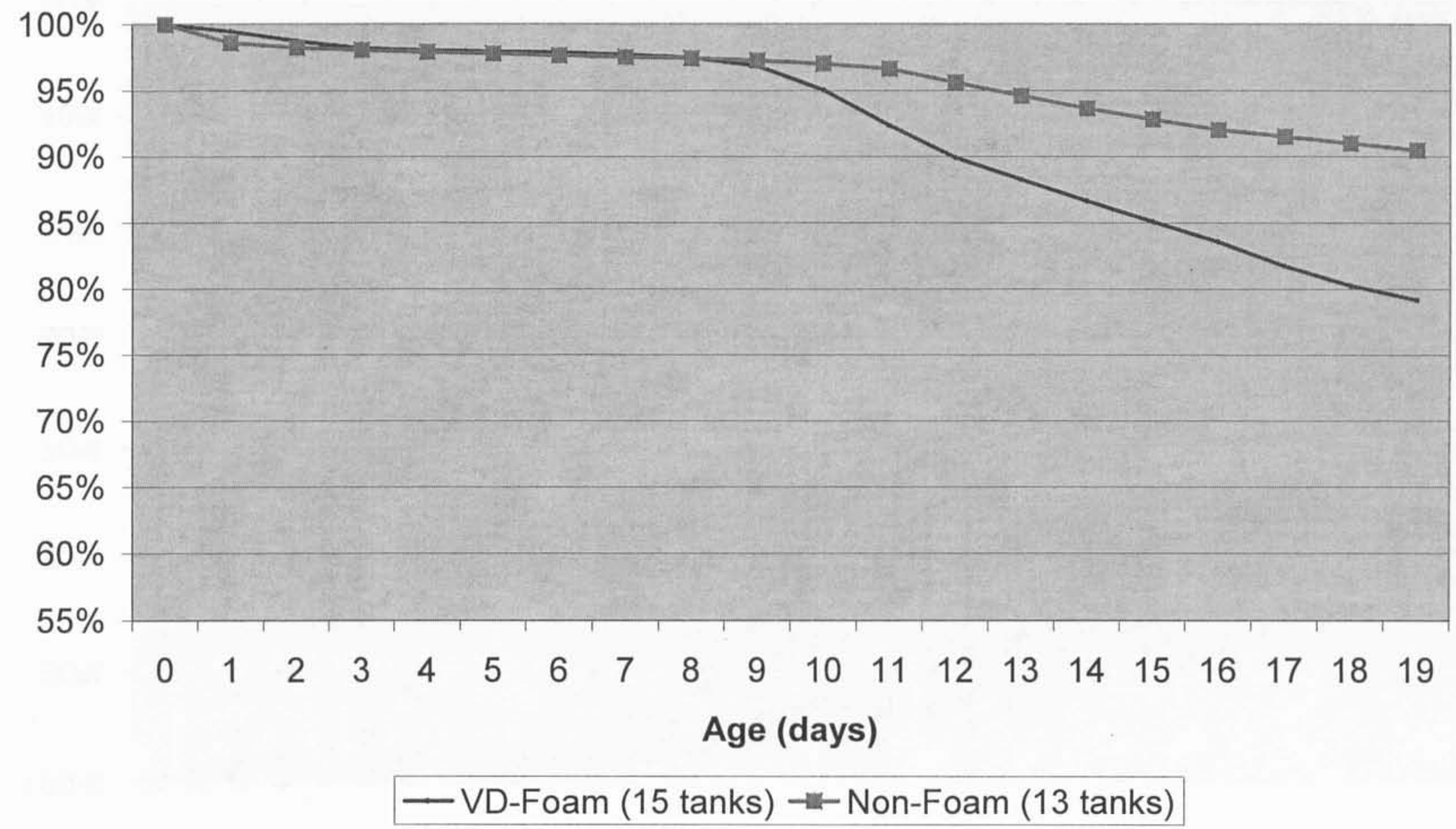


Figure 4. Percent viability of Hudson River American shad eggs incubated in various egg jar types (test lots), Van Dyke, 2003.

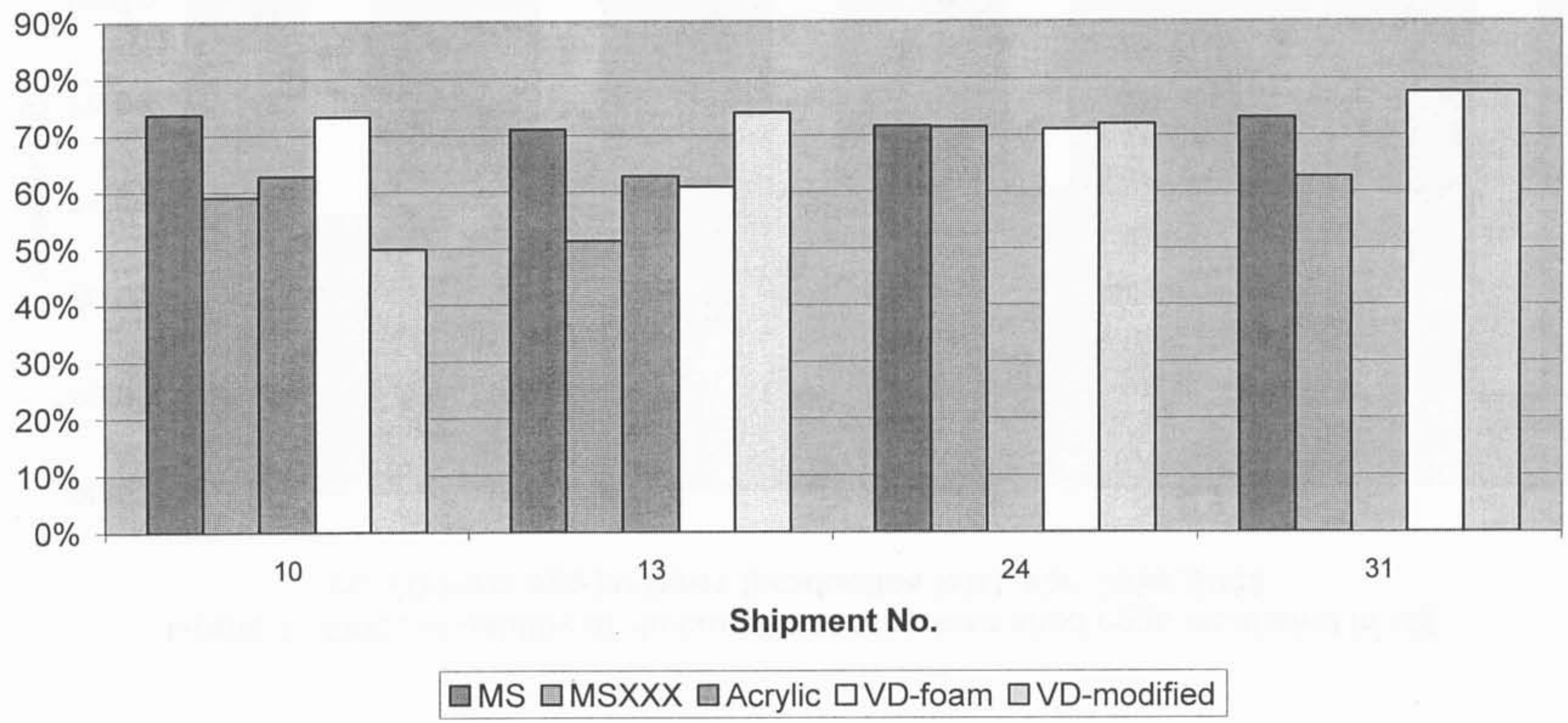


Figure 5. Percent viability of Hudson River American shad eggs incubated in MS vs. VD-foam egg jar types (production lots), Van Dyke, 2003.

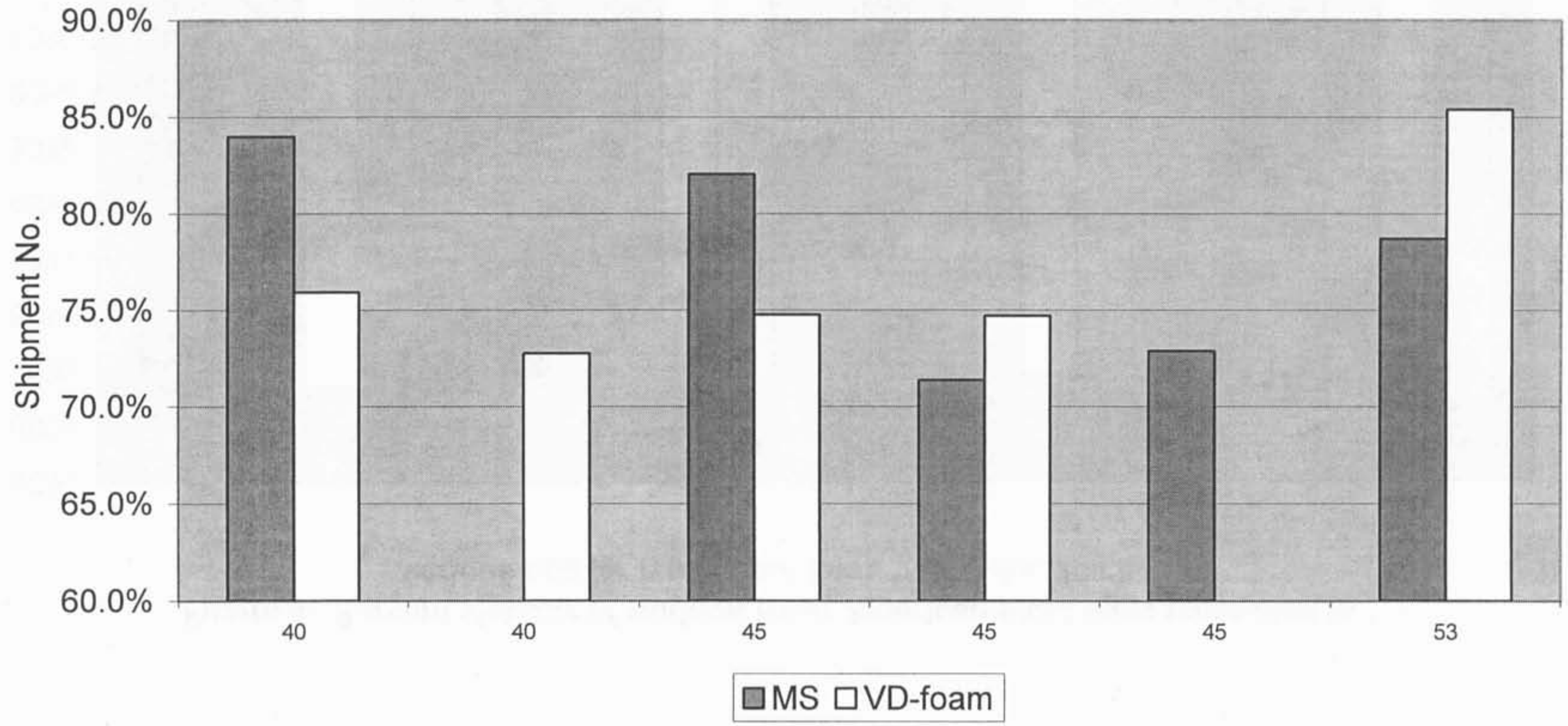


Figure 6. Percent viability of Hudson River American shad eggs incubated in MSXXX vs. VD-foam egg jar types (production lots), Van Dyke, 2003.

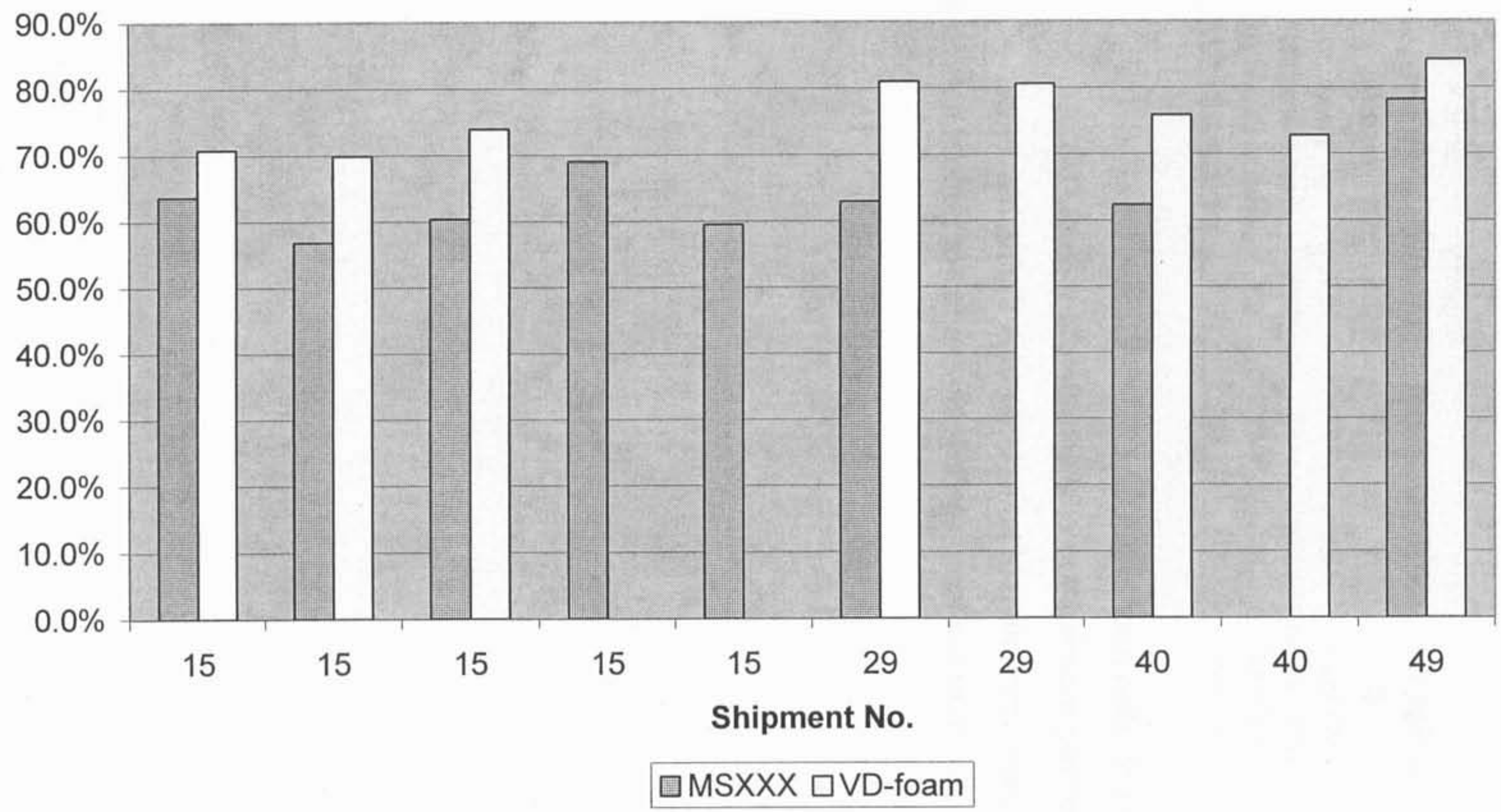


Table 1. Egg jar specifications, Van Dyke, 2003.

Egg Jar	Width	Height	Capacity (Liters)	Bottom Screen	Notes
MS	6"	17"	2.5	window	
VD-foam	13.5"	17"	12.5	foam	
VD-modified	13.5"	17"	12.5	Perf. aluminum	a, d
MSXXX	6"	42"	6.5	window or perf Al.	a,b
Acrylic	6"	60"	8.5	window or perf Al.	a,b,c

a- jar untested prior to 2003

b- required modification of egg battery supports

c- required mounting of jar outside tank during hatching.

d- diffuser required to spray flow across top of bottom screen to prevent dead spots

Table 2. Viability of Hudson River American shad eggs incubated in various egg jar types, Van Dyke, 2003.

Shipment No.	Jar No.	Jar Type	Initial Dry Vol (L)	Number of eggs	Percent Live Eggs
Test Lots					
10	1	MS	2.5	66,600	73.7%
10	111	MSXXX	6.5	173,161	59.0%
10	202	Acrylic	8.5	226,441	62.8%
10	302	VD-foam	12.0	319,681	73.3%
10	303	VD-modified	12.0	319,681	50.0%
10	305	Vd-foam*	3.4	90,576	67.2%
13	3	MS	2.5	65,832	71.1%
13	109	MSXXX	6.5	171,163	51.3%
13	203	Acrylic	8.5	223,828	62.7%
13	306	VD-foam	9.5	250,161	60.9%
13	304	VD-modified	9.0	236,994	74.0%
13	102	MSXXX*	7.0	184,329	63.6%
13	110	MSXXX*	6.8	179,062	59.0%
13	112	MSXXX*	7.0	184,329	58.2%
24	8	MS	2.5	61,345	71.7%
24	101	MSXXX	6.8	166,858	71.5%
24	302	VD-foam	12.0	294,455	71.1%
24	303	VD-modified	12.0	294,455	72.1%
24	111	MSXXX*	5.6	137,412	64.1%
31	12	MS	2.5	64,313	73.1%
31	109	MSXXX	6.8	174,930	62.6%
31	305	VD-foam	13.0	334,426	77.6%
31	304	VD-modified	13.0	334,426	77.6%

*not part of controlled test

Table 2 (continued).

Shipment No.	Jar No.	Jar Type	Initial Dry Vol (L)	Number of eggs	Percent Live Eggs
Production lots					
11	105	MSXXX	6.0	147,228	53.7%
11	106	MSXXX	6.0	147,228	53.7%
11	107	MSXXX	6.1	149,681	56.8%
11	108	MSXXX	6.4	157,043	59.9%
15	115	MSXXX	6.5	163,324	63.7%
15	116	MSXXX	6.7	168,350	56.9%
15	117	MSXXX	6.8	170,862	60.4%
15	118	MSXXX	6.5	163,324	69.0%
15	119	MSXXX	6.6	165,837	59.5%
15	307	VD-foam	12.5	314,085	70.8%
15	308	VD-foam	12.5	314,085	69.9%
15	309	VD-foam	12.5	314,085	74.0%
29	107	MSXXX	3.6	93,700	63.0%
29	326	VD-foam	12.3	320,141	81.0%
29	327	VD-foam	12.0	312,333	80.7%
34	337	VD-foam	10.3	284,039	84.7%
34	339	VD-foam	10.4	286,796	85.3%
37	308	VD-foam	9.6	264,735	85.0%
37	309	VD-foam	9.5	261,978	85.6%
40	13	MS	1.4	36,439	84.0%
40	115	MSXXX	7.0	182,194	62.4%
40	312	VD-foam	12.5	325,346	75.9%
40	340	VD-foam	12.7	330,552	72.8%
43	14	MS	2.3	63,426	75.8%
43	329	VD-foam	12.0	330,919	79.4%
45	1	MS	2.6	67,672	82.1%
45	2	MS	2.6	67,672	71.4%
45	3	MS	2.5	65,069	72.9%
45	331	VD-foam	12.8	333,155	74.8%
45	333	VD-foam	12.4	322,744	74.7%
46	335	VD-foam	12.0	312,333	75.8%
46	338	VD-foam	11.2	291,510	74.5%
47	302	VD-foam	7.9	243,764	80.4%
48	101	MSXXX	4.1	147,068	61.9%
49	109	MSXXX	5.0	161,188	78.2%
49	305	VD-foam	12.0	386,852	84.1%
53	15	MS	2.4	66,945	78.7%
53	334	VD-foam	12.0	334,723	85.4%
55	306	VD-foam	8.8	259,731	68.2%
58	6	MS	1.6	52,710	86.3%

Table 3. Summary of viability of test lots of Hudson River American shad eggs incubated in various egg jar types, Van Dyke, 2003.

Shipment No.	MS	MSXXX	Acrylic	VD-foam	VD-modified
10	73.7%	59.0%	62.8%	73.3%	50.0%
13	71.1%	51.3%	62.7%	60.9%	74.0%
24	71.7%	71.5%		71.1%	72.1%
31	73.1%	62.6%		77.6%	77.6%
Mean	72.4%	61.1%	62.8%	70.7%	68.4%

Appendix 2

Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2003.

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

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

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

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

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

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

In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2003 and summarizes results from 1995 to 2003.

Materials and Methods

Production larvae, stocked in 2003, included 5.71 million Hudson River source (strip-spawn) larvae marked at three days of age; and 1.95 million Susquehanna River source (tank-spawn) larvae marked at 3,6, and 9 days of age. These groups were stocked at various sites in the Juniata River. Sites were generally stocked in succession, moving upriver. Repeated stockings at one site, within a short time interval, were avoided. Smaller numbers of uniquely marked larvae were stocked at other sites, including the Conestoga, Conodoguinet, West Conewago and Swatara Creeks, the West Branch Susquehanna River, the North Branch of the Susquehanna River in both Pennsylvania and New York, and the Chemung River in New York.

Juvenile American shad were sampled during autumn by lift net (Holtwood Dam), in intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam. Other juvenile samples were collected, but were not used in this analysis because of the potential that they were not representative of the out-migrating population as a whole. A sub-sample of 30 fish per site per sampling date was retained for otolith analysis. Shad were frozen whole and delivered to Benner Spring Fish Research Station for otolith analysis. Otoliths were extracted, mounted, ground and analyzed according to standard procedures (Hendricks et al., 1991). The number of fish observed with each unique mark was expanded to the entire sample by multiplying by the total number of fish collected in a sample and dividing by the number of fish sub-sampled for otolith analysis. Data for 1995 to 2001 was similarly corrected to account for the total number of shad collected, not just those sampled. Recovery rates were calculated for each group by dividing the expanded number of fish recovered by the number stocked and multiplying by 10,000 to remove the decimal point and convert the rate to a whole number. Relative survival was calculated by dividing the recovery rate for each group by the highest recovery rate.

Results and Discussion

In 2003, Susquehanna River source larvae stocked in the Juniata and middle Susquehanna Rivers exhibited the best survival (relative survival set to 1.00, Table A2-1). Hudson River egg source larvae stocked in the West Conewago Creek exhibited relative survival of 0.80. Hudson River source larvae stocked in Swatara Creek exhibited a relative survival of 0.72. Hudson River egg source larvae stocked in the North Branch Susquehanna River (PA) exhibited a relative survival of 0.58. Hudson River egg source larvae stocked in the West Branch Susquehanna River had a relative survival of 0.53. Hudson River egg source larvae stocked in Conodoguinet Creek had a relative survival of 0.46. Hudson River egg source larvae stocked in the North Branch Susquehanna River (NY) had a relative survival of 0.32. No larvae stocked in the Conestoga or Chemung Rivers were recovered.

A summary of the results of nine years of uniquely marking larvae according to stocking site is provided in Table A2-2. Recovery rates for 2003 varied from 0.00 to 0.13. The overall recovery rate for 2003 (0.07) was the lowest recorded for the series, indicating poor survival of larvae. The poor survival was probably due to high water during stocking. Abundant rainfall during May and June, 2003 caused repeated flooding which probably resulted in poor plankton production.

Over time, relative survival of larvae stocked at the various sites has varied with no apparent trend. For example, the Chemung River had the highest relative survival in 2002, but none were recovered in 2003. Relative survival has ranged from 0.00 (the lowest possible) to 1 (the highest possible) for the Conestoga River, the North Branch Susquehanna River, and the Chemung River. Annual variation has exceeded 0.85 for the Juniata and Susquehanna River at Montgomery Ferry, West Conewago Creek, and Swatara Creek. Except for larvae stocked in the Juniata and middle Susquehanna Rivers, all sites are generally stocked only once per year. The lack of trends over time suggests that survival of any one group is likely to be highly influenced by environmental conditions at the site, at the time of stocking. Favorable conditions promote good survival while poor conditions result in poor survival. The only clear trend across years was that relative survival for larvae stocked in the West Branch Susquehanna River was never high, ranging from 0.00 to 0.54.

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.

Hendricks, M. L. 1999. Survival of American shad larvae released at various sites in the Susquehanna River drainage, 1998. Appendix A, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1998. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2000. Survival of American shad larvae released at various sites in the Susquehanna River drainage, 1999. Appendix 1, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1999. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2001. Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2000. Appendix 1, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 2000. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2002. Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2001. Appendix 1, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 2001. 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 A2-1. 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, 2003.

Stocking Site	Egg Source	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ middle Susq. R. near Mont. Ferry	Hudson	6-28	5/19-6/30	5,712,662	53%	29	41	0.05	0.40
Juniata R./ middle Susq. R. near Mont. Ferry	Susq.-Con	10-25	5/19-6/30	1,947,223	18%	25	35	0.13	1.00
Conodoguinet Cr.	Hudson	26	6/18	167,774	2%	1	1	0.06	0.46
Conestoga R.	Hudson	37	6/30	158,146	1%	0	0	0.00	0.00
Swatara Cr.	Hudson	38	6/30	107,867	1%	1	1	0.09	0.72
W. Conewago Cr.	Hudson	25	6/18	293,183	3%	3	4	0.10	0.80
W. Br. Susq. R.	Hudson	24	6/13	591,558	6%	4	6	0.07	0.53
N. Br. Susq. R.(PA)	Hudson	22	6/12	800,129	7%	6	8	0.07	0.58
N. Br. Susq. R.(NY)	Hudson	19	6/5	491,988	5%	2	3	0.04	0.32
Chemung R.	Hudson	16	5/29	414,721	4%	0	0	0.00	0.00
			Total	10,685,251		71		0.07	

Table A2-2. Annual summary of relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995-2003.

Stocking Site	Recovery Rate								
	1995	1996	1997	1998	1999	2000	2001	2002	2003
Juniata R./Susq. R. @ Mont. Ferry	2.12	0.10	1.85			0.72	2.07	0.15	0.05
Juniata R.(various sites)			2.09	0.15	0.63				
Juniata R.(Susq. eggs)				0.10			1.32	0.37	0.13
Huntingdon			1.52						
Standing Stone Cr.		0.00		0.00					
Conodoguinet Cr.	2.52	0.12	0.29	0.05	0.51	0.54	0.07	0.00	0.06
mouth of Conodiguinet Cr.	2.96								
Conestoga R.	3.28	0.00	0.26	0.00	0.87	0.13	0.22	0.00	0.00
mouth of Conestoga Cr.	1.18								
Muddy Cr.	0.00								
Conewago Cr.				0.19	0.18	0.61	0.18	0.00	0.10
Swatara Cr.				0.20	0.69	0.00	1.15	0.00	0.09
W. Br. Susq. R.		0.09	0.86	0.00	0.00	0.17	0.09	0.54	0.07
N. Br. Susq. R.(PA)		0.34	2.02	0.21	0.19	0.40	1.06	0.00	0.07
N. Br. Susq. R.(NY)								0.64	0.04
Chemung R.								1.02	0.00
Overall	2.13	0.12	1.77	0.15	0.54	0.62	1.37	0.27	0.07
	Relative Survival								
Juniata R./Susq. R. @ Mont. Ferry	0.65	0.31	0.89			1.00	1.00	0.15	0.40
Juniata R.(various sites)			1.00	0.72	0.73				
Juniata R.(Susq. eggs)				0.49			0.64	0.37	1.00
Huntingdon			0.72						
Standing Stone Cr.		0.00		0.00					
Conodoguinet Cr.	0.77	0.37	0.14	0.25	0.59	0.74	0.03	0.00	0.46
mouth of Conodiguinet Cr.	0.90								
Conestoga R.	1.00	0.00	0.12	0.00	1.00	0.18	0.11	0.00	0.00
mouth of Conestoga Cr.	0.36								
Muddy Cr.	0.00								
Conewago Cr.				0.89	0.20	0.84	0.09	0.00	0.80
Swatara Cr.				0.96	0.80	0.00	0.56	0.00	0.72
W. Br. Susq. R.		0.28	0.41	0.00	0.00	0.23	0.05	0.54	0.53
N. Br. Susq. R.(PA)		1.00	0.97	1.00	0.21	0.56	0.51	0.00	0.58
N. Br. Susq. R.(NY)								0.62	0.32
Chemung R.								1.00	0.00

JOB IV
ABUNDANCE AND DISTRIBUTION OF JUVENILE AND ADULT AMERICAN SHAD IN THE SUSQUEHANNA RIVER, 2003

Michael L. Hendricks and R. Scott Carney
Pennsylvania Fish and Boat Commission
State College, Pennsylvania

INTRODUCTION

This report summarizes the results of bio-monitoring activities for adult and juvenile alosines conducted in the Susquehanna River and its tributaries in 2003. The Conowingo West Fish Lift continued to be used as a source of adult American shad and river herring to support monitoring activities and tank spawning. Some 9,802 adult shad were collected at the Conowingo West Lift. The majority of these were released back into the Conowingo tailrace. Some 1,504 were retained for tank spawning. No alosines were transported and released upstream.

Since the completion of fish passage facilities at Holtwood and Safe Harbor in 1997, the Conowingo East Lift has operated in fish passage mode. American shad had access to the Fabri-Dam on the Susquehanna main stem, and Warrior Ridge or Raystown Dams on the Juniata. Portions of large tributaries including Muddy Creek, West Conewago Creek, Conestoga River, Conodoguinet Creek, and Swatara Creek were also accessible to American shad.

During the 2003 spring migration, Conowingo East Lift passed 125,135 American shad while fishways at Holtwood, Safe Harbor, and York Haven passed 25,254, 16,646 and 2,534 American shad, respectively. Only 551 river herring were passed at Conowingo Dam and five herring were passed at Holtwood.

Juvenile American shad in the Susquehanna River above Conowingo Dam are derived from two sources - natural reproduction of adults passed at the lower river hydroelectric projects, and marked hatchery produced larvae from Pennsylvania Fish and Boat Commission's (PFBC) Van Dyke Hatchery 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 from upstream releases in Pennsylvania.

During the 2003 production season, the PFBC Van Dyke Research Station for Anadromous Fish released 10.69 million shad larvae in the Susquehanna Basin, Pennsylvania. Larvae were released between 19 May and 30 June in the following locations and numbers:

Juniata River (various sites)	4,008,719
Susquehanna River (near Montgomery Ferry)	3,651,168
Conodoguinet Creek	167,774
Conestoga River	18,924
Swatara Creek	107,867
West Conewago Creek	293,183
North Branch Susquehanna River (PA)	800,129
West Branch Susquehanna River	591,558
North Branch Susquehanna River (NY)	491,988
Chemung River (NY)	414,721

METHODS

Electrofishing for adult American shad was conducted in selected tributaries to document homing of adults to streams where juveniles had been stocked three to six years earlier. Sampling for juvenile American shad was conducted at locations in the Susquehanna River Basin during the summer and fall in an effort to document in-stream movement, out-migration, abundance, growth, and stock composition/mark analysis. Juvenile recoveries from all sources were provided to the PFBC for otolith analysis. Otoliths were analyzed for tetracycline marks to determine hatchery versus wild composition of the samples.

Electrofishing- adults

Electrofishing was conducted on May 21, 2003, in West Conewago Creek. Electrofishing was cancelled in Swatara and Conodoguinet creeks due to the low number of alosines passed at York Haven Dam. Electrofishing was not conducted in the Conestoga River to minimize disturbance to the fish and permit maximum fish passage and spawning. Daytime electrofishing employed the use of a Coffelt VVP-15 variable voltage pulsator, powered by a 3.5 kW generator, and mounted in a 6 ft inflatable raft. Pulsed current of 225 to 400 volts was used. Surveys covered 500 to 1,000 m of stream and were concluded after one hour of electrofishing. The total number of shad captured and number observed, but not captured, was enumerated.

Push-netting

Push-netting for juvenile alosids was conducted at various sites in the upper portion of Conowingo pool beginning in late June and ending in mid-July for a total of 6 sampling dates. A total of 10 stations were sampled on each date (five minute push per station). The push-net utilized was a 5-ft beam trawl with a 60-in square mouth opening lashed to a 4-ft 11-in by 4-ft 11-in steel frame. The net was made of No. 63 knotless 1/4-in stretch mesh netting. It was tailored and tapered to a length of 7-ft terminating at a 12-in canvas collar cod-end. The net was attached to the front of an 18-ft jon-boat. For each survey the push-net was suspended into the water and pushed into the current for five minutes. Push-netting was conducted during the evening hours in deep pools or runs and along shorelines of islands in upper Conowingo pool and in the vicinity of Muddy Run Pump Storage Station.

Haul Seining - Main Stem

Haul seining in the lower Susquehanna River was scheduled once each week beginning mid-July and continuing through October. A total of 8 sampling events occurred. High water prevented sampling during 2 three week periods. Sampling was concentrated near the Columbia Borough boat launch since this location proved very productive in past years. Sampling consisted of 6 hauls per date beginning at sunset and continuing into the evening with a net measuring 400 ft x 6 ft with 3/8 in stretch mesh.

Haul Seining - Tributaries

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

Electrofishing - main stem

Electrofishing was conducted at two upper river reaches located on the Susquehanna River near Clemson Island, and the Juniata River at Mifflintown. Electrofishing employed the use of a 14-ft jon-boat and variable voltage electrofisher with the anode mounted on the bow. Sampling consisted of several short electrofishing runs per date at each site beginning at sunset and ending after dark. Both sites were scheduled for eight sampling dates during the months of August to October, however the Juniata River site was sampled only seven times due to high water. The total number of shad captured and number observed, but not captured, was enumerated.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Sampling at Holtwood Dam inner forebay was conducted using a fixed 8-ft square lift-net beginning in mid-September and continuing every three days through early December (30 total dates). Sampling began at sunset and consisted of 10 lifts with a 10-minute interval between lift cycles. The lift-net was placed on the north side of the coffer cell in the inner fore-bay. A lighting system was used to illuminate the water directly over the lift-net similar to that employed in previous years.

Intake screen sampling for impinged alosines at Peach Bottom Atomic Power Station was conducted three times per week from 6 October to 3 December for a total of 23 samples. Conowingo Hydroelectric Station's cooling water intake screens were also sampled for impinged alosines twice weekly from 3 October to 8 December for a total of 16 samples.

Susquehanna River Mouth and Flats

Maryland DNR sampled the upper Chesapeake Bay weekly using 100-ft haul seines during July through September.

Disposition of Samples

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

RESULTS

Biomonitoring collections for adult and juvenile alosines in the entire Susquehanna River basin are summarized in Table 1.

Electrofishing - adults

Electrofishing was conducted in West Conewago Creek on May 21, 2003. In approximately 70 minutes of electrofishing time, no American shad were observed or collected.

Push-netting

No juvenile American shad were captured in approximately 300 minutes of push-netting. Table 2 lists other species collected by push net.

Haul Seining - Main Stem

A total of 17 juvenile American shad were captured by haul seine resulting in a Geometric Mean Catch-Per-Unit-Effort (GM CPUE, individual haul) of 0.20 (Tables 3 and 4). Juvenile American shad were captured on August 27 (8), September 2 (5) and September 12 (4). Two of the eight shad captured on August 27 were wild, the remainder were of hatchery origin. Table 5 lists weekly catches of American shad by haul seine from 1989 to 2003. Catches generally peaked in August and September except in 1989 and 1992 when catches peaked in July.

Haul Seining - Tributaries

No juvenile American shad were collected by haul seine in tributaries. Tables 6-9 list other species collected by haul seine in tributaries.

Electrofishing - main stem

The Susquehanna River site was sampled on 8 dates, for a total of 491 minutes of electrofishing time, resulting in no American shad captured or observed (Table 10). The Juniata River site was sampled on seven dates, for a total of 430 minutes of electrofishing time, resulting in the capture of seven juvenile American shad and observation of three which avoided capture (Tables 11 and 12).

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Lift-netting at Holtwood Dam inner fore-bay resulted in the capture of 61 juvenile American shad in 300 lifts (Table 13). Shad were captured between 28 September and 19 October when water temperatures ranged from 13°C to 18.5°C and river flows ranged from 24,900 cfs to 77,700 cfs. The peak collection (31 shad) occurred on 7 October at a water temperature of 13°C and a river flow of 37,700 cfs. GM CPUE (individual lift) was 0.07; GM CPUE (daily combined lifts) was 0.13 (Table 14). Historical weekly catches peaked in October, except in 1985, 1997, 2000, and 2001 when catches peaked in November (Table 15). Total length of specimens ranged from 102 to 141 mm (Table 16) with over 77% measuring 116 to 140 mm TL. No juvenile river herring were captured by lift-net in 2003.

Peach Bottom intake screens produced 7 juvenile American shad, 48 blueback herring, and 2 alewives (Tables 17 and 18). Peak catch for shad occurred on 29 October when 3 juveniles were captured. Cooling water strainers at Conowingo produced 18 juvenile American shad, 2 blueback herring, and 4 alewives (Tables 19 and 20). Peak catch for shad occurred on 29 October, when 9 juveniles were captured.

Susquehanna River Mouth and Flats

A total of 140 juvenile American shad were collected by haul seine from the upper Chesapeake Bay by Maryland DNR Juvenile Finfish Survey biologists during the summer and early fall of 2003 (Table 21). A total of 57 hauls were made at twelve sites.

Otolith Mark Analysis

Results of otolith analysis for juvenile shad taken at and above Conowingo Dam are presented in Table 22. A total of 110 juvenile American shad were collected in summer and fall collections. Eight specimens collected from intake samples could not be processed due to the poor condition of the fish. Of the remaining 102 specimens processed, 91.7% were marked (hatchery origin) and 8.3% were wild. Otoliths from juvenile shad captured at Holtwood Dam or downstream at Peach Bottom and Conowingo were exactly the same in origin as total river samples (91.7% hatchery and 8.3% wild). Recapture of shad from various stocking sites is discussed in Job III.

Of the 116 fish examined for marks from Maryland DNR's juvenile shad collections in the upper Bay, three (2.6%) were determined to be of hatchery origin. Two had day three marks from releases in the Juniata or Susquehanna Rivers and one had a day 3, 9, 12 mark from the West Branch Susquehanna River.

DISCUSSION

Spring river conditions for the Susquehanna River basin during 2003 could be characterized by relatively consistent high flows and below normal water temperatures. During the month of May, river flow measured at Harrisburg ranged from 29,000 cfs to 53,000 cfs. By comparison, in May 2001, river flows at Harrisburg never exceeded 20,000 cfs. May 2002 flows fluctuated from 32,000 cfs to 188,000 cfs. Persistent rainfall continued during summer and fall of 2003, making 2003 one of the wettest years on record. Fish passage at Holtwood and York Haven were severely impaired by persistent high river flows and constant spilling which adversely affected attraction at the fishway entrances. High flows also appeared to have a negative impact on survival of stocked hatchery larvae.

Abundance – Main Stem

Comparison of relative abundance of juvenile alosines in the Susquehanna River from year to year is difficult due to the opportunistic nature of sampling and wide variation in river conditions which may influence catches. Based on river haul seine and lift-net catch rates, abundance of juvenile American shad in 2003 was among the lowest recorded in recent history.

GM CPUE for haul seine (both individual lifts, and combined daily lifts) was the third lowest value ever recorded for that gear type since 1990. Likewise, GM CPUE of 0.07 by lift-net (individual lifts) was the lowest recorded since this estimate was required by ASMFC in 1997 (Table 13). GM CPUE of 0.13 by lift-net (combined daily lifts) was the second lowest recorded since 1985 and well below the ten-year average of 0.72. Low juvenile shad abundance in 2003 is most likely attributed to a combination of poor survival of hatchery fish and limited natural reproduction resulting from poor fish passage performance.

In-Stream Movements and Out-migration Timing

Generally, out-migration of juvenile American shad is episodic in nature. It typically occurs when the water temperature falls below 15.6° C and river flow increases, with the majority of the out-migration occurring over a four-week period. In 2003, out-migration, based on juvenile shad captured at Holtwood, Peach Bottom, and Conowingo, occurred during the nine-week period from 28 September to 24 November. Most juveniles (88%) were captured in October when the river temperature was 13°C to 16°C and flows were less than 60,000 cfs. The timing of the out-migration was consistent with that observed during previous years, but high flows may have impacted the effectiveness of the gear during portions of the season (Figure 1).

Stock Composition and Mark Analysis

Of the otoliths analyzed from collections at Holtwood, Peach Bottom and Conowingo Dam, 8.3% were wild and 91.7% were hatchery fish (Table 22). This compares to 22% wild in 2002, 43% wild in 2001, and 2% - 58% wild from 1991 to 2000. In 2003, 24 juvenile shad were captured upstream of Holtwood, including 2 wild and 22 hatchery fish.

Push-netting

No juvenile alosines were captured by push-net in 2002 or 2003, compared to 2 juvenile shad and 134 blueback herring captured by push-net in 2001. Holtwood passed only 25,254 (20%) of the 125,135 adult American shad passed at Conowingo. This suggests that some 99,881 adult shad remained in Conowingo Pool. Poor catches of juvenile shad by push-net may reflect that

Conowingo pool provides poor spawning habitat for American shad and/or juvenile shad are adept at avoiding capture by push-net. Low catches of juvenile blueback herring reflects low numbers of adults passed at Conowingo (551). In contrast, the catch of 134 juvenile blueback herring in 2001 suggests that push-netting can be an effective method of sampling alosines, specifically, blueback herring in Conowingo pool. It is hoped that increases in alosines abundance associated with stock restoration will enhance the effectiveness of push-netting in the future.

Blueback herring and alewives

Decreased passage of adult blueback herring resulted in lower catches of juveniles. In 2003, the Conowingo East Lift passed only 551 blueback herring, while Holtwood passed only 5. Similar results were found in 2002 when the Conowingo East Lift passed 2,100 blueback herring and Holtwood passed 13. This compares to a total of 284,921 and 1,300 passed by the Conowingo East Lift and Holtwood in 2001, respectively. Combined catches of juvenile blueback herring at Peach Bottom and Conowingo totaled 50 in 2003, and 2 in 2002, compared to 187 in 2001. A total of 6 juvenile alewife were collected at Peach Bottom and Conowingo combined, in 2003. No juvenile river herring were captured by lift-net in 2003, resulting from of the absence of adult spawners upstream of Holtwood Dam.

SUMMARY

- Small numbers of juvenile American shad were collected by electrofisher, haul seine, and lift-net.
- Haul seine GM CPUE (combined daily lifts) of 0.28 was the third lowest recorded for that gear type since 1985.
- Lift-netting GM CPUE (combined daily lifts) of 0.13 was the second lowest recorded for that gear type since 1985.
- Push-netting catches suggest poor production of blueback herring in Conowingo pool.
- Peak out-migration of shad, based on lift-net catches and impingement samples, occurred during October.

- Otolith analysis determined that 8% of the juvenile shad collected above Conowingo Dam were of wild origin as compared to 22% in 2002 and 40% in 2001.
- Juvenile production in the Susquehanna River basin was poor and was influenced by decreased numbers of adult fish passed by fish passage facilities and poor hatchery survival resulting from persistent high river flows.

ACKNOWLEDGMENTS

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

Figure 1. Water temperature and river flow in relation to the catch of juvenile American shad by lift net at Holtwood Power Station, 2003.

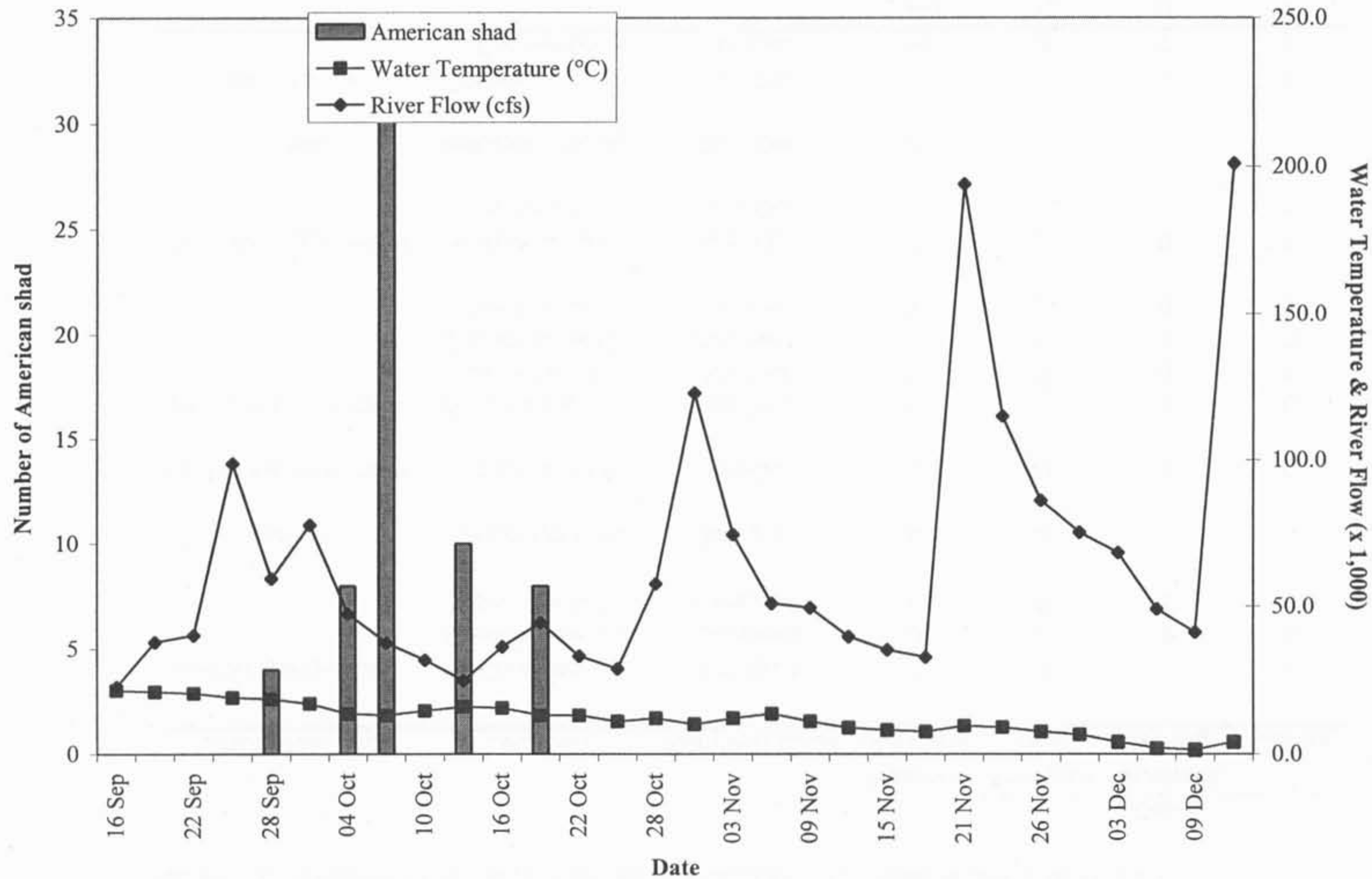


Table 1. Summary of adult and juvenile Alosine catches in the Susquehanna River, 2003.

Method/Gear Type	Location	Sampling dates	Number of events	Catch: American shad	Catch: Blueback herring	Catch: Alewife
Electrofishing-Adults	W. Conewago Cr.	5/21/2003	1	0	0	0
	Conodoguinet Cr.	Cancelled	0	0	0	0
	Swatara Cr.	Cancelled	0	0	0	0
Push-net	Conowingo Pond	July-Sept.	6	0	0	0
Haul Seine- main stem	Susquehanna R.	July-Oct.	8	17	0	0
Haul Seine- tributaries	W. Conewago Cr.	July-Sept.	5	0	0	0
	Conestoga R.	July-Sept.	5	0	0	0
	Conodoguinet Cr.	July-Sept.	5	0	0	0
	Swatara Cr.	July-Sept.	5	0	0	0
Electrofishing-juveniles	Susquehanna R.	Aug.-Oct.	8	0	0	0
	Juniata R.	Aug.-Oct.	7	7	0	0
Lift-Net	Holtwood forebay	Sept.-Dec.	30	61	0	0
Intake Screen	Peach Bottom	Oct.-Dec.	23	7	48	3
	Conowingo	Oct.-Dec.	16	18	2	4
			Total	**110**	**50**	**7**

Table 2. Summary of fishes collected by pushnet in Conowingo Reservoir in spring 2003.

Species	06/18/03	06/25/03	06/30/03	07/03/03	07/08/03	07/11/03	Total
Alewife		1			1		2
Gizzard shad			2			11	13
Common carp			2				2
Comely shiner	10	34	51	23	4		122
Spotfin shiner	1		1				2
Mimic shiner			1				1
Creek chub	1						1
Channel catfish			1		3	1	5
Yellow perch	1	1					2
Total	13	36	58	23	8	12	**150**

Table 3. Number of fish collected by haul seine from the lower Susquehanna River near Columbia, Pennsylvania, 2003.

Date	**16-Jul**	**22-Jul**	**21-Aug**	**27-Aug**	**2-Sep**	**12-Sep**	**17-Sep**	**13-Oct**	**Total**
Daily Mean River Flow (cfs)	17,800	15,450	27,100	16,600	21,000	28,700	24,500	24,900	
Water Temperature (°C)	27.0	27.0	27.0	26.0	23.0	20.5	22.0	16.5	
Secchi Disk (in)	38	8	22	28	13	18	30	30	
American shad				8	5	4			17
Gizzard shad			8	3	2	7	9		29
Golden shiner				1				1	2
Comely shiner								1	1
Spottail shiner	2		7	1	1				11
Spotfin shiner	45	5	11	6	2	6	6	9	90
Mimic shiner								3	3
Bluntnose minnow	1							1	2
Creek chub		2		2					4
Quillback					1		1		2
White sucker							1		1
Northern hog sucker	1								1
Channel catfish	1		5	6	1				13
Rock bass				1	1				2
Redbreast sunfish	2								2
Pumpkinseed		3							3
Smallmouth bass	1					1			2
Tessellated darter			2	2					4
Walleye				1					1
Total	**53**	**10**	**33**	**31**	**13**	**18**	**17**	**15**	**190**
No. of Species	**7**	**3**	**5**	**10**	**7**	**4**	**4**	**5**	**19**

Table 4. Index of abundance for juvenile American shad collected by haul seine at Marietta, Columbia and Wrightsville, 1990-2003.

Year	No. Hauls	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Haul CPUE*	No. Wild Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)
1990	87	285	4.40	1.23		0	0.15	0.11
1991	144	170	1.01	0.54		80	0.48	0.35
1992	92	269	4.24	1.45		146	2.49	0.78
1993	111	218	1.90	1.22		174	1.61	1.01
1994	110	390	4.74	2.29		254	3.19	1.38
1995	48	409	8.92	7.89		58	1.29	1.06
1996	105	283	2.89	2.05		157	1.61	1.20
1997	90	879	9.77	6.77	3.36	136	1.51	1.24
1998	94	230	2.51	1.03	0.50	5	0.05	0.05
1999	90	322	3.58	1.16	0.67	13	0.15	0.13
2000	90	31	0.34	0.26	0.14	0	0.00	0.00
2001	90	377	4.19	3.04	1.52	119	1.32	1.25
2002	84	0	0.00	0.00	0.00	0	0.00	0.00
2003	48	17	0.35	0.28	0.20	2	0.04	0.04

* Required by ASMFC

Table 5. Weekly catch of juvenile American shad by haul seine from the lower Susquehanna River, 1989 - 2003.

Week	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
I Jul				0		2										2
II Jul	1,048		0	120	0	27		2	44	10	0	7				1,258
III Jul			0	6		70	53	18	28	14	0	3	46	0	0	238
IV Jul	45	31			0	60	24	15	22	144	1	0	23	0	0	365
I Aug		0	0	20	0	24	29	32	14	30	1	2	19	0	*	171
II Aug	61	0	0	2	8	13	35	56	20	0	0	6	70	0	*	271
III Aug	7	69	0	16	0	46	40	43	171	9	0	1	37	0	*	439
IV Aug					13		42	39	120	10	8	0	36	0	0	268
I Sep		25	12		20		43	34	129	3	2	0	36	0	8	312
II Sep		4			15	50	31	3	46	3	*	0	23	0	5	180
III Sep		93	16		26	25	34	1	89	3	264	0	31	0	4	586
IV Sep		28	30		27	14	46	12	59	1	17	0	15	0	0	249
V Sep		0	73		11	5	15	15	32	0	20	1	34	0	*	206
I Oct		0	69	2	22	5	19	10	91	3	1	0	6	0	*	228
II Oct		0	7		0	2	31	3	0	0	3	11	1	0	*	58
III Oct			5			10			14	0	5	0	0	*	0	34
IV Oct			0	0			0	0					0	0	*	0
TOTAL	1,161	250	212	166	142	353	442	283	879	230	322	31	377	0	17	4,865

* No sampling due to high river flow.

Table 6. Summary of fish collected by seine in the Conestoga River, 2003.

Date	28 Jul	04 Aug	13 Aug	20 Aug	25 Aug	
Daily mean flow (cfs)	460	390	409	369	303	
Water temp. range (°C)	24.0-26.0	24.0-25.5	24.0-25.5	24.5-26.0	22.0-24.0	
Secchi range (in)	24-36	24-36	12-30	24-38	40	Totals
Common shiner	1		1			2
Spottail shiner		2	5	1	1	9
Swallowtail shiner	11	2				13
Rosyface shiner	1	13	49	11	29	103
Spotfin shiner	108	51	89	37	52	337
Mimic shiner	7	16	4	17	36	80
Bluntnose minnow		1		3	1	5
Longnose dace	2		1			3
Northern hog sucker			1			1
Banded killifish		2	4			6
Rock bass				1	2	3
Redbreast sunfish	2			4		6
Smallmouth bass			3	3	1	7
Largemouth bass		1				1
Tessellated darter	2		3			5
Total	134	88	160	77	122	581
No. Species	8	8	10	8	7	15

Table 7 . Summary of fish species collected by seine in West Conewago Creek, 2003.

Date	29 Jul	05 Aug	14 Aug	21 Aug	26 Aug	
Daily mean flow (cfs)	165	233	521	373	215	
Water temp. range (°C)	25.5-27.0	26.0-27.0	26.0-27.0	26.0-26.5	25.0-27.0	
Secchi range (in)	24-36	16-36	12-18	12-18	40	Totals
Central stoneroller			2			2
Common shiner	5	3	4	3	11	26
Spottail shiner				2		2
Rosyface shiner	27	16	5	9	10	67
Spotfin shiner	32	41	33	24	37	167
Mimic shiner	1	8	2	1	13	25
Bluntnose minnow	3	26	7	1	2	39
Fallfish				1		1
Quillback		2	2			4
White sucker			1		2	3
Northern hog sucker			1	1		2
Channel catfish	1		2	2		5
Rock bass	11	1	2		1	15
Redbreast sunfish	1	3				4
Pumpkinseed		3				3
Bluegill	1	1				2
Smallmouth bass	4	1	5	1	4	15
Greenside darter			1			1
Tessellated darter		1	10	1	3	15
Total	86	106	77	46	83	398
No. Species	10	12	14	11	9	19

Table 8. Summary of fish species collected by seine in Conodoguinet Creek, 2003.

Date	29 Jul	05 Aug	14 Aug	20 Aug	26 Aug	
Daily mean flow (cfs)	249	268	374	283	235	
Water temp. range (°C)	21.5-23.5	21.5-25.0	22.0-25.0	21.0-24.0	22.5-24.5	
Secchi range (in)	40	36	24-40	40	40	**Totals**
Golden shiner			1			1
Common shiner	10	5	9	6	11	41
Swallowtail shiner			1			1
Spotfin shiner	93	42	24	44	24	227
Mimic shiner	1	13	33	24	5	76
Bluntnose minnow	1	4	16	12	6	39
Creek chub	3	1				4
Fallfish			4	1	1	6
Pearl dace				1		1
White sucker		6				6
Northern hog sucker			1	2	1	4
Shorthead redhorse				1		1
Yellow bullhead				1		1
Margined madtom					3	3
Banded killifish	10	23	28	36	35	132
Rock bass			1	38	25	64
Redbreast sunfish		3	1		3	7
Smallmouth bass	2	9	1	18	9	39
Total	120	106	120	184	123	653
No. Species	7	9	12	12	11	18

Table 9. Summary of fish species collected by seine in Swatara Creek, 2003.

Date	28 Jul	04 Aug	21 Aug	25 Aug	03 Sep	
Daily mean flow (cfs)	611	500	650	466	526	
Water temp. range (°C)	20.5-23.0	21.5-23.5	19.5-22.0	18.5-21.0	17.5-19.5	
Secchi range (in)	18-24	12-18	30-36	36-42	20-30	**Totals**
Central stoneroller				2	1	3
River chub					3	3
Comely shiner				1		1
Common shiner		2	1			3
Spottail shiner	5	3		3		11
Swallowtail shiner					4	4
Rosyface shiner					1	1
Spotfin shiner	48	33	40	39	38	198
Mimic shiner	3	5		6		14
Bluntnose minnow	1			2		3
Creek chub	1			5		6
Fallfish	15	20	31	2	28	96
White sucker	2	1				3
Northern hog sucker				6	1	7
Banded killifish	2		3		3	8
Redbreast sunfish	1		2	3		6
Bluegill			1	1	1	3
Smallmouth bass	1	1	1			3
Tessellated darter				2	4	6
Total	79	65	79	72	84	379
No. Species	10	7	7	12	10	19

Table 10. Number of fish collected by boat-mounted electrofisher from the Susquehanna River near Clemson Island, 2003.

Date	**20-Aug**	**26-Aug**	**2-Sep**	**11-Sep**	**17-Sep**	**7-Oct**	**16-Oct**	**21-Oct**	**Total**
River Flow (cfs)	25,800	13,300	22,800	28,200	22,400	32,800	36,000	33,200	
Water Temperature (°C)	25.0	25.0	21.0	21.0	21.5	12.2	13.0	12.0	
Secchi Disk (in)	42	60	68	90	27	100	26	100	
Volts	220	200	150	220	200	300	240	250	
Amps	6.0	6.0	6.0	6.0	6.0	5.0	6.0	5.0	
Gizzard shad							1		1
Common carp		1						1	2
Comely shiner			2						2
Spotfin shiner	2		6	24	21				53
Fallfish				5				1	6
Quillback	2	1		9			1	27	40
Northern hog sucker				2				3	5
Shorthead redhorse	2	1		14		1	1	30	49
Channel catfish				1				1	2
Rock bass				4					4
Redbreast sunfish				1					1
Smallmouth bass	1	2	2	50	7	2	13	36	113
Largemouth bass		2							2
Walleye				2	1		1	26	30
Total	**7**	**7**	**10**	**112**	**29**	**3**	**17**	**125**	**310**
No. of Species	**4**	**5**	**3**	**10**	**3**	**2**	**5**	**8**	**14**

Table 11. Number of fish collected by boat-mounted electrofisher from the Juniata River near Mifflintown, Pennsylvania, 2003.

Species	21-Aug	28-Aug	9-Sep	16-Sep	*	9-Oct	13-Oct	23-Oct	Total
River Flow (cfs)	1,510	1,719	2,420	2,350		2,700	1,880	2,560	
Water Temperature (°C)	26.0	24.0	20.0	19.8		14.0	13.5	10.8	
Secchi Disk (in)	45	71	38	20		87	90	123	
Volts	200	160	200	180		200	210	230	
Amps	6.0	6.0	6.0	6.0		6.0	6.0	6.0	
American shad			1	6					7
Gizzard shad								9	9
Central stoneroller								1	1
Common carp						1			1
River chub							1	3	4
Comely shiner			1						1
Rosyface shiner			3						3
Spotfin shiner	24	22	8	4		23	61	12	154
Mimic shiner	12								12
Fallfish				1		6		5	12
Quillback		1		7				4	12
White sucker	1		1	15		2	3	5	27
Northern hog sucker		1	1	8		4	2	5	21
Shorthead redhorse		2	1	6		8	1	1	19
Channel catfish			1						1
Margined madtom								1	1
Rock bass		2	3			2	9	2	18
Bluegill								1	1
Smallmouth bass	4	9	25	28		17	38	21	142
Largemouth bass			2						2
Walleye			1	2		4			7
Total	**41**	**37**	**48**	**77**	**0**	**67**	**115**	**70**	**455**
No. of Species	**4**	**6**	**12**	**9**	**0**	**9**	**7**	**13**	**21**

* No sampling due to high river flow.

Table 12. Summary of the electrofishing catch of juvenile American shad in the Juniata River near Mifflintown, 2003.

Date	Duration (min)	Number of Shad Captured	Number of Shad Observed	No. American Shad	CPUE (No./hour)
21 Aug	60	0	0	0	0.00
28 Aug	63	0	0	0	0.00
9 Sep	61	1	0	1	0.98
16 Sep	62	6	3	9	8.71
*					
9 Oct	61	0	0	0	0.00
13 Oct	63	0	0	0	0.00
23 Oct	60	0	0	0	0.00
Total	***430***	***7***	***3***	***10***	
Mean					***1.40***

* No sampling due to high river flow.

Table 13. Number and percent composition of fishes collected by an 8 x 8 ft lift net from Holtwood Power Station inner forebay, 16 September through 12 December 2003.

Date:	*16 Sep*	*20 Sep*	*22 Sep*	*25 Sep*	*28 Sep*	*01 Oct*	*04 Oct*	*07 Oct*	*10 Oct*	*13 Oct*	*16 Oct*	*19 Oct*	*22 Oct*	*25 Oct*	*28 Oct*	*31 Oct*
Water Temp (°C):	*21.5*	*21.0*	*20.5*	*19.0*	*18.5*	*17.0*	*13.5*	*13.0*	*14.5*	*16.0*	*15.5*	*13.0*	*13.0*	*11.0*	*12.0*	*10.0*
Secchi (in):	*28*	*23*	*21*	*10*	*20*	*21*	*28*	*33*	*30*	*30*	*31*	*36*	*29*	*36*	*21*	*10*
River Flow (cfs):	*22,800*	*38,000*	*40,300*	*98,900*	*59,450*	*77,700*	*47,600*	*37,700*	*31,900*	*24,900*	*36,400*	*44,500*	*33,200*	*28,900*	*57,750*	*123,000*
Start Time (hr):	*1840*	*1841*	*1838*	*1845*	*1829*	*1818*	*1807*	*1813*	*1805*	*1808*	*1810*	*1808*	*1745*	*1750*	*1701*	*1637*
End Time (hr):	*2020*	*2000*	*1955*	*2003*	*1953*	*1937*	*1931*	*1925*	*2000*	*1930*	*1940*	*1940*	*1915*	*1904*	*1850*	*1755*
American shad	-	-	-	-	4	-	8	31	-	10	-	8	-	-	-	-
Gizzard shad	-	3	-	-	13	-	1	-	-	-	-	-	-	-	-	-
Comely shiner	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spotfin shiner	-	13	32	-	13	1	8	-	2	-	5	-	-	-	-	-
Striped bass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Pumpkinseed	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	1	2	1	2	-	-	-	-	-	-	-	-	-	-
Total	***5***	***16***	***35***	***2***	***31***	***3***	***17***	***31***	***2***	***10***	***5***	***8***	***0***	***0***	***1***	***0***
No. of Species	***1***	***2***	***3***	***1***	***4***	***2***	***3***	***1***	***1***	***1***	***1***	***1***	***0***	***0***	***1***	***0***

Table 12. Continued.

Date:	*03 Nov*	*06 Nov*	*09 Nov*	*12 Nov*	*15 Nov*	*18 Nov*	*21 Nov*	*24 Nov*	*26 Nov*	*30 Nov*	*03 Dec*	*06 Dec*	*09 Dec*	*12 Dec*	
Water Temp (°C):	*12.0*	*13.5*	*11.0*	*8.8*	*8.0*	*7.5*	*9.5*	*9.0*	*7.5*	*6.5*	*4.0*	*2.0*	*1.5*	*4.0*	
Secchi (in):	*27*	*29*	*28*	*40*	*28*	*50*	*8*	*7*	*13*	*18*	*23*	*28*	*50*	*6*	
River Flow (cfs):	*74,500*	*51,000*	*49,500*	*39,800*	*35,300*	*32,900*	*194,000*	*115,000*	*86,100*	*75,200*	*68,300*	*49,100*	*41,200*	*201,000*	
Start Time (hr):	*1643*	*1629*	*1638*	*1617*	*1620*	*1620*	*1603*	*1614*	*1611*	*1603*	*1603*	*1600*	*1608*	*1555*	
End Time (hr):	*1811*	*1735*	*1800*	*1736*	*1750*	*1734*	*1713*	*1714*	*1730*	*1728*	*1712*	*1720*	*1709*	*1705*	***TOTAL***
American shad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**61**
Gizzard shad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**17**
Comely shiner	-	-	-	-	-	1	-	-	-	-	-	-	-	-	**6**
Spotfin shiner	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**74**
Striped bass	1	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
Bluegill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**6**
Total	***1***	***0***	***0***	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***168***
No. of Species	***1***	***0***	***0***	***0***	***0***	***1***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***7***

Table 14. Index of abundance for American shad collected by lift net in the forebay of Holtwood Hydroelectric Station, 1985-2003.

Year	No. Lifts	No. Fish	Mean Combined Daily CPUE	GM Combined Daily CPUE	GM Individual Lift CPUE*	No. Wild Fish	Mean Combined Daily CPUE (Wild)	GM Combined Daily CPUE (Wild)	Migration Duration (days)
1985	378	3,626	20.31	7.55		**	**		65
1986	404	2,926	10.30	5.71		**	**		64
1987	428	832	3.17	1.90		**	**		72
1988	230	929	3.87	1.28		**	**		51
1989	286	556	0.86	0.43		**	**		35
1990	290	3,988	13.75	3.67		70	0.24	0.18	72
1991	370	208	0.56	0.39		19	0.05	0.05	71
1992	250	39	0.16	0.12		14	0.06	0.05	43
1993	250	1,095	4.38	1.20		669	2.79	0.86	56
1994	250	206	0.82	0.48		35	0.15	0.13	71
1995	115	1,048	9.11	1.26		83	0.72	0.32	34
1997	300	1,372	4.57	0.88	0.61	100	0.33	0.23	46
1998	300	180	0.60	0.37	0.22	9	0.03	0.03	67
1999	300	490	1.63	0.78	0.50	19	0.06	0.07	40
2000	300	406	1.35	0.61	0.18	4	0.01	0.01	43
2001	299	1,245	4.18	1.37	0.43	538	1.81	0.45	73
2002	220	68	0.31	0.15	0.09	15	0.07	0.05	13
2003	300	61	0.20	0.13	0.07	3	0.01	0.01	22

* Required by ASMFC

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

Table 15. Historical weekly catch per unit effort (CPUE) of juvenile American shad collected by an 8 x 8 ft lift net at Holtwood Power Station inner forebay, August-December 1985-2003*.

	Historical Years																	
Week	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
II Aug	-	-	-	-	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-
III Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-
IV Aug	-	-	-	-	-	0.0	0.0	0.0	-	-	0.0	-	-	-	-	-	-	-
I Sep	-	-	-	0.0	-	0.8	0.0	1.4	0.0	0.5	0.0	-	-	-	-	-	-	-
II Sep	-	-	1.3	-	-	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.0	0.0	-	-
III Sep	-	-	0.7	-	2.3	0.0	0.0	0.5	0.0	0.0	-	0.0	0.0	9.7	0.0	0.0	-	-
IV Sep	-	-	0.3	-	-	7.5	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.3	0.0	2.6	0.0	**0.0**
V Sep	-	-	0.9	0.0	1.2	3.9	0.1	0.1	0.2	4.3	0.1	0.0	0.1	4.7	0.0	0.5	0.0	**0.0**
I Oct	-	16.7	4.1	0.1	1.2	2.0	0.1	0.0	0.2	3.5	0.0	0.0	0.8	3.7	0.0	0.1	0.0	**0.4**
II Oct	0.1	30.3	4.5	0.0	3.2	52.0	0.6	0.2	0.1	0.7	5.0	0.0	1.9	2.1	0.1	0.2	0.0	**1.6**
III Oct	1.0	5.4	1.3	10.0	0.5	50.2	0.9	0.3	17.5	0.3	68.9	0.2	1.3	1.0	0.7	0.0	1.7	**0.5**
IV Oct	41.6	5.3	4.8	19.1	0.0	34.3	1.1	0.1	14.8	0.1	56.0	0.0	1.7	0.0	2.5	2.5	1.7	**0.3**
I Nov	28.6	4.1	4.5	2.0	0.0	1.7	2.4	0.0	19.0	0.6	9.3	25.1	1.6	0.0	0.6	4.7	0.0	**0.0**
II Nov	10.8	19.5	0.3	0.3	0.0	0.4	0.5	0.7	1.6	0.1	0.0	27.1	0.1	0.0	13.2	4.2	0.0	**0.0**
III Nov	57.6	6.3	0.7	0.5	-	0.0	0.8	0.0	0.1	0.0	0.0	3.0	0.1	0.0	5.5	0.1	0.0	**0.0**
IV Nov	15.1	-	-	0.3	-	0.0	1.6	-	0.0	0.0	0.0	0.5	0.0	0.0	1.2	7.0	0.0	**0.0**
I Dec	62.8	14.2	0.0	0.0	-	-	-	0.9	-	0.0	-	0.0	0.0	0.0	0.0	30.9	0.0	**0.0**
II Dec	4.3	0.1	-	-	-	-	1.2	-	-	-	-	-	0.6	-	-	-	-	**0.0**
III Dec	0.5	0.0	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-
Total shad	3,626	2,926	832	929	556	3,988	208	39	1,095	206	2,100	1,372	180	490	406	1,245	68	**61**
Total lifts	378	404	428	230	286	290	370	240	240	250	230	300	300	300	290	300	260	**300**
CPUE	9.6	7.2	1.9	4.0	1.9	13.8	0.6	0.2	4.6	0.8	9.1	4.6	0.6	1.6	1.4	4.2	0.3	**0.2**

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

Table 16. Length frequency distribution of juvenile American shad collected for otolith analysis by an 8 x 8 ft lift net in the Holtwood Power Station inner forebay, 28 September through 19 October, 2003.

Total Length	September	October							Total
(mm)	28	1	4	7	10	13	16	19	
101-105			1						1
106-110	2	N	2		N		N		4
111-115	2	O	4	1	O	1	O		8
116-120				5		1		2	8
121-125		S		7	S	1	S	4	12
126-130		H		9	H	1	H	1	11
131-135		A		5	A	3	A	1	9
136-140		D		4	D	3	D		7
141-145			1						1
Total	*4*	*0*	*8*	*31*	*0*	*10*	*0*	*8*	61

Table 17. Number of fish collected during intake screen sampling by unit at Peach Bottom Nuclear power Station, October-November, 2003.

Species	Unit 2	Unit 3	Total
American shad	3	4	**7**
Blueback herring	33	15	**48**
Alewife	0	2	**2**
Gizzard shad	734	800	**1,534**
Rainbow smelt	0	1	**1**
Common carp	1	2	**3**
Golden shiner	1	2	**3**
Comely shiner	0	16	**16**
Spotfin shiner	2	2	**4**
Spottail shiner	0	1	**1**
White sucker	1	0	**1**
Quillback	1	0	**1**
Yellow bullhead	1	0	**1**
Channel catfish	28	52	**80**
Rock bass	5	4	**9**
Redbreast sunfish	0	2	**2**
Green sunfish	8	15	**23**
Pumpkinseed	0	2	**2**
Bluegill	136	413	**549**
Smallmouth bass	3	7	**10**
Largemouth bass	2	2	**4**
White crappie	18	24	**42**
Black crappie	0	1	**1**
Yellow perch	24	73	**97**
Walleye	1	2	**3**
Tessellated darter	2	3	**5**
Hybrid Striped bass	0	1	**1**
TOTAL	*1,004*	*1,446*	*2,450*

Table 18. Number of juvenile American shad collected during intake screen sampling by unit at Peach Bottom Atomic Power Station, October- November, 2003.

Date	Unit 2	Unit 3	Total
17 Oct	1	0	**1**
24 Oct	0	1	**1**
29 Oct	2	1	**3**
03 Nov	0	1	**1**
24 Nov	0	1	**1**
TOTAL	***3***	***4***	***7***

Table 19. Species and number of fish collected during cooling water intake sampling at Conowingo Dam, October-November, 2003.

Species	Francis Units (7)	Kaplan Units (4)	Total
American shad	3	15	**18**
Alewife	1	3	**4**
Blueback herring	0	2	**2**
Gizzard shad	121	1,826	**1,947**
Comely shiner	5	0	**5**
Spotfin shiner	0	2	**2**
Channel catfish	2	5	**7**
Green sunfish	0	1	**1**
Bluegill	0	3	**3**
Yellow perch	0	5	**5**
TOTAL	***132***	***1,862***	***1,994***

Table 20. Number of juvenile American shad collected during cooling water intake strainer sampling, Conowingo Dam, October- November, 2003.

Date	Francis Units (7)	Kaplan Units (4)	Total
04 Oct	0	1	**1**
20 Oct	2	1	**3**
23 Oct	0	9	**9**
31 Oct	0	4	**4**
02 Nov	1	0	**1**
TOTAL	***3***	***15***	***18***

Table 21. Catch, effort and catch-per-unit-of-effort of juvenile American shad by location from the upper Chesapeake Bay during the 2003 Maryland DNR Juvenile Finfish Haul Seine Survey.

	Round 1		Round 2		Round 3		Totals	
Location	Catch #	Hauls	Catch #	Hauls	Catch #	Hauls	Catch #	Hauls
A. Permanent stations								
Howell Pt.	0	2	11	2	25	2	36	6
Worten Cr.	0	2	1	2	0	2	1	6
Ordinary Pt.	1	2	1	2	1	2	3	6
Parlor Pt.	0	2	1	2	0	2	1	6
Elk Neck Pt.	0	2	1	2	3	2	4	6
Welch Pt.	1	2	14	2	13	2	28	6
Hyland Pt.	2	2	14	2	8	2	24	6
Totals	4	14	43	14	50	14	97	42
CPUE	0.29		3.07		3.57		2.31	
B. Auxiliary stations								
Carpenter Pt.	1	1	0	1	2	1	3	3
Plum Pt.	0	1	11	1	17	1	28	3
Spoil Is.	0	1	8	1	3	1	11	3
Tydings Est.	0	1	1	1	0	1	1	3
Tolchester	0	1	0	1	0	1	0	3
Totals	1	5	20	5	22	5	43	15
CPUE	0.20		4.00		4.40		2.87	
Grand Total	5	19	63	19	72	19	140	57
CPUE	0.26		3.32		3.79		2.46	

Table 22. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 2003.

Collection Site	Coll. Date	Immersion marks: Day 3 Jun. R./ Susq. R.	Days 3,6,9 Jun. R./ Susq. R.*	Days 3,6,12,15 Conodoguinet Cr.	Days 3,6,12 W. Conewago Cr.	Days 3,6,9,15,18 Swatara Cr.	Days 3,9,12,15 Conestoga Cr.	Days 3,9,12 W. Br. Sus. R.	Days 3,6,12,15,18 N. Br. Sus. R.(PA)	Days 3,6,9 12,18 N. Br. Sus. R.(NY)	Days 3,12,15 Chemung	Atypical mark	Total Hatchery	Total Wild	Total Processed	Total Collected
Juniata R.	9/9/2003	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	9/16/2003	1.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	6	6
Columbia	8/27/2003	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	6.0	2.0	8	8
	9/2/2003	3.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	5.0	0.0	5	5
	9/12/2003	1.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4	4
Holtwood	9/28/2003	2.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	4.0	0.0	4	4
	10/4/2003	3.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	7.0	1.0	8	8
	10/7/2003	11.0	13.0	1.0	1.0	0.0	0.0	2.0	2.0	0.0	0.0	1.0	31.0	0.0	31	31
	10/13/2003	7.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	10.0	0.0	10	10
	10/19/2003	2.0	3.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	6.0	2.0	8	8
Peach Bottom Impingement	10/17/2003	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	10/24/2003	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	10/29/2003	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5 **	1.5 **	2	3
	11/3/2003	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
	11/24/2003	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
Conowingo Strainers	10/4/2003	not processed													0	1
	10/20/2003	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	3	3
	10/23/2003	1.5	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	7.5 **	1.5 **	6	9
	10/31/2003	2.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	2	4
	11/2/2003	not processed													0	1
Holt./P. Bot./Con.		30.5	26.5	1.0	3.0	2.0	0.0	4.0	7.0	2.0	0.0	1.0	77.0 **	7.0 ***	78	86
Percent		35.5%	30.8%	1.2%	3.5%	2.3%	0.0%	4.7%	8.1%	2.3%	0.0%	1.2%	91.7%	8.3%		
Grand Total		37.5	37.5	1.0	4.0	2.0	0.0	4.0	8.0	2.0	0.0	3.0	99.0 **	9.0 ***	102	110
Percent		34.1%	34.1%	0.9%	3.6%	1.8%	0.0%	3.6%	7.3%	1.8%	0.0%	2.7%	91.7%	8.3%		

*Susquehanna River source eggs.

**When the entire sample collected was not processed, the shad successfully processed were weighted to ensure that row totals equalled the total number collected.

***Total Hatchery plus Total Wild does not equal Total Collected due to unprocessed shad on 10/4 and 11/2.

Job V – Task 1

ANALYSIS OF ADULT AMERICAN SHAD OTOLITHS, 2003

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

ABSTRACT

A total of 197 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2003. Based on tetracycline marking 26% of the 196 readable otoliths were identified as wild and 74% were identified as hatchery in origin. No double marked fish (released below Conowingo Dam) were collected in the Conowingo West Lift samples.

Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1986-1997 year classes, stocking of approximately 183 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 133 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.64 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1997 year class is not fully recruited. Actual survival is even higher since not all surviving adults enter the lifts.

Age composition and otolith marking data was also used to analyze virtual and relative survival rates of adults stocked as larvae at different sites. Few trends were noted except that fish stocked in Conodoguinet Creek appeared to exhibit higher than average survival and fish stocked in the West Branch Susquehanna River appeared to exhibit lower than average survival. There was no correlation between relative survival of juveniles and that of adults, possibly as a result of aging errors.

INTRODUCTION

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). Primary restoration approaches consisted of (1) trapping of pre-spawn adults at Conowingo Dam and transfer to areas above dams (1972 to 1999), (2) direct fish passage (1997 to the present), and (3) planting of hatchery-reared fry and fingerlings.

In order to evaluate and improve the program, it was necessary to know the relative contribution of the hatchery program to the overall restoration effort. Toward that end, the Pennsylvania Fish Commission developed a physiological bone mark which could be applied to developing fry prior to release (Lorson and Mudrak, 1987; Hendricks et al., 1991). The mark was produced in otoliths of hatchery-reared fry by immersion in tetracycline antibiotics. Analysis of otoliths of outmigrating juveniles allows discrimination of "wild" vs. hatchery reared fish. The first successful application of tetracycline marking at Van Dyke was conducted in 1984. Marking on a production basis began in 1985 but was only marginally successful (Hendricks, et al., 1986). In 1986, 97.8% tag retention was achieved (Hendricks, et al., 1987) and analysis of outmigrants indicated that 84% of the upstream production (above Conowingo Dam) was of hatchery origin vs 17% wild (Young, 1987). Similar data has been collected in subsequent years.

Determination of the contribution to the overall <u>adult</u> 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 planted below Conowingo Dam from 1986 to 1996.

Since mark retention did not approach 100% until 1987, adult hatchery shad from cohorts produced before 1987 did not exhibit 100% marking. For the years in which these fish returned to the river as adults, marking rates could therefore be used only to determine minimum contribution of hatchery-reared fish. For fish which did not exhibit a mark, otolith microstructure (Hendricks et al., 1994) was used to distinguish hatchery fish from wild fish.

From 1989 to 1994 most American shad fry stocked in the Susquehanna River Basin were marked according to egg source river. Recaptures of those fish as juveniles showed consistently better survival for Hudson River larvae, however, recaptures as adults at Conowingo Dam showed better survival for Delaware River source fish (Hendricks, 2001). From 1994 to 2003, American shad stocked in the Susquehanna River Basin were marked according to stocking site. Recaptures rates of these fish as juveniles were highly variable and showed no indication that there were consistent differences in survival of larvae between stocking sites (see Job III, Appendix 2). The only clear trend was that survival of larvae stocked in the West Branch Susquehanna River was never among the highest for any cohort. Since several of these cohorts are nearly or fully recruited, it is now possible to investigate the effect of stocking site on survival of larvae to adulthood. This report presents results of evaluation of otoliths from adult American shad collected in 2003 and summarizes results from prior years collections.

METHODS

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad to enter the West lift. Adult American shad collected in the upper Chesapeake Bay by Maryland DNR were processed by MDNR staff and are not reported here. Each sampled fish was sexed, measured and decapitated. Whole heads were frozen and delivered to the Van Dyke Hatchery. Otoliths (sagittae) were extracted and one otolith was mounted for mark analysis in Permount® on a microscope slide, while the other was mounted for ageing on clear tape in two part, rod-building epoxy. For mark analysis, otoliths were ground on both sides to produce a thin sagittal section and the specimen examined under UV light for the presence of a tetracycline mark.

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

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 2002. Age composition data was gathered as follows: for 1996 to 2003, age composition data were collected from the aforementioned otolith analysis. For 1991-1995, age composition data were taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1989 and 1990, age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transporting mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991).

Recruitment to the lifts by year class was determined for hatchery and wild origin fish by partitioning the lift catch for each year into its component year classes based upon age composition and otolith marking data. Total recruitment by year class was determined for hatchery and wild groups by summing the data for each year class over its recruitment history. The number of larvae required to return one adult to the lifts (L/A) was determined for each year class by dividing the number of larvae stocked above dams by the total recruitment of adults which originated as hatchery larvae. Similarly, the number of fingerlings required to return one adult (F/A) was determined for each year class by dividing the number of finglerlings stocked above dams by the total recruitment of adults which originated as hatchery fingerlings. The number of transported adults required to return one adult (TA/A) was determined for each year class by dividing the number of adults transported upstream by the total recruitment of unmarked (wild) adults. Overall L/A, F/A and TA/A were calculated by dividing the sum of the number stocked or transported by the sum of the total recruitment of the group, for the cohorts in question.

Recruitment to the Conowingo fish lifts by year class and stocking site was determined by partitioning the lift catch for each year into its components based upon age composition and otolith marking data. Total recruitment by year class and stocking site was determined by summing the data for each component over its recruitment history. Virtual survival rate was calculated by dividing total recruitment to the lifts for each component by the number stocked for that group, and multiplying by 10,000 to remove the decimals and convert to the rate to a whole number. Relative survival was calculated by dividing the virtual survival rate for each group by the highest virtual survival rate for that cohort.

RESULTS AND DISCUSSION

A total of 197 shad was sacrificed for otolith analysis from the West Lift catch at Conowingo Dam in 2003. No samples were collected from the East Lift since it was operated in fish passage mode. There was one unreadable otolith (Table 1). A total of 50 (26%) otoliths exhibited wild microstructure and no tetracycline mark. One hundred and forty-six (74%) exhibited tetracycline marks including single, triple, quadruple, and quintuple immersion marks. No specimens exhibited double marks or feed marks. Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. The contribution of wild (naturally produced) fish to the adult population entering the Conowingo Dam fish lifts during 1989-2003 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in Conowingo Lift collections was low prior to 1996, the numbers of wild fish showed an increasing trend from 1989 to 2000 and have decreased since 2000 (Figure 2).

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 3). Overall mean age was 4.6 years for males and 5.6 years for females. For wild fish, mean ages were 4.8 for males and 5.6 for females (Table 4). For hatchery fish, mean age was 4.6 for males and 5.6 for females. Overall sex ratio was 0.90 to 1, males to females. Length frequencies and mean length at age are tabulated in Tables 5 to 8. As expected, females were larger than males. Age and length distributions were similar for wild and hatchery fish.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 9. Analysis of otoliths to assess hatchery contribution was not conducted prior to 1989. As a result, the catch for year classes prior to 1986 could not be partitioned into hatchery and wild and are not presented. Year classes after 1996 are not fully recruited and are not included in the analysis. For the period 1986-1997, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 60 to 620, with an overall value of 183 (Table 10). This is a maximum estimate since the 1997 year class is not fully recruited. L/A was highest (431-620) for the early cohorts (1986 – 1989). During 1990 to 1996, L/A improved to 60-289, presumably due to improvements in fish culture practices.

L/A was surprisingly low in comparison to the reproductive potential of wild fish. If fecundity of wild females is assumed to be 200,000, then 2 of 200,000 eggs must survive to maturity to replace the spawning pair in a stable population. If we assume a fertilization rate of 60% (comparable to strip-spawning), 60,000 fertilized eggs would be required to produce one wild adult at replacement. This suggests that mortality in the wild is extremely high during incubation and/or for the first week after hatch.

This analysis was repeated for fingerlings stocked above Conowingo Dam (Table 11). For the period 1986-1997, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 40 to 386, with an overall value of 133. Again, this is a maximum estimate since the 1996 year class is not fully recruited. At first glance, it would appear that stocking fingerlings is advantageous over stocking larvae, however, on average, one must stock 100,000 larvae in a pond to harvest 10,000 to 20,000 fingerlings. Therefore, it would take 700 to 1,400 larvae, stocked in a pond, then harvested and stocked in the river as fingerlings to produce one adult. Considering the cost of pond culture, it is clearly better to stock larvae directly. In future years, F/A is unlikely to change since the last significant fingerling stockings were in 1994 and the last fingerlings recovered were in 1999. The appearance of 225 recruited adults for the 1995 cohort and 43 for the 1996 cohort, when no fingerlings were stocked, is an artifact of erroneous aging, and highlights the problems with aging American shad.

A similar analysis was tabulated for wild fish (Table 12). For the period 1986 to 1996, transport of an average of 0.64 adults was required to produce one returning adult, above the level required for replacement. The actual stock/recruitment ratio of wild fish is unknown since some of the wild fish which entered the lifts would have been of Upper Bay origin and not all recruited fish entered the lifts. These factors may act to cancel each other out, but the magnitude of each is not known.

Stress during trucking may account for reduced performance of transported spawners. The high fecundity of the species has the potential to overcome this, since just a few successful spawners can produce huge numbers of offspring. Another possible explanation is that there may be some threshold number of spawners required to ensure successful spawning. Whatever the cause, stock/recruitment ratios are improving in recent years and must continue to do so to allow for successful restoration.

Virtual survival rates by cohort and stocking site are reported in Table 13. As expected, some cohorts survived better than others, probably due to environmental conditions. The 1996 cohort exhibited the highest virtual survival rate (145) followed by 1997 (120) and 1995 (73). The 1998 and 1999 cohorts are not yet fully recruited.

Relative survival for individual stocking sites was highly variable between cohorts (Table 13). For example, relative survival for the Juniata River/Juniata or middle Susquehanna sites ranged from 0.23 to 0.93. For the North Branch Susquehanna River the range was from 0.21 to 0.76. For West Conewago Cr. , relative survival ranged from 0.00 to 1.00. For Swatara Cr., relative survival ranged from 0.00 to 0.75. For Conodoguinet Creek, relative survival ranged from 0.22 to 1.00. Conodoguinet Creek exhibited the highest survival for both the 1997 and 1999 cohorts and a very high relative survival (0.83) for the 1996 cohort. Both virtual and relative survival rates were consistently poor for the West Branch Susquehanna River.

Stocking site/cohort specific relative survival of juvenile shad had no relationship to that for adult shad (Figure 3). This result is counter-intuitive since it is logical to assume that groups which exhibited better survival as juveniles would also exhibit better survival as adults. It is clear from Figure 3 that that is not the case. Either survival to the juvenile stage has no relationship to survival to adulthood, one of the recapture samples are not representative of the population, or errors in aging resulted in incorrect partitioning of the lift catch which had the effect of randomizing the data. It is difficult to believe that stocking site carries with it some survival advantage (or disadvantage) which is expressed between the Fall outmigration, when juveniles are recaptured, and the Spring spawning migration, when returning adults are recaptured several years later. It is equally unlikely that the Conowingo Fish Lifts select for or against adult shad based on the site where they were stocked. It seems more likely that collections of juveniles at Holtwood, Peach Bottom and Conowingo somehow select for or against fish based on stocking site, however the mechanism by which that occurs is not known. Perhaps distance between the stocking site and juvenile recapture site, coupled with river flow and migration rate are somehow interacting to produce a recapture sample that is not representative of the population. Errors in otolith aging certainly occur and can be as much as 30 to 40% (unpublished data based on known age specimens from the Lehigh River). Aging errors, coupled with small sample size in some of the recapture groups (Table 13) could explain the lack of correlation between juvenile and adult survival.

It is interesting that a similar phenomenon was detected when analyzing recaptures of shad marked according to egg source river. For the 1989 to 1994 cohorts, relative survival of juveniles from Hudson River source larvae was always 1.00, while relative survival of Delaware River source larvae ranged from 0.06 to 0.83 with a mean of 0.29 (Hendricks, 2001). Clearly, Hudson River source juveniles were recaptured at a much higher rate than Delaware River source juveniles. When recapture rates of adults at the Conowingo Fish Lifts were analyzed, the trend was reversed. Relative survival of Delaware source adults ranged from 0.83 to 1.00 with a mean of 0.96, compared to a range of 0.29 to 1.00 and a mean of 0.75 for Hudson River adults. This analysis was also dependent upon correct aging. It is possible that aging errors were the cause of both of these anomalous observations. For this reason, I am recommending that future marking protocols include an alternating marking scheme to provide known age specimens, in addition to continued marking based on stocking site (see Job III).

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. 1999. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1998. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1998. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 2001. Job V, Task 2. Analysis of adult American shad otoliths. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 2000. 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., T.R. Bender, and V.A. Mudrak. 1992. American shad hatchery operations, 1991. 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, Jr. 1993. American shad hatchery operations, 1992. 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. 1995. American shad hatchery operations, 1994. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

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 Amercian shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking.

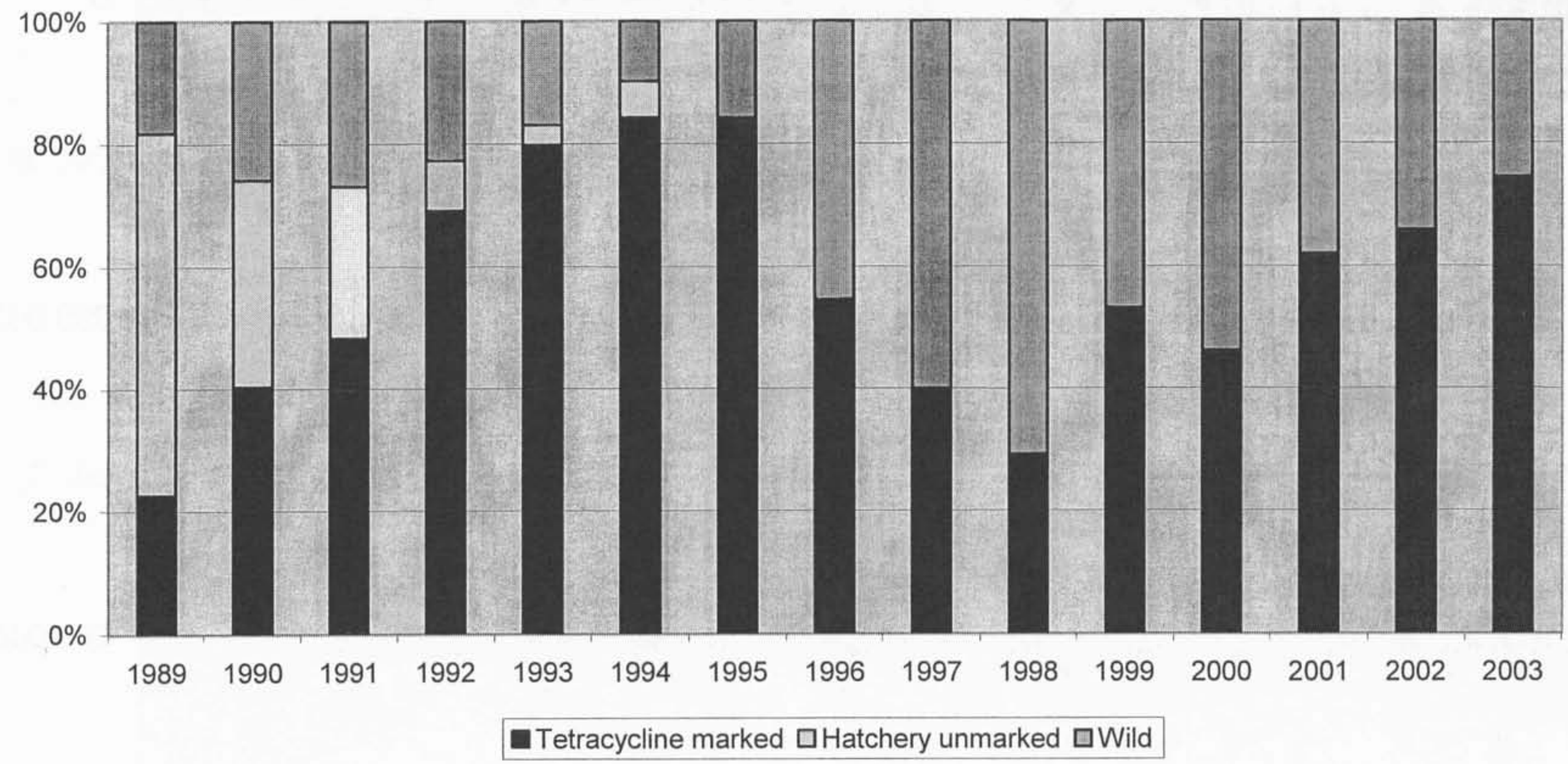


Figure 2. Catch of American shad at the Conowingo Dam Fish Lifts.

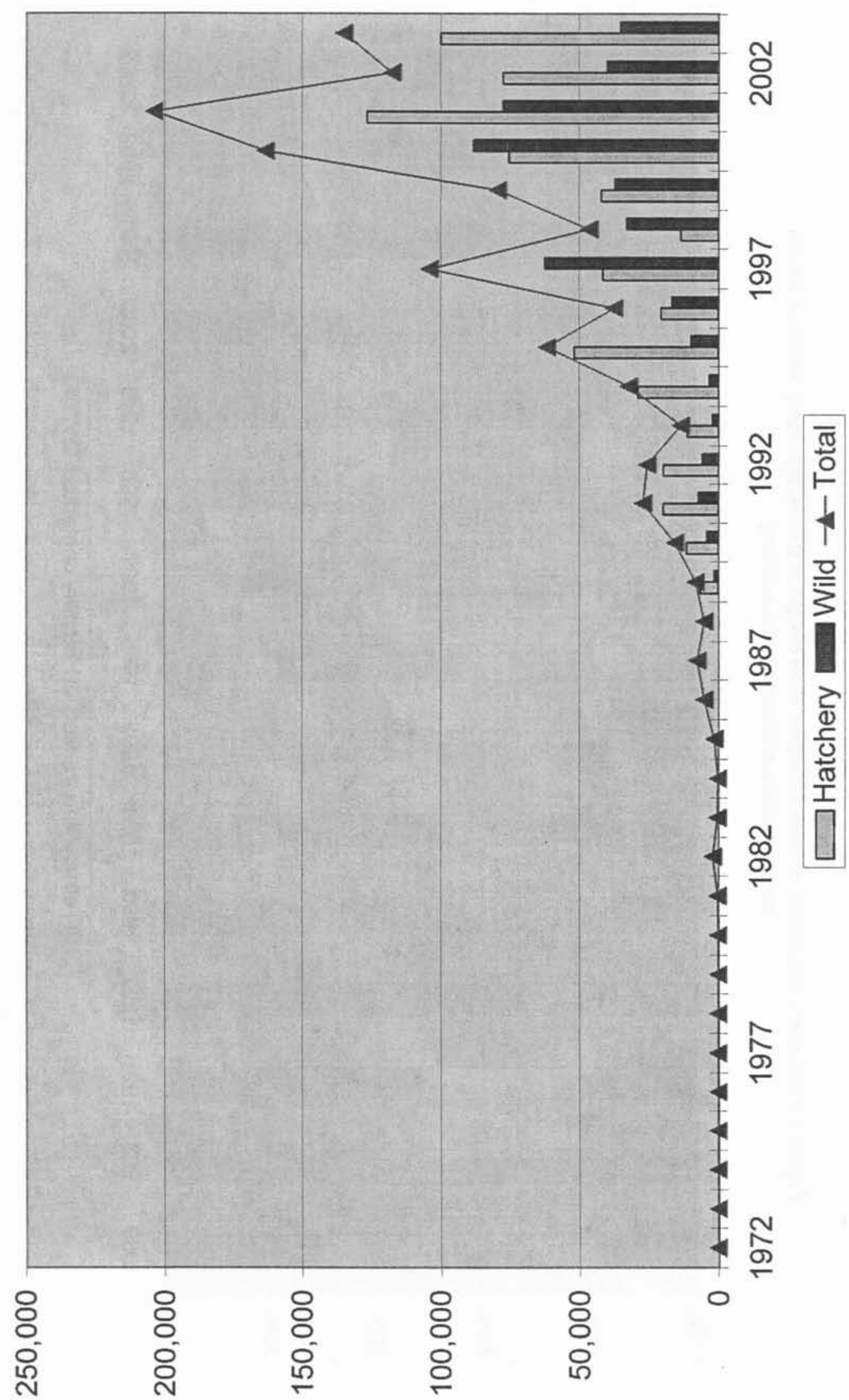


Figure 3. Stocking site/cohort specific relative survival of juvenile shad vs. adult shad, Susquehanna River, 1995-1999.

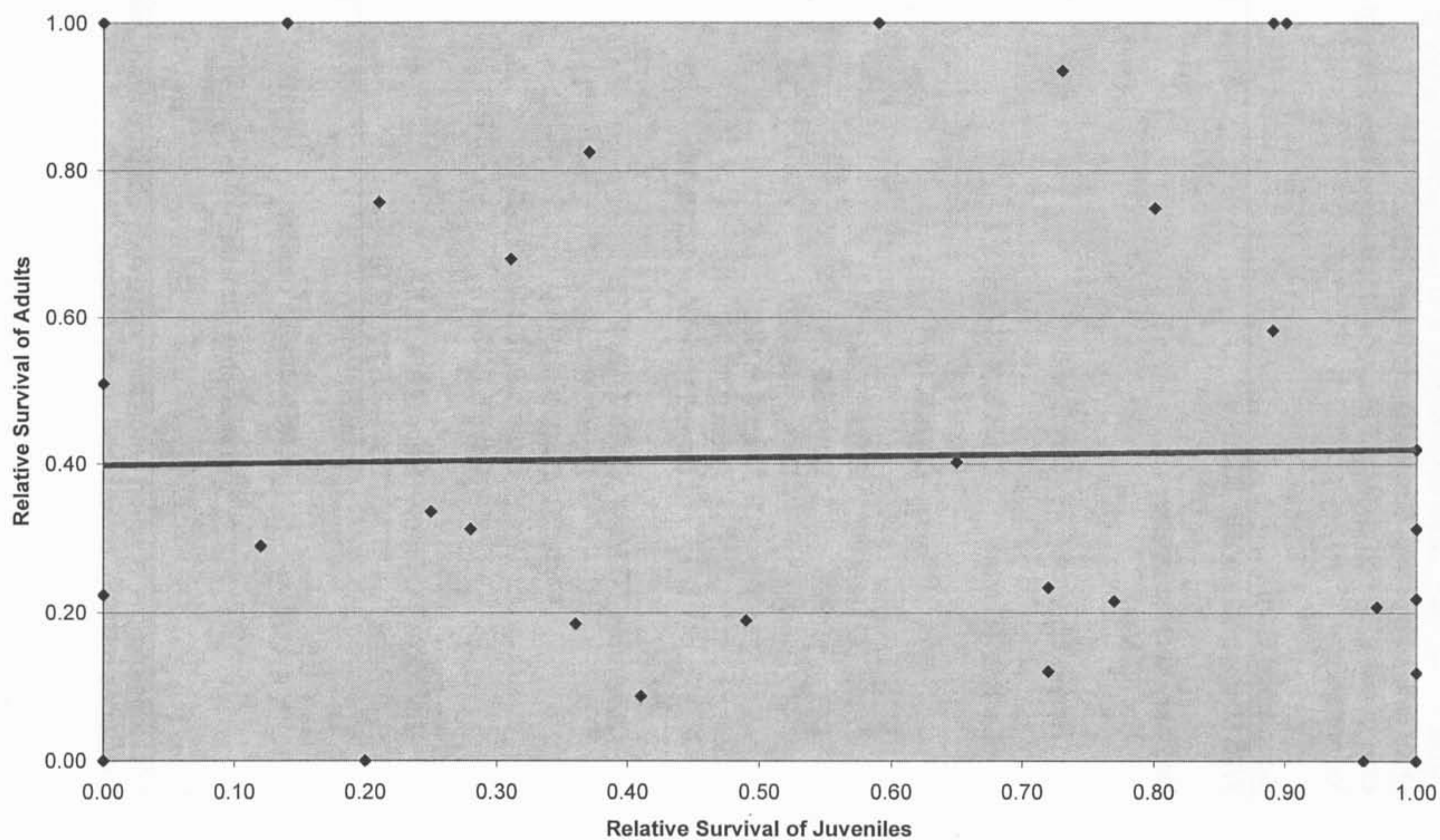


Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2003.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

Conowingo Dam		N	%
Wild Microstructure, No TC Mark		50	26%
Hatchery Microstructure			
No TC Mark*			0%
Single TC Mark	Day 3 or 5	105	54%
Double TC Mark	Days 5,9, 3,6 or 3,7		0%
	Days 3,17		0%
	Days 6,12		0%
Triple TC Mark	Days 3,6,9	2	1%
	Days 5,9,13		0%
	Days 3,13,17	13	7%
	Days 3,9,12	2	1%
	Days 9,12,15		0%
	Days 11,14,17 or 12,15,18	3	2%
Quadruple TC Mark	Days 3,13,17,21		0%
	Days 3,6,9,12	11	6%
	Days 3,9,12,15		0%
	Days 5,9,13,17 or 3,6,9,12	5	3%
	Days 5,9,13,21		0%
Quintuple TC Mark	Days 3,6,9,15,18	1	1%
	Days 3,6,12,15,18	4	2%
	Total Hatchery	146	74%
	Total readable otoliths	196	
	Unreadable Otoliths**	1	
	Total	197	

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

Table 2. Origin of adult American shad collected at Conowingo Dam Fish Lifts, based on otolith analysis.

	Sample:	Hatchery									
		Larvae									
	One in	Susquehanna		below Conowingo Dam		Fingerling		Unmarked**	Naturally reproduced		Total sample
Year	??	N	%*	N	%*	N	%*	N	N	%	size
1989	50	36	82	-		-		94	29	18	159
1990	100	49	73	1	1	-		42	32	26	124
1991	100	111	67	8	5	3	2	63	68	27	253
1992	100	154	73	8	4	2	1	19	54	23	237
1993	100	76	64	21	18	2	2	4	21	17	124
1994	100	217	81	22	8	3	1	17	28	10	287
1995	100	255	77	19	6	4	1	1	52	16	331
1996	100	180	48	22	6	4	1	1	172	45	379
1997	50	84	34	12	5	4	2	0	150	60	250
1998	50	29	22	7	5	2	2	0	92	71	130
1999	50	90	48	9	5	1	1	0	88	47	188
2000	50	78	40	11	6	0	0	0	104	54	193
2001	50	120	58	9	4	0	0	0	79	38	208
2002	50	118	65	2	1	0	0	0	62	34	182
2003	50	146	74	0	0	0	0	0	50	26	196
Totals		1,743	61	151	5	25	1	241	1,081	33	3,241

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

Table 3. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2003.

Age	2	3	4	5	6	7	8	9	??	Totals	Mean
Male		4	49	17	17	2	1		2	92	4.6
Female		1	12	30	44	13	1			101	5.6
Unknown			1		1					2	5.0
Totals	0	5	62	47	62	15	2	0	2	195	5.1

Table 4. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2003.

Age	2	3	4	5	6	7	8	9	??	Totals	Mean
Male- Wild		2	8	7	5	1				23	4.8
Male- Hatc.		2	41	10	12	1	1		2	69	4.6
Female- Wild			4	7	11	4				26	5.6
Female- Hatc.		1	8	23	33	9	1			75	5.6
Totals	0	5	61	47	61	15	2	0	2	193	5.1

Table 5. Length frequency (mm, FL) by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2003.

Sex	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	Total
Male	1	7	23	27	20	12	1	1			92
Female				8	19	14	20	29	10	2	102
Unknown				1		1					2
Totals	1	7	23	36	39	27	21	30	10	2	196

Table 6. Length frequency (mm, FL) by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 2003.

Sex	326-350	351-375	376-400	401-425	426-450	451-475	476-500	501-525	526-550	551-575	Total
Male- Wild	1	1	5	3	10	3					23
Male- Hatc.		6	17	24	10	9	1	1			68
Female- Wild				1	5	2	9	6	3	1	27
Female- Hatc.				7	14	12	11	23	7	1	75
Totals	1	7	22	35	39	26	21	30	10	2	193

Table 7. Mean fork length (mm) at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2003.

	Age													
Sex	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)	9	(n)
Male	382	4	405	49	433	17	452	17	452	2	451	1		
Female	405	1	435	12	480	31	494	44	510	13	510	1		

Table 8. Mean fork length (mm) at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2003.

		Age													
Sex		3	(n)	4	(n)	5	(n)	6	(n)	7	(n)	8	(n)	9	(n)
Male- Wild		371	2	406	8	434	7	434	5	459	1				
Male- Hatc.		393	2	405	41	432	10	460	12	445	1	451	1		
Female- Wild				436	4	488	8	503	11	518	4				
Female- Hatc.		405	1	434	8	477	23	491	33	506	9	510	1		

Table 9. Age composition and origin of American shad collected at the Conowingo Dam Fish Lifts, 1988-2003.

										Hatchery Release Site			Wild
										Above Dams		Below Dams	
	Fish lift	% Age composition								larvae	fingerlings		
Year	catch	9	8	7	6	5	4	3	2	%	%	%	%
1988	5,146	0.0	0.0	4.0	31.7	38.1	21.2	4.7	0.4	71% *		6% *	23%
1989	8,218	0.0	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719	0.0	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%		1%	26%
1991	27,227	0.0	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	2%	5%	27%
1992	25,721	0.0	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	1%	4%	23%
1993	13,546	0.0	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	2%	18%	17%
1994	32,330	0.0	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	1%	8%	10%
1995	61,650	0.0	0.0	3.2	12.4	51.9	28.5	4.0	0.0	77%	1%	6%	16%
1996	37,513	0.0	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%	1%	6%	45%
1997	103,945	0.0	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%	2%	5%	60%
1998	46,481	0.0	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370	0.0	0.5	1.1	8.1	33.5	46.5	10.3	0.0	48%	1%	5%	47%
2000	163,331	0.0	0.0	1.0	9.9	27.6	51.0	10.4	0.0	40%	0%	6%	54%
2001	203,776	0.0	0.0	2.0	21.4	50.5	24.0	2.0	0.0	56%	0%	4%	38%
2002	117,348	0.5	1.6	6.0	27.7	40.2	15.2	8.7	0.0	65%	0%	1%	34%
2003	134,937	0.0	1.0	7.8	32.1	24.2	32.1	2.6%	0.0	74%			26%

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

Table 10. Recruitment of hatchery larvae, stocked above dams, to the Conowingo Fish Lifts, 1986-2003.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1988	13											
1989	373	16										
1990	1,706	166	0									
1991	6,956	2,250	307	0								
1992	6,652	6,870	2,181	545	0							
1993	277	1,867	4,563	1,867	69	0						
1994	0	859	5,918	14,318	5,059	0	0					
1995		0	1,517	5,907	24,746	13,570	1,916	0				
1996			0	152	2,881	7,430	6,015	1,365	51			
1997				0	0	3,676	6,363	15,695	9,191	141		
1998					0	80	1,125	4,983	3,858	322	0	
1999						205	411	3,081	12,734	17,663	3,902	0
2000							0	688	6,532	18,221	33,692	6,876
2001								0	2,339	24,562	57,897	27,486
2002								413	1,240	4,548	21,088	30,599
2003									0	998	7,786	32,044
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,963	15,830	26,225	35,945	66,456	124,366	97,005
Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00	7.47	8.02
Number of larvae to return 1 adult:	620	431	445	591	172	289	192	249	179	150	60	83

L/A- Overall number of larvae to return 1 adult (1986-1997): 183

Table 11. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 2003.

	Cohort										
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	3 *										
1989	0	0									
1990	0	0	0								
1991	188	61	8	0							
1992	86	89	28	7	0						
1993	7	49	120	49	2	0					
1994	0	12	82	198	70	0	0				
1995		0	24	93	388	213	30	0			
1996			0	3	64	165	134	30	1		
1997				0	0	174	302	744	436	7	
1998					0	6	78	344	266	22	0
1999						2	5	34	141	196	43
2000							0	0	0	0	0
2001								0	0	0	0
2002								0	0	0	0
2003									0	0	0
Total recruits to lifts:	285	211	262	350	524	560	548	1,153	845	225	43
Fingerlings stocked/10,000:	7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95	0.00	0.00
Number of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	165	0	0

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

Table 12. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986- 2003.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1988	55 *											
1989	83	4										
1990	607	59	0									
1991	2,811	910	124	0								
1992	2,091	2,159	685	171	0							
1993	73	496	1,211	496	18	0						
1994	0	104	714	1,727	610	0	0					
1995		0	308	1,201	5,029	2,758	389	0				
1996			0	144	2,741	7,069	5,723	1,298	48			
1997				0	0	6,538	11,317	27,914	16,346	251		
1998					0	255	3,570	15,810	12,240	1,020	0	
1999						201	402	3,012	12,451	17,271	3,816	0
2000							0	917	8,710	24,295	44,923	9,168
2001								0	1,580	16,585	39,093	18,559
2002								217	652	2,390	11,080	16,077
2003									0	351	2,739	11,271
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,822	21,400	49,169	52,026	62,163	101,650	55,075
Adults transported/1000:	4.17	7.20	4.74	6.47	15.08	24.66	15.67	11.72	28.68	56.37	33.83	103.95
No. of adults transported to return 1 adult:	0.73	1.93	1.56	1.73	1.79	1.47	0.73	0.24	0.55	0.91	0.33	1.89

TA/A- Overall number of adults transported to return 1 adult (1986-1996): 0.64

Table 13. Virtual survival rates of hatchery marked American shad, stocked at various sites and recaptured as adults at the Conowingo Dam West Fish Lift.
Virtual Survival rate = Recruitment to the Conowingo Fish Lifts X 10,000, divided by the number stocked

Cohort	Number Stocked (M)	Stocking location	Egg source	Number Recaptured (R)	Recruitment to Conowingo Fish Lifts	Virtual Survival Rate	Cohort Virtual Survival Rate	Adult Relative Virtual Survival Rate	Juvenile Relative Survival Rate
1995	230,000	Conodoguinet (mouth)	Hudson	7	4,175	182		1.00	0.90
1995	93,000	Muddy Cr.	Hudson	1	860	92		0.51	0.00
1995	520,000	below Conowingo (mid-channel)	Hud./Del.	6	3,847	74		0.41	
1995	9,070,999	Juniata or middle Susq.	Hud./Del.	93	66,229	73		0.40	0.65
1995	411,000	below Conowingo (nearshore)	Hud./Del.	6	2,862	70		0.38	
1995	220,000	Conodoguinet Cr.	Hudson	1	860	39		0.22	0.77
1995	190,000	Conestoga (mouth)	Hudson	1	638	34		0.18	0.36
1995	198,000	Conestoga R.	Hudson	1	429	22	73	0.12	1.00
1996	43,000	Standing Stone Cr.	Delaware	2	1,067	248		1.00	0.00
1996	172,000	Conodoguinet Cr.	Delaware	4	3,521	205		0.83	0.37
1996	5,730,000	Juniata or middle Susq.	Delaware	117	96,643	169		0.68	0.31
1996	1,087,000	below Conowingo	Hud./Del./Susq.	13	11,563	106		0.43	
1996	683,000	North Br. Susq. R. (PA)	Hudson	9	7,105	104		0.42	1.00
1996	561,000	West Br. Susq. R.	Hud./Del.	5	4,337	77		0.31	0.28
1996	277,000	Conestoga R.	Delaware	0	0	0	145	0.00	0.00
1997	174,000	Conodoguinet Cr.	Delaware	8	5,821	335		1.00	0.14
1997	3,037,000	Juniata or middle Susq.	Hud./Del.	80	59,175	195		0.58	0.89
1997	231,000	Conestoga R.	Hudson	3	2,237	97		0.29	0.12
1997	2,270,000	Juniata	Hud./Del.	24	16,589	73		0.22	1.00
1997	1,199,000	North Br. Susq. R. (PA)	Hud./Del.	11	8,332	69		0.21	0.97
1997	486,000	Jun. R. (Huntingdon)	Hudson	3	1,971	41		0.12	0.72
1997	622,000	West Br. Susq. R.	Hudson	2	1,821	29	120	0.09	0.41
1998	321,000	W. Conewago Cr.	Hudson	6	4,000	125		1.00	0.89
1998	305,000	Conodoguinet Cr.	Hudson	2	1,276	42		0.34	0.25
1998	1,126,000	North Br. Susq. R. (PA)	Hudson	6	4,381	39		0.31	1.00
1998	8,925,000	Jun. & Susq. R.	Hud./Del.	38	26,003	29		0.23	0.72
1998	229,000	Conestoga R.	Hudson	1	638	28		0.22	0.00
1998	565,000	Juniata R.	Susq.	2	1,333	24		0.19	0.49
1998	230,000	Swatara Cr.	Hudson	0	0	0		0.00	0.96
1998	56,000	West Br. Susq. R.	Susq.	0	0	0	32	0.00	0.00
1999	373,000	Conodoguinet Cr.	Hudson	2	1,391	37		1.00	0.59
1999	10,229,000	Juniata R.	Hud./Del.	52	35,649	35		0.93	0.73
1999	1,211,000	North Br. Susq. R. (PA)	Hudson	5	3,420	28		0.76	0.21
1999	249,000	Swatara Cr.	Hudson	1	696	28		0.75	0.80
1999	984,000	W. Br. Susq. R.	Hudson	0	0	0		0.00	0.00
1999	236,000	Conestoga R.	Hudson	0	0	0		0.00	1.00
1999	219,000	W. Conewago Cr.	Hudson	0	0	0	30	0.00	0.20

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

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

Introduction

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

Methods and Materials

Collection location for adult American shad in 2003 remained unchanged from 2002 (Figure 1). Hook and line captured fish were again marked with uniquely colored tags in order to differentiate between gear types, tagging locations, and fish marked in previous years. All other adult data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Results

Hook and line effort commenced on 21 April and ended 2 June. Of the 774 adult American shad angled, 757 (98%) were tagged and 216 (29%) were subsequently recaptured (Table 1). Sport anglers returned two tags from fish marked in the tailrace during 2003, and one fish each marked in 2001 and 2002. Conowingo lift recapture data for the 2003 season included:

LOCATION	YEAR/TAG TYPE	#	LOCATION	YEAR/TAG TYPE	#
East Lift	2003 h&l tags	189	West Lift	2003 h&l tags	27
	2002 h&l tags	8		2002 h&l tags	2

Since our hook and line marking effort did not begin until 21 April and some American shad captured by the west lift were returned to the tailrace, only individuals collected by the east lift from April 21 through June 7 were used in the 2003 Petersen tailrace calculation. The R value for the Petersen statistic also does not reflect any fish marked prior to 2003 and subsequently recaptured or any tagged fish caught by sport anglers regardless of the year marked.

The 2003 adult American shad Petersen estimate for the Conowingo tailrace population was 487,073 (Table 2, Figure 2), and has been increasing exponentially since 1984 (r^2=0.69, P<0.001). A 3% adjustment for tag loss was included in this calculation.

Prior to 1997, all American shad captured from both fish lifts were individually handled so that all fish, both marked and unmarked, could be totaled. Beginning in 1997, the east fish lift became fully automated. Consequently, both total counts and numbers of tagged shad were recorded by two trained observers stationed at the east lift viewing chamber. This change in operating procedure at the east lift increased the chances of missing both tagged and untagged American shad and misidentifying tag colors. These errors could, therefore, affect the accuracy of the Petersen population estimates.

Effort, catch, and catch-per-unit-effort (CPUE) by hook and line and the two fish lifts during 2003 and previous years (expressed as arithmetic means) is presented in Table 3. Relative abundance of American shad can also be estimated and associated trends noted by examining these annual CPUE's. Measures of relative abundance for hook and line and the Conowingo fish lifts were calculated as the geometric means (based on log e transformations) of fish caught per angling hour and fish caught per lift hour, respectively. This data was log e transformed and geometric means used in order to normalize the data.

Analysis of the CPUE estimates indicates that the catch of adult American shad has been increasing exponentially in both gear types over time: hook and line (1984-2003) r^2 = 0.74, P <0.001; fish lifts (1980-2003) r^2 = 0.66, P <0.001 (Figure 3). Comparisons of the CPUE estimates to the tailrace Petersen estimates for these respective years also indicates that hook and line and fish lift CPUE's were correlated with log e transformed tailrace estimates (r^2=0.88 P<0.001, r^2=0.74 P=<0.001, respectively; Table 4). The increases in both hook and line and fish lift CPUE's over time and their associated positive correlations with the Petersen tailrace estimates continued in 2003 indicating that the previous upward trend in the number of American shad returning to spawn in the upper Chesapeake Bay also continued in 2003.

DNR biologists subsampled 325 of the 774 American shad collected by hook and line for age and spawning history determination. A length-at-age key was developed by determining the proportional age per 20mm length groups by sex and applying that proportion to the total number at length. For 2003, males were present in age groups 3-7 and 9 while females were found in age groups 4-7 and 9 (Table 5). The 1998 year-class of males (age V) was the most abundant age group sampled, accounting for 46% of the total catch. For females, the 1997 (VI) and 1998 (V) cohorts were the most abundant age groups, accounting for 34% and 31%, respectively, of the total catch. Age frequency modes occurred at age 5 for males and at age 6 for females. The overall incidence of repeat spawning in male American shad decreased slightly from 21.5% in 2002 to 21.1% in 2003 while female American shad repeat spawning decreased from 48% in 2002 to 26.2% in 2003.

Table 1. Number of American shad captured and tagged by location and method of capture from the Conowingo tailrace, 2003.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Hook and Line	Conowingo Tailrace	774	757
Fish Lifts	Conowingo Tailrace	125,135 (East) 9,802 (West)	
	TOTALS	134,937	757

Table 2. Relative population estimate of adult American shad in the Conowingo tailrace during spring, 2003 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 2003 survey -

C = 125,909
R = 189
M = 734

Therefore -

$$N = \frac{(125{,}909 + 1)(734 + 1)}{(189 + 1)} = \mathbf{487{,}073}$$

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)

$$\text{Upper } N^* = \frac{(125{,}909 + 1)(734 + 1)}{164.90 + 1} = 561{,}212$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(125{,}909 + 1)(734 + 1)}{218.94 + 1} = 422{,}690$$ @ .95 confidence limits

* M adjusted for 3% tag loss
** C includes hook and line observed fish plus only those shad caught in the east lift from April 21 through June 7

Table 3. Arithmetic means of catch, effort, and catch-per-unit-effort (CPUE) for adult American shad collected by hook and line (1984-2003) and fish lifts (1980-2003).

A. Hook and Line

Year	Hours Fished	Total Catch	CPUE CPBH*	CPUE HTC**	Population Estimates Upper Bay	Population Estimates Tailrace
1984	52.0	126	2.42	0.41	8,074	3,516
1985	85.0	182	2.14	0.47	14,283	7,876
1986	147.5	437	2.96	0.34	22,902	18,134
1987	108.8	399	3.67	0.27	27,354	21,823
1988	43.0	256	5.95	0.17	38,386	28,714
1989	42.3	276	6.52	0.15	75,820	43,650
1990	61.8	309	5.00	0.20	123,830	59,420
1991	77.0	437	5.68	0.18	139,862	84,122
1992	62.8	383	6.10	0.16	105,255	86,416
1993	47.6	264	5.55	0.18	47,563	32,529
1994	88.5	498	5.63	0.18	129,482	94,770
1995	84.5	625	7.40	0.14	333,891	210,546
1996	44.3	446	10.10	0.10	203,216	112,217
1997	58.0	607	10.47	0.10	708,628	423,324
1998	20.3	337	16.60	0.06	487,810	314,904
1999	52.0	823	15.83	0.06	685,058	583,198
2000	44.0	730	16.59	0.06	1,357,400	957,249
2001	65.8	972	14.77	0.07	693,033	560,912
2002	60.0	812	13.53	0.07	-	555,597
2003	69.3	774	11.20	0.09	-	487,073

* Catch-per-boat-hour

** Hours to catch one American shad

Table 3, continued.

B. Conowingo Fish Lifts (West/East)

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

Table 3, continued.

B. Conowingo Fish Lifts (West/East)

Year	Lift	Hours Fished	Total Catch	Catch Per Lift Hour	Population Estimates Upper Bay	Tailrace
1997	E	640	90,971	142.14		
	W	349	12,974	37.17		
	T	989	193,945	105.10	708,628	423,324
1998	E	433	39,904	92.16		
	W	226	6,577	29.10		
	T	659	46,481	70.53	487,810	314,904
1999	E	467	69,712	149.28		
	W	235	9,658	41.10		
	T	702	79,370	113.06	685,058	583,198
2000	E	368	153,546	417.24		
	W	207	9,785	47.27		
	T	575	163,331	284.05	1,357,400	957,249
2001	E	360	193,574	537.71		
	W	195	10,940	56.10		
	T	555	204,514	368.49	693,033	560,912
2002	E	441	108,001	244.90		
	W	117	9,347	79.89		
	T	558	117,348	210.30	-	555,597
2003	E	432	125,135	289.66		
	W	172	9,802	115.13		
	T	604	134,937	223.41	-	487,073

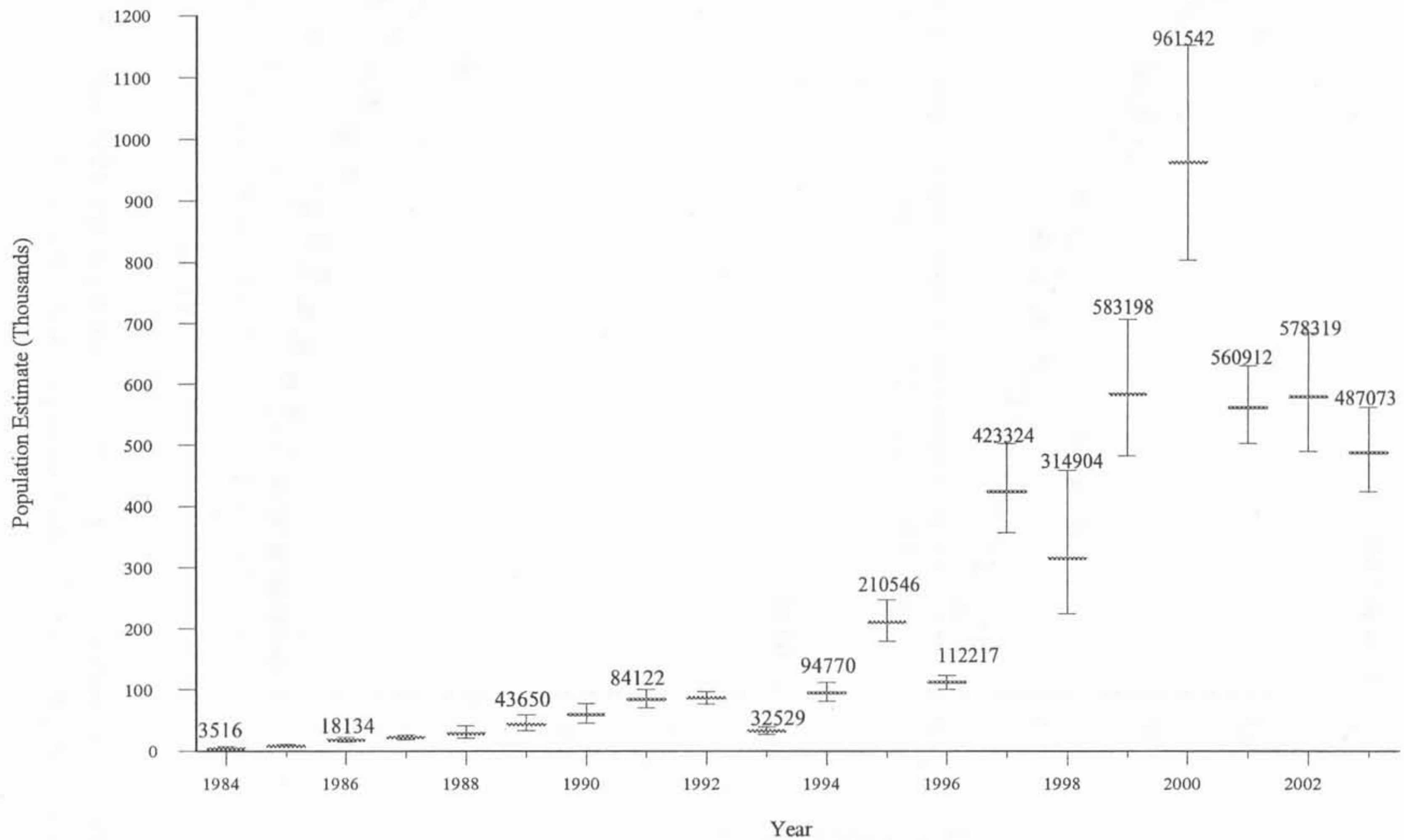
Table 4. Pearson Product Moment Correlation (r_p) for the annual Conowingo tailrace Petersen shad population estimates, and geometric mean CPUE's for two gear types (1984-2003) where N = number of years.

Hook & Line		Fish Lifts	
r_p	0.88	r_p	0.74
N	20	N	20
P	<0.001	P	<0.001

Table 5. Catch (N), age composition, number and percent repeat spawners, mean fork length and length ranges by sex and age group for adult American shad collected by hook and line during 2003.

	Males				Females			
Age	N	Number Repeats	Mean Length	Length Range	N	Number Repeats	Mean Length	Length Range
III	4	0	361	345-370	0	0	0	0
IV	85	0	389	315-465	23	0	420	380-438
V	100	27	415	380-465	33	4	442	405-470
VI	25	16	450	410-482	36	14	473	420-517
VII	3	2	447	440-485	14	9	500	480-520
IX	1	1	480	-	1	1	510	-

Figure 2. Conowingo Dam tailrace population estimates of American shad, 1984-2003. Bars indicate 95% confidence ranges and numbers above indicate the yearly population estimate.



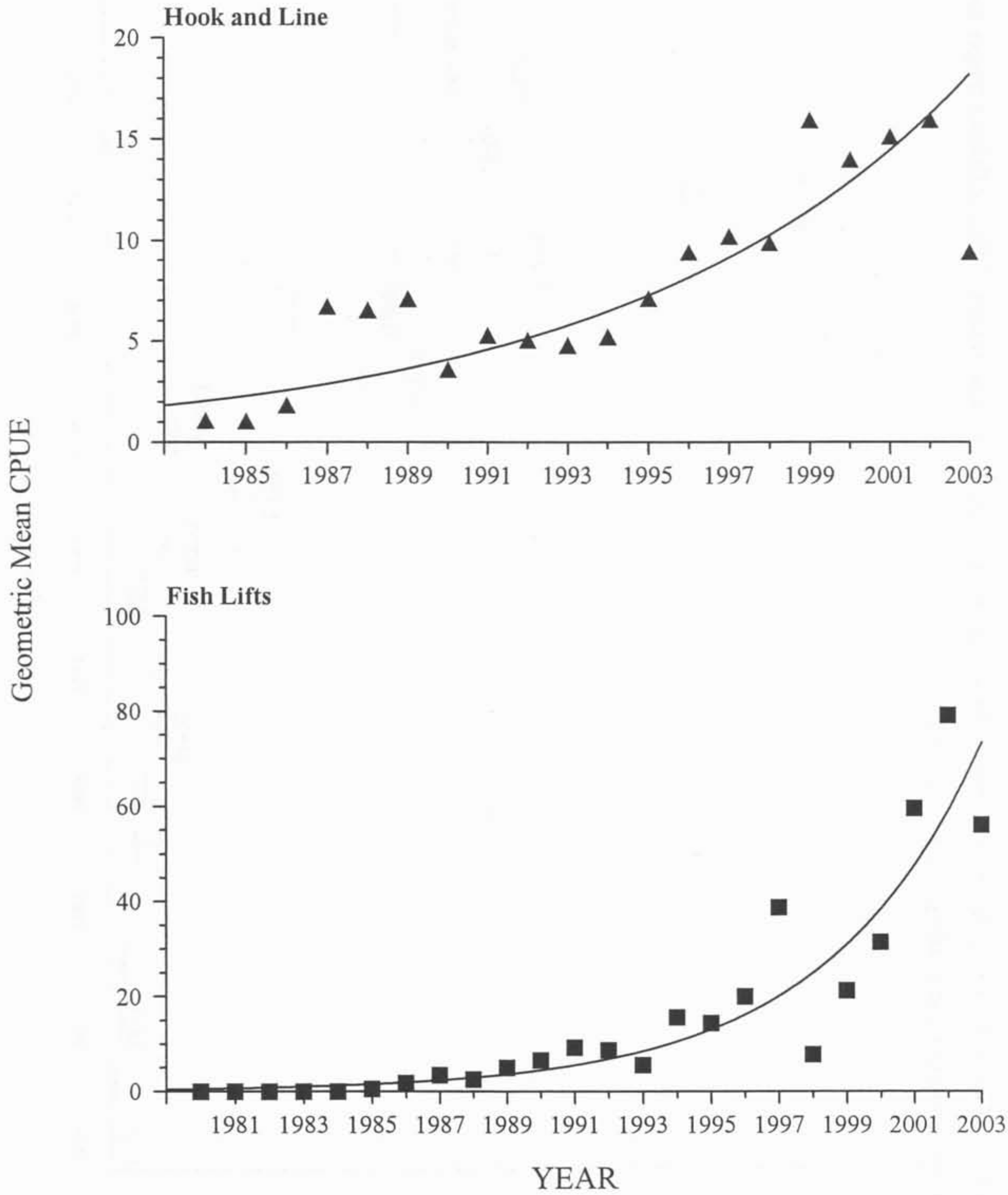


Figure 3. Regression analysis of geometric mean catch-per-unit-efforts (CPUEs) of American shad sampled by hook and line and Conowingo fish lifts, 1980-2003.

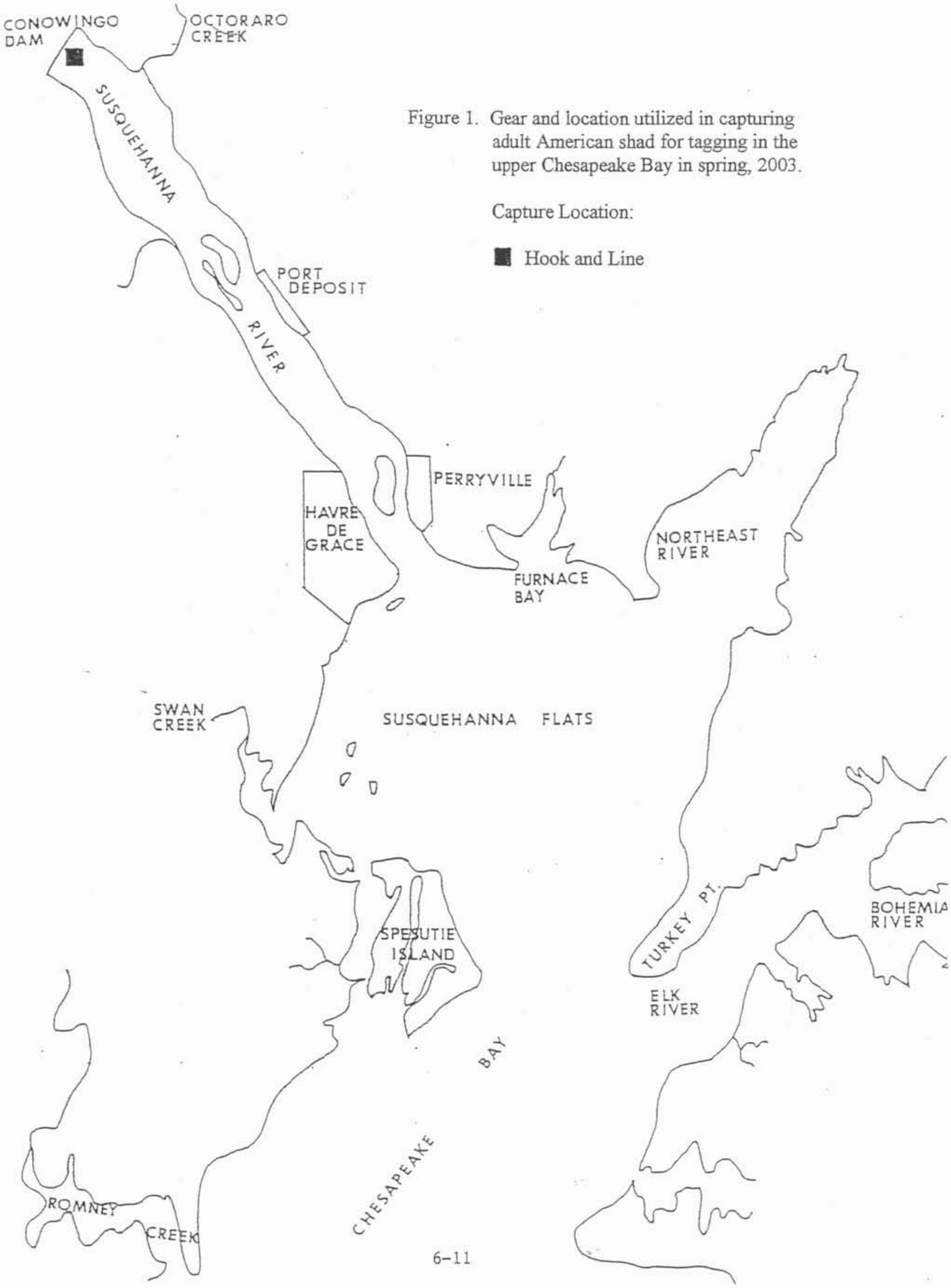


Figure 1. Gear and location utilized in capturing adult American shad for tagging in the upper Chesapeake Bay in spring, 2003.

Capture Location:

■ Hook and Line

LAST
PAGE