Final Report

Bio-Monitoring and Assessment of American Shad and River Herring in the Susquehanna River Basin

July 1, 2000 to March 31, 2002

3-ACA-083

NOAA Award Number ***NA06FG0356***
Submitted to:

United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
One Blackburn Drive
Gloucester, MA 01930

Roland S. Carney
Fisheries Biologist, Division of Research
Pennsylvania Fish and Boat Commission
1225 Shiloh Road
State College, PA 16801
June 30, 2002

Table of Contents

IV. Attachment #2 - Monitoring for the presence of adult alosids at the base of selected dams and tributaries in the Susquehanna Basin, 2001

R. Scott Carney
Pennsylvania Fish and Boat Commission
State College, PA 16801

V. Attachment #3 - Report on bio-monitoring for juvenile alosids by push-net in Conowingo Reservoir in 2001

Normandeau Associates
Drumore, PA 17518

VI. Attachment #4 - Summary of Conowingo Dam West fish lift operations - 2001

Normandeau Associates
Drumore, PA 17518

VII. Attachment #5 - Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2000

Michael L Hendricks
Pennsylvania Fish and Boat Commission
State College, PA 16801

VIII. Attachment #6 - Analysis of American shad adult otoliths, 2001

Michael L Hendricks
Pennsylvania Fish and Boat Commission
State College, PA 16801

Preface

Historically, the Susquehanna River Basin in Pennsylvania sustained one of the largest runs of alosids on the east coast of the United States. Since the early 1900's, migrations of anadromous fish have been blocked by four large hydroelectric dams; Conowingo Dam (r.m. 9.9); Holtwood Dam (r.m. 24.8), Safe Harbor Dam (r.m. 31.7); and York Haven Dam (r.m. 54.7).

The Pennsylvania Fish Commission, now the Pennsylvania Fish and Boat Commission (PFBC), was created in 1866 for the specific purpose of restoring American shad to the Susquehanna River. Renewed efforts to restore anadromous fish began in the 1960's and are presently conducted under the auspices of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). SRAFRC membership includes the PFBC, New York Department of Environmental Conservation, Maryland Department of Natural Resources (MDNR), Susquehanna River Basin Commission, U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service.

The primary focus of the restoration to date has been migratory alosids, particularly American shad. The restoration approach involves egg collection (Delaware, Hudson, and Susquehanna river sources); hatchery production; collection,

transport and release of pre-spawn adults; bio-monitoring of adult and juvenile populations; and special studies as identified by SRAFRC.

The population of American shad returning to the Susquehanna to spawn, based on fish lifts catches at Conowingo Dam, has increased from fewer than one hundred in the early 1980's to more than 200 thousand in 2001. An index of adult American shad abundance in the upper Chesapeake Bay has also increased steadily since 1984 (first years monitored). The goal of the restoration is to produce a self-sustaining spawning population of three million adult American shad and 15 million river herring.

The cornerstone of the restoration has been the development of a mass marking technique in which otoliths of all hatchery fish are marked using tetracycline antibiotics. These marks can be detected in ground otolith sections using ultraviolet microscopy. Application of these techniques to systematic samples of juvenile or adult shad collected in the wild permits evaluation of the relative contribution of hatchery production and natural reproduction to the overall restoration. Multiple marking allows refinement of restoration activities by permitting evaluation of the relative survival of groups which receive unique marks based upon stocking sites, size/age at stocking, and

egg-source rivers. Perhaps the most important contribution of the marking technique is its utility in demonstrating that extirpated populations of American shad can be restored to the Susquehanna Basin through hatchery introductions and trap and transport efforts.

Through the 2001 production year, the PFBC's Van Dyke Hatchery has produced 175 million American shad larvae and 1.6 million fingerlings stocked in the Susquehanna Basin. Since 1982, more than 285 thousand pre-spawn adult shad and thousands of pre-spawn adult river herring have been collected at Conowingo Dam and transported to upstream spawning areas. Otolith analysis of juvenile American shad has demonstrated survival among the fry stocked in the Susquehanna River and tributaries. Likewise, the general trend for the percentage of wild verses hatchery adults in the population indicate that stocks is rebuilding themselves through natural reproduction.

Funding support for restoration initiatives has been provided by settlement agreements with the utilities. In 1993, owners of the three upstream dams agreed to install fish passage facilities. The 1993 Settlement Agreement provided for continued funding for egg collection and hatchery operation until fish passage has been achieved at all four main stem dams in the year 2000. Funding for bio-monitoring was not addressed by the 1993

agreement and expired at the end of 1994. Beginning in 1995, managing the fishery, including bio-monitoring, has been the responsibility of state and federal fishery agencies. Funding provided by the Atlantic Coastal Fisheries Cooperative Management Act, Environmental Protection Agency's Chesapeake Bay Program, and the PFBC are currently supporting Susquehanna River Basin bio-monitoring efforts.

With the completion of fish lifts at Holtwood and Safe Harbor dams in 1997, the East Lift at Conowingo began directly lifting fish over the dam. There was obligation for Conowingo to continue operation of the West Lift. In acknowledgment of the importance of the West Lift operation for continuity of the restoration effort, SRAFRC entered into an agreement with Susquehanna Electric Company whereby the company refurbished the lift and continued its operation for an additional five years. The fishery agencies are responsible for funding transport, monitoring, and research activities as they pertain to West Lift operation. A portion of funding for continuation of West Lift operation is being provided under this project.

This project includes a study to determine if migrating shad are attracted upstream by the presence of other shad, and, if so, what chemical cue(s) are involved. The study has the potential to significantly increase American shad passage efficiency through fish passage facilities at dams. Catches of American shad at the Holtwood Dam fish lift have been much lower than

desirable for the facility. Since 1997, Holtwood Dam, second upstream on the Susquehanna River, has on average passed only 30% of the shad lifted over Conowingo Dam.

Bio-monitoring and assessment of adult and juvenile shad and herring is essential for tracking the progress of the restoration, and maximizing products and benefits from the limited resources available to support the restoration effort. In addition to providing specimens for otoliths analysis, bio-monitoring of adult and juvenile shad has also provided information on the timing of migration, distribution, growth, reproduction, and relative abundance.

This report provides information on bio-monitoring and assessment for American shad and river herring under funding provided by the FFY' 2000/01 Atlantic Coastal Cooperative Fisheries Management Act. Due to the structure of the federal funding cycle, the project period includes two different calendar years and address jobs to evaluate the 2000 juvenile year-classes, as well as the 2001 spawning stocks. Ancillary information on restoration initiatives not funded under this project is provided because of their direct bearing on project results. Overall study objectives of the Susquehanna River Basin alosid bio-monitoring effort as it pertains to juvenile and adult alosids includes:

Juvenile Bio-monitoring Objectives

1) Determine which methods are feasible for sampling juvenile alosids (what?, where?, when?);
2) Determine relative effectiveness of alternative methods for sampling juvenile alosids;
3) Determine distribution of juvenile alosids;
4) Assess (index) abundance of juvenile alosids;
5) Provide specimens to evaluate hatchery stockings and wild contribution to juvenile year-class;
6) Assess growth;
7) Define timing and duration of juvenile out migration.

Adult Bio-monitoring Objectives

1) Determine distribution of adult alosids (particularly at blockages);
2) Evaluate fidelity to natal rivers;
3) Define timing of migration;
4) Assess adult alosid spawning stock abundance and composition.

The fiscal year 2000/01 bio-monitoring project includes twelve jobs: 1) tributary haul seining for juvenile alosids (Summer and Fall 2000); 2) lower river haul seining for juvenile alosids in the main-stem Susquehanna River (Summer and Fall 2000); 3) upper river electrofishing for the collection of juvenile alosids from sites in the main-stem Susquehanna River area between Clarks Ferry and Sunbury and sites in the area between the Juniata River from Amity Hall to Huntingdon (Summer and Fall 2000); 4) lift-netting for juvenile alosids from Holtwood Dam Inner Fore bay (Summer and Fall 2000); 5)electrofishing for adult alosids - large tributaries (Spring 2001); 6) electrofishing for adult alosids - small tributaries (Spring 2001); 7) electrofishing for adult alosids - main stem dams (Spring 2001); and 8) push-netting for juvenile alosids - Susquehanna River (Spring/Summer 2001); 9) Conowingo Dam West Fish Lift operation for the collection of adult alosids (Spring 2001); 10) American shad pheromone study, phase II (Spring 2001); 11) American shad otolith analysis (2000 juvenile year-class and 2001 spawning adults); 12) contract administration and project oversight (July 1, 2000 through March 31, 2002).

This report utilizes Geometric Mean Catch-Per-Unit Effort (GM CPUE) to interpret catch results as recommended by the Atlantic State Marine Fisheries Committee Alosid Management Plan.

GM CPUE is used for job 2, lower river haul seining, and job 4; lift-netting in Holtwood Dam inner forebay. GM CPUE is not used in other jobs due to lack of sufficient catch data. By using GM CPUE it is hoped that an index of juvenile abundance can be developed that will effectively predict future spawning stock (adult) abundance

Project Duration

This project was originally scheduled to begin on July 1, 2000 and terminated September 30, 2001. The project was amended to terminate on March 31, 2002 to allow an additional time for data analysis and report preparation.

Susquehanna River Basin Alosid Assessment - July 1, 2000 through June 30, 2001

Executive Summary

This report presents results from activities and studies directed at monitoring and assessing the restoration of American shad and river herring in the Susquehanna River Basin, Pennsylvania. Information on push-netting in lower Susquehanna impoundments during spring 2000 (funded under NA96FU0318), juvenile alosid collections from Peach Bottom Atomic Power

Station and Conowingo Dam during fall 2000 (funded by utilities), and Maryland DNR 2000 juvenile alosid surveys (funded by MD DNR) are included as part of the 2000 juvenile alosid assessment provided in Attachment #1. Methods, results, and discussion of individual jobs are provided in Attachments #1 - #6. These attachments are completion reports that were included as jobs/tasks in the 2000 and 2001 Susquehanna River Anadromous Fish Restoration Committee's Annual Progress Report. Providing information in this manner eliminates the need to duplicate data analysis, interpretation, and report preparation to satisfy deliverables under this award.

Relatively low river levels, clear water conditions and small number of spawners above Safe Harbor Dam contributed to poor summer-fall juvenile alosid collections at most locations during fall 2000. A total of only 31 juvenile shad no river herring were taken from the Susquehanna River at Columbia with haul seines on 15 sampling dates. CPUE here was one of the lowest on record. No juvenile alosids were taken by seine in tributaries (294 hauls), by electrofishing in the Juniata and upper Susquehanna (16 surveys), or by push-net in Conowingo Pond (13 surveys). Lift-netting at Holtwood produced 406 juvenile shad in 300 lifts (comparable to 1999) with most fish passing this site during a 4-week period October 30 - November 26. Over

200 juveniles were collected with electrofishing gear at York Haven and Muddy Run. Peach Bottom screens produced 100 shad, six blueback herring and two alewives, while intake strainers at Conowingo provided 63 shad and one blueback.

Otoliths from a total of 536 juvenile shad collected in 2000 were examined for tetracycline marks from combined collections made at and above Conowingo Dam. Of these, 523 (98%) were marked (compared to 95% in 1998-1999) of which the majority (423 fish - 81%) carried the single day mark indicating that they were stocked at various locations in the Juniata and main stem Susquehanna rivers. Of the remaining fish examined, 75 fish (14.3%) were stocked in the North Branch; 11 (2%) were stocked in the West Branch; 8 fish (1.5%) were from West Conewago Creek; and the remaining 6 fish (3 each) were from the Conodoguinet Creek and Conestoga River.

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

During spring 2001, the Conowingo West lift operated on 41 days from late April through early June, fishing for 195 hours and making 425 separate lifts. Total catch amounted to 309,804 fish including 218,124 gizzard shad, 10,940 American shad, 16,320 blueback herring, and 7,824 alewives. Sex ratio in the American shad run was 0.7:1.0 favoring females. Every 50th shad collected throughout the season was sacrificed for otolith analysis and a scale sample.

A total of 5,049 pre-spawn blueback herring was stocked in the Conestoga River, Little Conestoga Creek, Conodoguinet Creek with very low mortality. Conestoga and Little Conestoga also received 1,820 alwives. Other transfers from the West lift included 823 shad provided to Maryland DNR and 970 delivered to USFWS-Lamar, both for tank spawning. Fifty-two DNR tags were recovered from adult shad as part on Maryland's upper bay population assessment.

Based on otolith analysis of 208 readable otoliths from adults taken at the Conowingo West Lift, 129 (62%) were of hatchery origin and 79 (38%) were wild. This compares to 46% hatchery and 54% wild in 2000. The majority of fish (99 or 77%) carried the single day 3 or 5 tetracycline mark suggesting they

were stocked in the Juniata River of main stem Susquehanna below Sunbury. Others were fairly evenly split between double (12 fish), triple (9 fish), or quadruple marks (9 fish). Based on the analysis of hatchery vs. wild adult shad returning to Conowingo, age of fish, and known stocking numbers, the PFBC calculated that, on average for the recruited year-classes of 1986-1996, it took 284 stocked larvae, 134 stocked fingerlings, and/or 0.79 transplanted or passed adults to produce each adult return to Conowingo Dam.

Electrofishing for adult alosids in the Susquehanna watershed during spring 2001 produced 45 American shad including 24 at the inflatable dam at Sunbury, 17 in the Conestoga River near Lancaster, and two each in Muddy Creek and West Conewago Creek. Nine of the 12 shad taken in upstream tributary locations carried hatchery marks, whereas 11 of the 16 examined from collections at Sunbury were unmarked.

Four juvenile American shad and 132 blueback herring were collected by push-net in Conowingo Pond during 2001 juvenile collections. These will be included in the 2001 juvenile assessment funded under a separate award (NA16FG1326).

Below lists individual jobs funded under this project and location of job-related information relative to attachments.

Job 1. Juvenile Alosid Sampling - Tributaries

Methods, results and discussion for this job are provided in Attachment #1 - *Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000.*

Job 2. Lower River Haul Seining for Juvenile Alosids

Methods, results and discussion for this job are provided in Attachment #1 - *Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000.*

Job 3. Upper River Electrofishing for Juvenile Alosids

Methods, results, and discussion for this job are provided in Attachment #1 - *Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000.*

Job 4. Lift-netting for Juvenile Alosids

Methods, results and discussion for this job are provided in Attachment #1 - *Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000.*

Job 5. Electrofishing for Adult Alosids - Large Tributaries

Methods, results and discussion for this job are provided in Attachment #2 - *Monitoring for the presence of adult alosids at the base of selected dams and tributaries in the Susquehanna Basin, 2001.*

Job 6. Electrofishing for Adult Alosids - Small Tributaries

Results and discussion for this job are provided in Attachment #2- *Monitoring for the presence of adult alosids at the base of selected dams and tributaries in the Susquehanna Basin, 2001.*

Job 7. Electrofishing for Adult Alosids - Main Stem Dams

Methods, results and discussion for this job are provided in Attachment #2 - *Monitoring for the presence of adult alosids at the base of selected dams and tributaries in the Susquehanna Basin, 2001.*

Job 8. Push-netting for Juvenile Alosids

Methods, results and discussion for this job are provided in Attachment #3 - *Report on bio-monitoring for juvenile alosids by push-net in Conowingo Reservoir in 2001.*

Job 9. Conowingo West Lift Operations

Methods, results and discussion for this job are provided in Attachment #4 - *Summary of Conowingo Dam West fish lift operations, 2001.*

Job 10. American Shad Pheromone Study

This job was cancelled due to the inability to obtain a researcher for the project. Funding originally allocated for this job was re-allocated to cover costs under Job 9.

Job 11. American Shad Otolith Analysis

American shad otolith analysis includes evaluation of the 2000 juvenile year-class and 2001 spawning adults. Results and discussion of juvenile otolith analysis is provided in Attachment #1 - *Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000*, and Attachment #5 - *Survival of American shad larvae released at various sites in the Susquehanna River drainage, 2000.* Results and discussion of adult otolith analysis is provided in Attachment #6 - *Analysis of adult American shad otoliths, 2001.*

Job 12. Contract Administration and Project Oversight

The project was completed as proposed with minor changes including provisions for additional sampling under Job 3 - *Upper river electrofishing for juvenile alosids*, and the cancellation of Job 10 - *American shad pheromone study*. Reports and financial documentation were prepared and submitted in accordance with grant requirements. The project was amended a single time to allow an additional time for data analysis and report preparation.

Attachment #1

Abundance and distribution of juvenile American shad and herring in the Susquehanna River Basin, 2000

Information in this report will address:

Job 1. Juvenile Alosid Sampling - Tributaries

Job 2. Lower River Haul Seining for Juvenile Alosids

Job 3. Upper River Electrofishing for Juvenile Alosids

Job 4. Lift-netting for Juvenile Alosids

Information in this report will partially address:

Job 11. American Shad Otolith Analysis (in part) - 2000 Juvenile Year-Class

Abundance and Distribution of Juvenile American Shad and Herring in the Susquehanna River Basin, 2000

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

INTRODUCTION

Juvenile American shad in the Susquehanna River above Conowingo Dam are derived from two sources - natural reproduction of adult spawners, and hatchery stocking of marked larvae from Pennsylvania Fish and Boat Commission (PFBC) and United States Fish and Wildlife Service (USFWS) facilities in Pennsylvania. Juveniles occurring in the river below Conowingo and the upper Chesapeake Bay may result from natural spawning below or above dams and hatchery fry stockings either in Maryland or from upstream releases in Pennsylvania.

Since the completion of fish passage facilities at Holtwood and Safe Harbor in 1997, the Conowingo East Lift has operated in fish passage mode. The Conowingo West Lift continues to be used as a source of adult American shad and river herring to support special studies or transport to spawning sites above dams. During the 2000 spring migration, Conowingo East Lift passed a record 153,546 American shad while lifts at Holtwood and Safe Harbor passed 29,421 and 21,079, respectively. Fish passage

facilities were completed at York Haven Dam in 2000. During its inaugural season, 4,675 adult shad were counted passing the fishway at York Haven - additional shad may have passed through the open channel portion of the fishway and went uncounted. For the first time in nearly a century, American shad had free access from the mouth of the Susquehanna to the Fabri Dam on the Susquehanna main stem and Warrior Ridge or Raystown on the Juniata. Several large tributaries including Muddy and West Conewago creeks, York County; Conestoga River and Little Conestoga Creek, Lancaster County; Conodoguinet Creek, Cumberland County and Swatara Creek, Dauphin/Lebanon County are now accessible with the completion of main stem fishways.

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

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

Juniata R.(various sites)	6,249,719	age 6-13d (3)
Susq. R. (various sites)	1,119,141	age 9-13d (3)
W. Br. Susq. R.	632,386	age 21d (3,6,9,15)
N. Br. Susq. R.	974,614	age 19d (3,6,12,15,18)
Conodoguinet Ck.	111,017	age 15d (3,9,12)
Conestoga R.	231,178	age 23d (3,9,12,15)
W. Conewago Ck.	109,352	age 18d (9,12,15)
Swatara Ck.	33,321	age 25d (3,6,9,15,18)

METHODS

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

Haul Seining - Main Stem

Haul seining was conducted at Columbia by RMC/Normandeau Associates, Incorporated (RMC) once each week on 15 dates during the period 12 July through 17 October. Sampling was concentrated near the Columbia Borough boat launch since this location proved very productive in past years. Sampling consisted of 6 hauls per date beginning at sunset and continuing into the evening with a net measuring 400-ft x 6-ft with 3/8 in stretch mesh.

Haul Seining - Tributaries

The Conestoga River, Little Conestoga Creek (Lancaster County), West Conewago Creek (York County), Swatara Creek (Dauphin/Lebanon County), and Conodoguinet Creek (Cumberland County) were sampled by seine on a weekly basis from 24 July through 23 August. A total of 288 hauls were conducted at 30 stations in five tributaries (six stations per tributary) using a seine measuring 30-ft X 6-ft with 3/8 in stretch mesh. All tributaries were sampled on five dates with the exception of Swatara Creek, which was sampled on four dates.

Push-netting

Push-netting for juvenile alosids was conducted by RMC at various sites in the upper portion of Conowingo pool between 1 June and 7 July for a total of 13 sampling dates. A total of 10 stations

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

Electrofishing

Electrofishing was conducted by RMC at two upper river reaches located on the Susquehanna River between Clarks Ferry and the Fabri-Dam at Sunbury, and the Juniata River between Amity Hall and Huntingdon. Electrofishing employed the use of a 14 or 18-ft jon-boat and variable voltage pulsator electrofisher with anode mounted on bow. Sampling consisted of four 15-minute electrofishing runs per date at each site beginning at sunset and ending after dark. Both reaches were sampled on eight dates during the months of August and September. In addition, upon the request of the PFBC, ten additional sampling events were

conducted in the lower Susquehanna River in the vicinity of Muddy Run Pump Storage Station and Peach Bottom Atomic Power Station, and in the York Haven Hydroelectric Station forebay.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

Sampling at Holtwood Dam inner forebay was conducted by RMC using a fixed 8-ft square lift-net beginning 12 September and continuing every three days through 8 December (30 total). Sampling began at sunset and consisted of 10 lifts with 10-minute intervals between lift cycles. After 12 October, modifications were made to the sampling method in an effort to meet lift-net program objectives. These modifications included moving the lift-net from the south side of the coffer cell to the north side, and the use of a lighting system to illuminate the water over the lift-net. Additional sampling with a cast-net was conducted on 30 October.

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

Susquehanna River Mouth and Flats

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

Disposition of Samples

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

RESULTS

Haul Seining - Main Stem

The principal purpose for haul seine sampling in the Columbia reach of the lower river during summer and fall months was to document the occurrence and relative abundance of both naturally produced juvenile shad and hatchery stocked fish. A total of 31 juveniles American shad were collected in 90 hauls for an overall Geometric Mean Catch-Per-Unit-Effort (GM CPUE) of 0.26 (Table 1). Daily Catch-Per-Unit-Effort (D CPUE) ranged from zero on seven sampling dates to 1.83 shad per haul on 10 October (Table 2). Of

the total 31 juveniles captured, 11 (35%) were taken during on 10 October (Table 3). The length of juvenile shad ranged from 33 mm on 12 July to 137 mm on 10 October (Table 4). A total of 25 taxa were collected by seine.

Haul Seining - Tributaries

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

Push-netting

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

Electrofishing

The two upper river reaches on the Susquehanna and Juniata rivers were sampled for a total of 996 minutes of shock time resulting in the capture of no juvenile American shad. Lower river sites were sampled from 13 September to 31 October for a combined total of 766 minutes of shock time resulting in the capture of 148, 58, and 2 juveniles at York Haven, Muddy Run, and Peach Bottom, respectively (Table 5). Additional juvenile shad were observed at lower river sites but eluded capture (Table 5). Daily CPUE for

lower river sites ranged from zero to 48.39 shad/hour (Table 6). Nearly 95% of shad that were captured or observed occurred between 23 and 31 October at a water temperature of 12.0 to 15.0 degrees C. Juvenile American shad ranged from 100 to 191 mm TL; most were between 150 and 179 mm TL (Table 7). Mean length of captured juveniles was 153.6 mm TL. CPUE was highest on 23 October and exceeded 15 fish per hour between 23 and 31 October.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

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

most numerous. A single blueback herring was also captured by lift-net.

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

Susquehanna River Mouth and Flats

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

Otolith Mark Analysis

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

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

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

DISCUSSION

In-Stream Movements and Outmigration Timing

Spring river conditions for most of the Susquehanna River basin during 2000 could be characterized by highly variable and above normal flows. Flows measured at Holtwood Hydroelectric Station exceeded 90,000 cfs on sixteen dates in April and two dates in May. Water temperatures were also highly variable. Unseasonably warm weather in early May caused rapid increases in water

temperatures in the lower Susquehanna Basin. River temperatures at Holtwood jumped over twenty degrees Fahrenheit in an eleven-day period from 28 April to 10 May. Temperatures peaked (75.9 F) on 10 May and dropped steadily, in conjunction with a prolonged cold spell, until reaching a monthly low (61.0 F) on 24 May. Temperatures rebounded in June and remained in the high 60's and low to mid 70's until lift operations at Conowingo were suspended for the season. Summer flows in the most of the basin were normal excluding August, which had above normal flows. A notable exception was the North Branch of the Susquehanna, which maintained above normal flows throughout most of the summer. Fall river flows in lower basin were normal with the exception of November, which had below normal flows. Water clarity was very high in the lower Susquehanna Basin in summer and fall.

Haul seine collections during 2000 were lowest on record (Table 1) and never exceeded eleven juveniles captured for a given month from July through October (Table 2). Catches of juvenile shad by month were well below the ten-year average of 177.4, 123.7, 110.7, and 29.1 for July, August, September, and October, respectively (Table 13). Monthly seine catches during 2000 were insufficient in number to detect any apparent out migration pattern although the catch at Columbia seemed to correlate with river flow (Figure 1). Low numbers of juveniles

collected by seine may be related to lack of wild reproduction, low survival, or unfavorable river conditions - high water clarity during the seining period may have influenced catch rates.

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

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

this period thousands of shad were observed in the Holtwood forebay.

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

Generally, out migration of juvenile American shad based on lift-net sampling at Holtwood dam is episodic in nature. Typically it occurs when water temperature falls below 15.6 C and river flow increases, with the majority of the out migration occurring in a one to four week period. In 2000, the out migration occurred in a six-week period when water temperatures were between 14.0 C and 4.0 C, and river flow ranged from 8,680 cfs to 15,100 cfs (Figure 2 and 3). This pattern is consistent with previous years but somewhat later than the 16 September through 25 October out migration period observed in 1999 (Table 14). Delays could be

attributed to the lack of significant precipitation and stable water temperatures during the month of September.

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

Abundance

Comparison of relative abundance of juvenile shad in the Susquehanna River from year to year remains difficult due to the opportunistic nature of sampling and wide variation in river conditions, which may influence catches. Overall, 2000 GM CPUE by seine of 0.26 is the lowest on record since Columbia became the primary sampling site and well below the long-term average of 2.49 (Table 1). GM CPUE for lift-netting in 2000 was 0.66, ranking fourth lowest out of the last fifteen years of sampling by this method and well below the long-term average of 1.97 (Table 8). Based on the data collected to date there is no apparent relationship between GM CPUE by lift-net and adult recruitment to Conowingo lift (Figure 4). There does appear to be a relationship between lift net GM CPUE and river flow (Figure 3) suggesting that catches of shad at Holtwood may be more influenced by river flow than juvenile abundance. Low

catches by seining and lift-net are probably associated with poor reproduction success and survival of shad fry in response to highly variable flows and dramatic fluctuations in river temperatures observed during spring.

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

Despite the stocking of over 9.4 million American shad fry upstream of sampling sites on the Juniata and Susquehanna, electrofishing river reaches between Amity Hall and Huntingdon and Clarks Ferry and Sunbury failed to capture juvenile American shad. Electrofishing at York Haven, Muddy Run, and Peach Bottom

resulted in the highest CPUE (16.25) for this gear type to date (Table 6). Observed differences in upper river and lower river electrofishing catches are unknown. Few spawning adults above York Haven and reduced survival associated with environmental conditions most likely contributed to decreased abundance and poor catches of juveniles in upper river areas. Enhanced water clarity may have also played by making juvenile shad less susceptible to capture by this gear type. Electrofishing should become more efficient as a sampling method as juvenile densities increase and less than optimal habitat is utilized in response to overall increases in stock density.

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

During its first three operating seasons, the fish lift at Holtwood Dam lifted an average of less than 30% of the American shad passed at Conowingo Dam. In 2000, the Holtwood lift passed

less than 20% of those passed at Conowingo. Reproductive success of the adults that passed Conowingo but not Holtwood may be substantial, however poor catches of wild alosids by push-net in Conowingo pool fail to substantiate this hypothesis. It is hoped that low catches by push-net are a function of unrefined design and sampling techniques rather than low abundance.

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

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

Growth

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

Juvenile American shad captured by lift-net from 18 October to 29 November ranged from 114 - 186 mm with 84% of those captured measuring 121 - 150 mm TL (Table 11). In comparison, juvenile American shad captured by lift-net from 16 September to 25 October 1999 ranged from 70 - 150 mm with 81% of those captured measuring 101 - 130 mm TL. Juvenile American shad captured in 2000 appeared to be slightly larger than those captured in 1999. Reasons for this may include a longer growing season associated

with the delay in the out migration period, less competition among individuals due to a weak year-class, or increased food abundance associated with favorable river conditions during the growing season. Growth of wild fish was difficult to assess due to few individuals captured, but growth of hatchery and wild fish appeared to be similar. Growth of the 2000 cohort does fall within ranges observed in previous years.

Stock Composition and Mark Analysis

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

unfavorable river conditions during early spring may have also contributed to low natural reproduction.

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

Electrofishing in the York Haven forebay on 26 October resulted in the capture of 40 juvenile American shad all of which possessed the North Branch mark. The probability of this

occurring by chance is remote, and suggests that schooling behavior during out migration may be stronger than originally thought. The episodic nature of sampling for juveniles may have limitations when trying to determine relative survival of juvenile American shad and the production of wild fish.

Survival of the 2000 year-class will not be determined until they are fully recruited as adults. Relative survival of larval shad from the various stocking locations is discussed in Hendricks, 2001. All main stem and tributary stockings sites with the exception of Swatara Creek were represented in the Holtwood collections.

SUMMARY

- Juvenile American shad were successfully collected by haul seine, electrofisher, and lift-net.
- Haul seining GM CPUE of 0.26 was the lowest recorded for that gear since sampling at Columbia was standardized in 1992.
- Electofishing upper river sites on the Susquehanna and Juniata failed to capture juvenile shad.
- Electrofishing for juvenile shad in the lower Susquehanna resulted in a mean CPUE of 16.25 fish per hour.
- Lift-netting at Holtwood resulted in a GM CPUE of 0.66, the

fourth lowest on record since 1985.

- Push-netting catches in Conowingo pool failed to capture any juvenile alosids.
- No juvenile alosids were collected in major tributaries.
- Peak out-migration based on lift-net catches occurred during October/November and were associated with increased river flows and decreased water temperatures in association with fall freshets.
- Otolith analysis determined that only 2% of the juveniles collected above Conowingo Dam were of wild origin as compared to 5% observed in 1999.
- Several factors may have impacted ability to catch juveniles in 2000 including: 1) low juvenile abundance 2) ineffective sampling due to environmental conditions.
- Juvenile production in the Susquehanna River basin appeared to be low and may have been impacted by: 1) limited natural reproduction 2) poor survival of stocked fry.

ACKNOWLEDGMENTS

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

LITERATURE CITED

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

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

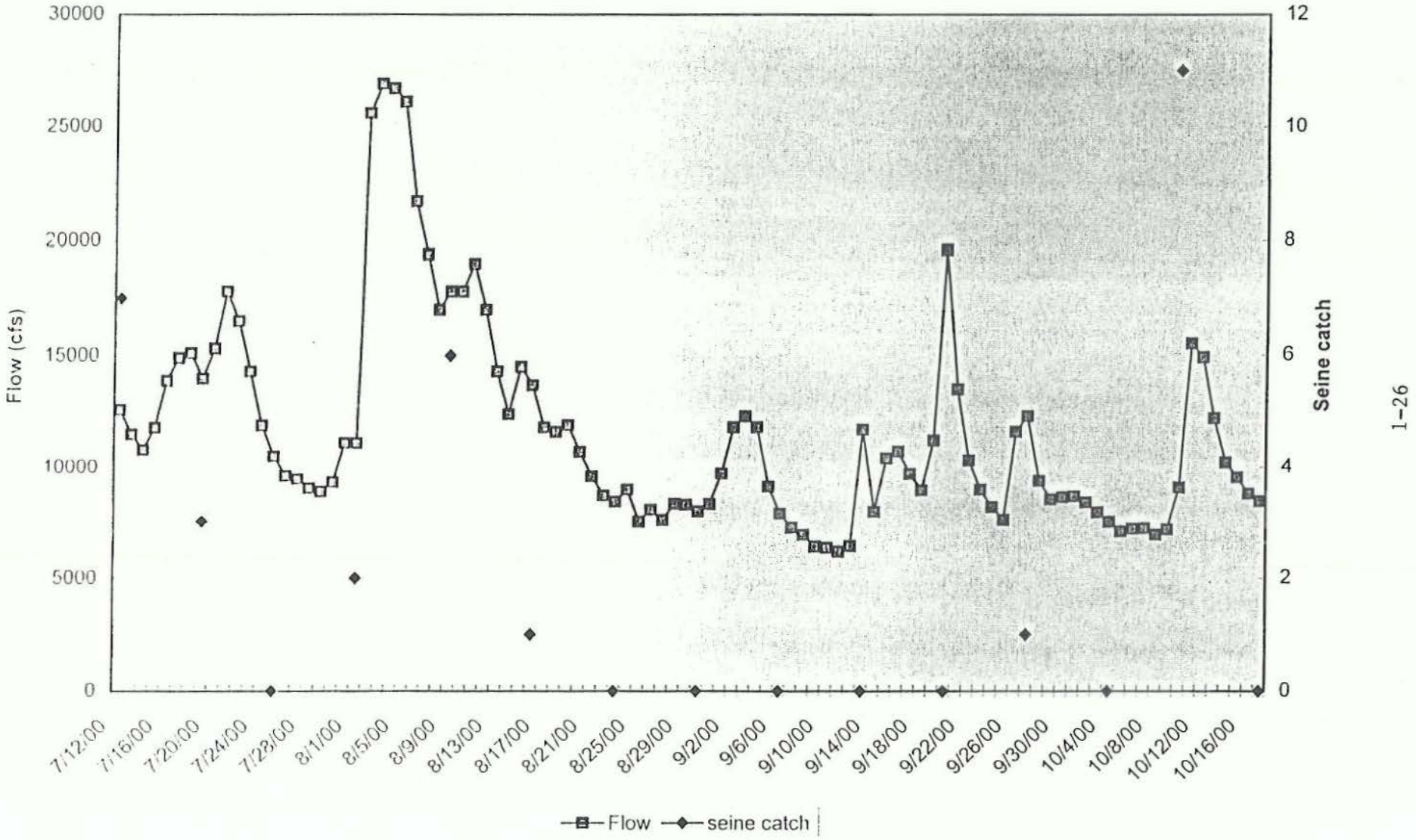
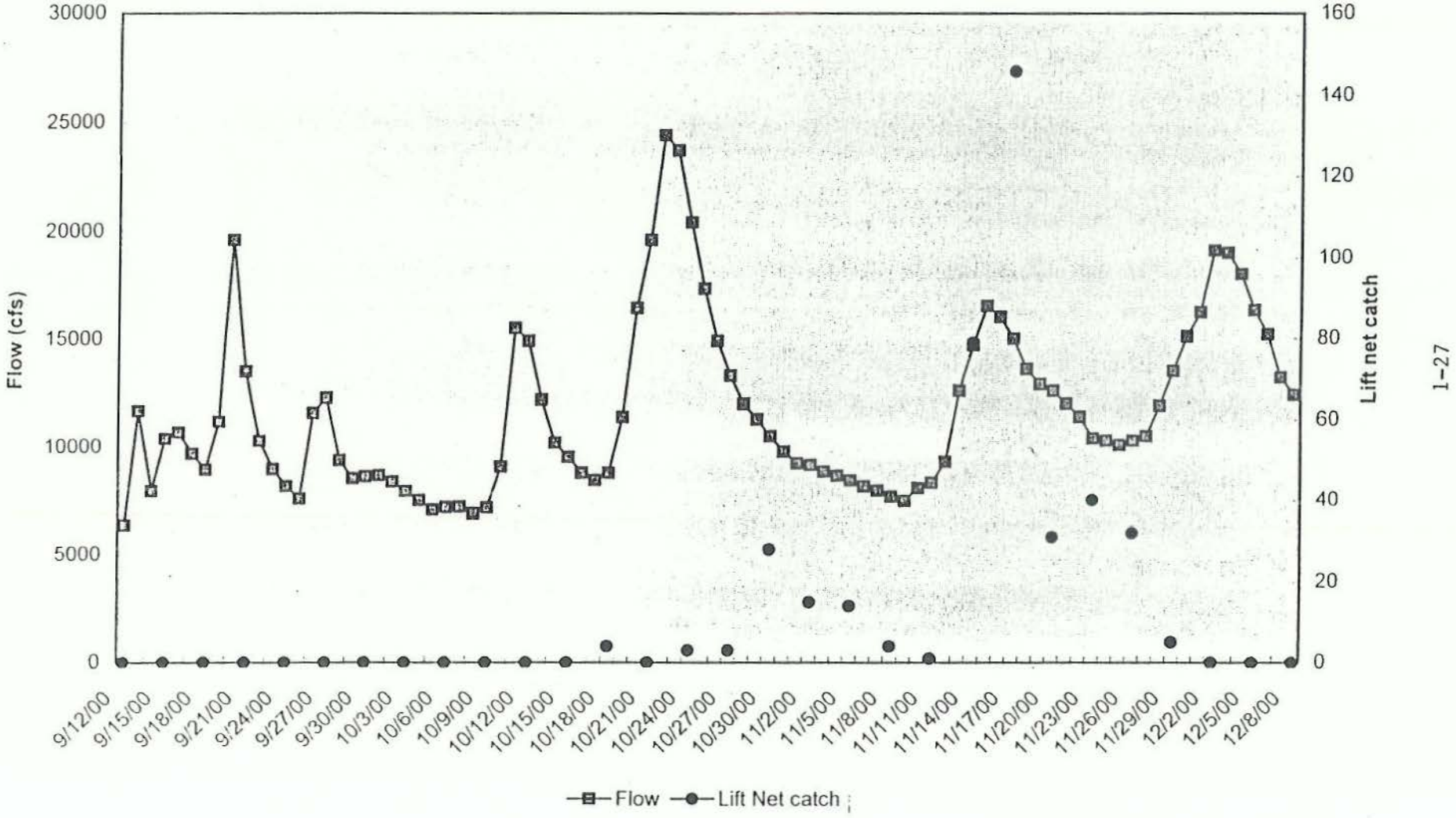


Figure 2. River flow and collection of juvenile American shad by lift net at Holtwood Dam, 2000.



1-27

Figure 3. River flow vs GMCPUE (Holtwood lift net)

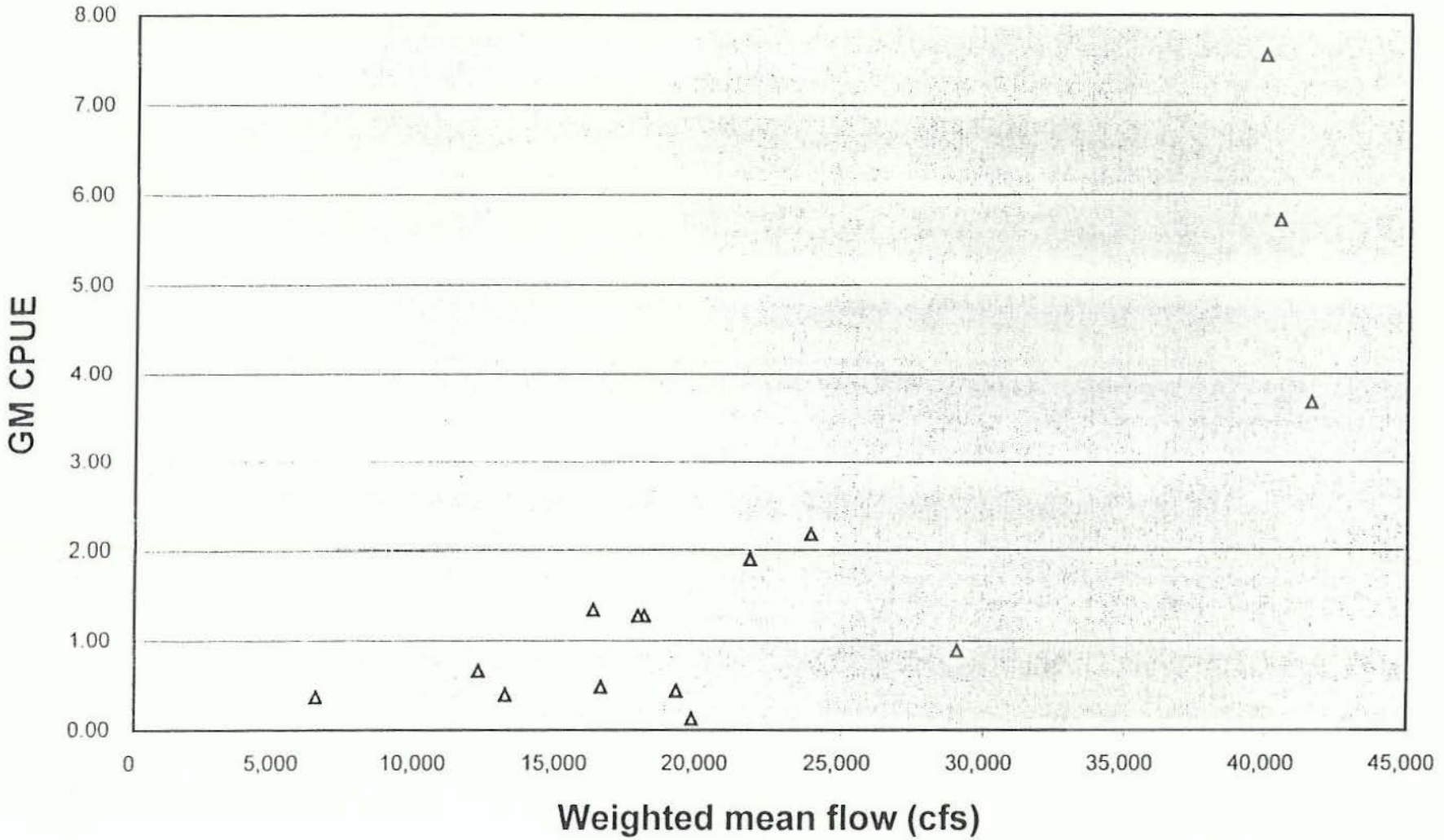


Figure 4. GMCPUE (Holtwood lift net) vs recruitment to Conowingo fish lifts

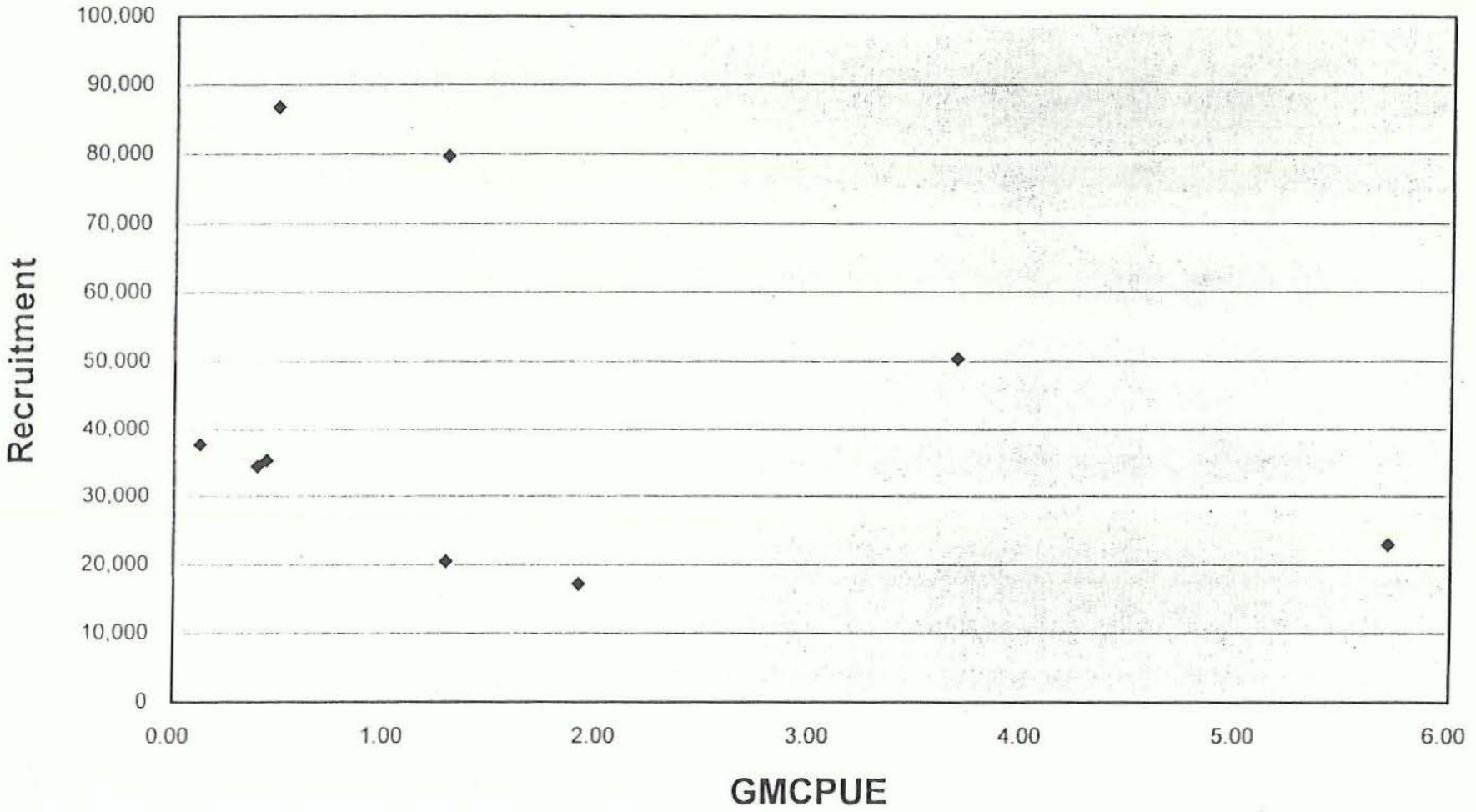


Table 1. Index of abundance for juvenile American shad collected by haul seine in at Marietta, Columbia and Wrightsville, 1985-2000.

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

* mean flow during successful collections

Table 2

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

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

Table 3

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

Date	Water Temp. (°C)	River Flow (cfs)	Secchi (in)	Time (h)	Upper Shore of East Bank	Upper East Shore of Tire Island	Lower East Shore of Tire Island	East Shore of 1st Old Bridge Pier	South End of 1st Old Bridge Pier	Columbia Boat Ramp	Total
12 Jul	27.0	12,400	75	2033-2156	0	0	0	0	6	1	7
19 Jul	24.5	14,400	80	2026-2215	0	3	0	0	0	0	3
25 Jul	24.5	10,700	95	2026-2155	0	0	0	0	0	0	0
1 Aug	27.0	9,790	80	2020-2158	0	0	0	0	2	0	2
9 Aug	27.0	18,300	75	2010-2125	0	0	0	3	2	1	6
16 Aug	26.0	13,300	62	2000-2059	0	0	0	0	1	0	1
23 Aug	23.5	8,310	80	1950-2115	0	0	0	0	0	0	0
30 Aug	25.5	7,920	60	1935-2048	0	0	0	0	0	0	0
6 Sep	24.0	7,370	64	1930-2031	0	0	0	0	0	0	0
13 Sep	25.0	13,300	100	1915-2030	0	0	0	0	0	0	0
20 Sep	20.5	20,000	18	1904-2010	0	0	0	0	0	0	0
27 Sep	17.5	11,000	31	1855-2030	0	0	0	1	0	0	1
4 Oct	20.0	7,370	120	1835-1938	0	0	0	0	0	0	0
10 Oct	12.5	11,000	120	1835-2014	0	0	0	0	11	0	11
17 Oct	15.5	8,000	120	1830-1920	0	0	0	0	0	0	0
TOTAL					**0**	**3**	**5**	**4**	**22**	**2**	**31**

Table 4

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

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

Table 5

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

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

Table 6

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

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

Table 7

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

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

[1] York Haven Hydroelectric Station forebay.

[2] Muddy Run Pumped Storage Station.

[3] Peach Bottom Atomic Power Station.

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

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

*Geometric mean values required by ASMFC.

Table 9

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

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

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

NA - Not Available

* 13 of the shad were caught via cast net.

Table 10

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

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

* 95 percent confidence level.

Table 11

Length frequency distribution of juvenile American shad collected for otolith analysis by an 8 x 8 ft lift net in the Holtwood Power Station inner forebay, 18 October through 29 November 2000. Only dates when American shad were caught are presented.

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

* 13 shad were caught via cast net.

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

		Immersion marks									
		Day 3	Days 3,9,12	Days 9, 12,15	Days 3,6,9, 15,18	Days 3,9, 12,15	Days 3,6, 9,15	Days 3,6,12, 15,18			
Collection Site	Coll. Date	Jun. R./ Susq. R.	Conodo-guinet Cr.	W. Cone-wago Cr.	Swat-ara Cr	Conest-oga Cr.	W. Br. Sus. R.	N. Br. Sus. R.	Hatchery Total	Wild	Total
Three Mile I.	9/13/00	4							4		4
York Haven	10/16/00						1	9	10		10
forebay	10/26/00							40	40		40
Columbia	7/12/00	7							7		7
	7/19/00	3							3		3
	8/1/00	2							2		2
	8/9/00	3		2					5		5
	8/16/00	1							1		1
	9/27/00			1					1		1
	10/10/00	10						1	11		11
Above Holtwood		30	0	3	0	0	1	50	84	0	84
Percent		36%	0%	4%	0%	0%	1%	60%	100%	0%	

(continued on the next page)

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

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

Table 13

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

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

* No sampling this week due to high river flows.

Table 14

Historical weekly catch per unit effort (CPUE) of juvenile American shad collected by an 8 ft x 8 ft lift net at Holtwood Power Station inner forebay, August-December 1985-2000*.

	Historical Years											Year			
Week	***1985***	***1986***	***1987***	***1988***	***1989***	***1990***	***1991***	***1992***	***1993***	***1994***	***1995***	**1997**	**1998**	**1999**	**2000**
Aug 13-19	-	-	-	-	-	-	*0.0*	-	-	-	*0.0*	-	-	-	-
Aug 20-26	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-
Aug 27-Sep 2	-	-	-	-	-	*0.0*	*0.0*	*0.0*	-	-	*0.0*	-	-	-	-
Sep 3-9	-	-	-	*0.0*	-	*0.8*	*0.0*	*1.4*	*0.0*	*0.5*	*0.0*	-	-	-	-
Sep 10-16	-	-	*1.3*	-	-	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.0*	0.0	0.0	0.4	**0.0**
Sep 17-23	-	-	*0.7*	-	*2.3*	*0.0*	*0.0*	*0.5*	*0.0*	*0.0*	-	0.0	0.0	9.7	**0.0**
Sep 24-30	-	-	*0.3*	-	-	*7.5*	*0.0*	*0.0*	*0.3*	*0.1*	*0.0*	0.0	0.0	0.3	**0.0**
Oct 1-7	-	-	*0.9*	*0.0*	*1.2*	*3.9*	*0.1*	*0.1*	*0.2*	*4.3*	*0.1*	0.0	0.1	4.7	**0.0**
Oct 8-14	-	*16.7*	*4.1*	*0.1*	*1.2*	*2.0*	*0.1*	*0.0*	*0.2*	*3.5*	*0.0*	0.0	0.8	3.7	**0.0**
Oct 15-21	*0.1*	*30.3*	*4.5*	*0.0*	*3.2*	*52.0*	*0.6*	*0.2*	*0.1*	*0.7*	*5.0*	0.0	1.9	2.1	**0.1**
Oct 22-28	*1.0*	*5.4*	*1.3*	*10.0*	*0.5*	*50.2*	*0.9*	*0.3*	*17.5*	*0.3*	*68.9*	0.2	1.3	1.0	**0.7**
Oct 29-Nov 4	*41.6*	*5.3*	*4.8*	*19.1*	*0.0*	*34.3*	*1.1*	*0.1*	*14.8*	*0.1*	*56.0*	0.0	1.7	0.0	**2.5**
Nov 5-11	*28.6*	*4.1*	*4.5*	*2.0*	*0.0*	*1.7*	*2.4*	*0.0*	*19.0*	*0.6*	*9.3*	25.1	1.6	0.0	**0.6**
Nov 12-18	*10.8*	*19.5*	*0.3*	*0.3*	*0.0*	*0.4*	*0.5*	*0.7*	*1.6*	*0.1*	*0.0*	27.1	0.1	0.0	**13.2**
Nov 19-25	*57.6*	*6.3*	*0.7*	*0.5*	-	*0.0*	*0.8*	*0.0*	*0.1*	*0.0*	*0.0*	3.0	0.1	0.0	**5.5**
Nov 26-Dec 2	*15.1*	-	-	*0.3*	-	*0.0*	*1.6*	-	*0.0*	*0.0*	*0.0*	0.5	0.0	0.0	**1.2**
Dec 3-9	*62.8*	*14.2*	*0.0*	*0.0*	-	-	-	*0.9*	-	*0.0*	-	0.0	0.0	0.0	**0.0**
Dec 10-16	*4.3*	*0.1*	-	-	-	-	*1.2*	-	-	-	-	-	0.6	-	-
Dec 17-23	*0.5*	*0.0*	-	-	-	-	*0.0*	-	-	-	-	-	-	-	-
								Total number of shad for season				1372	180	490	**406****
								Total number of lifts for season				300	300	300	**290**
								CPUE for entire season				4.6	0.6	1.6	**1.4**

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

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

Attachment #2

Monitoring for the presence of adult alosids at the base of selected dams and tributaries in the Susquehanna Basin, 2001

Information in this report will address:

Job 5. Electorfishing for Adult Alosids - Large Tributaries

Job 6. Electrofishing for Adult Alosids - Small Tributaries

Job 7. Electrofishing for Adult Alosids - Main Stem Dams

Monitoring for the Presence of Adult Alosids at the Base of Selected Dams and Tributaries in the Susquehanna Basin, 2001

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

INTRODUCTION

The Susquehanna River anadromous fish restoration effort has undertaken various activities in an attempt restore migratory alosids to the Susquehanna River Basin. Cornerstones to this effort have been the development of fish passage facilities at the lower Susquehanna hydro-electric projects, and stock restoration through the culture and stocking of hatchery reared American shad fry, and the transport and stocking of pre-spawn American shad and river herring (blueback herring and alewife) collected at Conowingo Dam West Fish Lift.

Fish passage facilities were completed at York Haven in 2000 re-opening portions of the upper Susquehanna and tributaries to spawning runs of migratory fishes. Completion of a fishway at the Fabri-dam in 2003 will re-open habitat in the North Branch of the Susquehanna to New York and the West Branch of the Susquehanna to Lock Haven, Pennsylvania. Utilization of newly accessible spawning habitat is essential if target restoration goals of two million adult American shad and 15 million river herring above Conowingo Dam are going to be reached.

Since 1995, the Pennsylvania Fish and Boat Commission (PFBC) has stocked uniquely marked shad fry in an attempt to establish sub-populations imprinted to specific waters. Waters stocked include Muddy Creek, West Conewago Creek, Conestoga River, Conodoguinet Creek, Swatara Creek, Juniata River, West Branch of the Susquehanna River, and North Branch of the Susquehanna River. It is hoped that these stockings will expand the distribution of alosids to waters other than the Susquehanna and Juniata while hastening overall stock restoration in the basin.

This study was designed to monitor the distribution and abundance of adult alosids within the Susquehanna River Basin. Information obtained in this study will provide insights on fidelity to natal waters, prioritize blockages for fish passage, and refine strategies for restoring extirpated populations of American shad and river herring to specific waters.

METHODS

Distribution and relative abundance of adult alosids was evaluated by conducting daytime electrofishing surveys using various gear types in the Susquehanna River and selected tributaries at or near the base of first upstream blockage to migration.

Fifteen surveys were conducted at the Fabri-dam on the Susquehanna River; about every third day from the onset of inflation of the dam on 16 May through 28 June 2001. Five surveys each were conducted on Muddy Creek, West Conewago Creek, Little Conestoga Creek, Conestoga River, and Conodoguinet Creek between 1 May and 27 June 2001. Fishing Creek and Peters Creek were surveyed on three dates each beginning on 17 May through 12 June. Timing of sampling and frequency was based on number of alosids passed at the main stem hydroelectric projects.

Otoliths from captured adult American shad were analyzed for tetracycline marks to determine origin (hatchery verses wild) and stocking location (for hatchery fish).

RESULTS

Boat electrofishing at the base of the Fabri-dam (r.m. 125.5) on the Susquehanna River resulted in the capture of 24 adult American shad in 1,800 minutes of shock time (Table 1). Daily CPUE ranged from zero to 4.50 shad per hour of sampling (Table 2). Captured shad consisted of 15 males and 9 females. Captured males averaged 486 mm total length (range 454 to 518 mm) and weighed 868 g (range 765 to 1,050 g); females averaged 514 mm total length (range 475 to 546 mm) and weighed 1,098 g (range 860 to 1,290 g). Shad were captured at water temperatures from 18.5 to 26.0°C and flows from 6,950 to 13,700 cfs (Table 1). Twenty-

four additional adult shad were observed during sampling but eluded capture (Table 1).

Twenty-one adult American shad were collected from tributaries between 1 May and 27 June (Table 3). Shad were captured in the Conestoga River (17), West Conewago Creek (2) and Muddy Creek (2). Total CPUE (No./hr) for all tributaries combined was 0.108 (Table 3). Of the shad captured, 10 were males and 11 were females. Captured males averaged 482 mm total length (range 465 to 510 mm) and weighed 881 g (range 700 to 1,070 g); females averaged 539 mm total length (range 532 to 547 mm) and weighed 1,469 g (range 1,140 to 1,870 g (Table 4). American shad were captured at water temperatures ranging from 13.0 to 17.5° C. Daily CPUE ranged from zero to 0.133 fish per hour in tributaries where shad were captured (Table 3). Adult shad from the Conestoga River and West Conewago Creek were captured at the base of the Lancaster Water Works Dam (r.m. 32.8) and Detter's Mill Dam (r.m. 27.7), respectively. Adult shad were also captured at the base of a natural barrier in Muddy Creek. Five adult American shad were observed in the Conestoga River but eluded capture (Table 3). No alosids were captured or observed in the other waters sampled (Tables 3 and 4).

Results of adult American shad otolith analysis are summarized in Job V, Task 2, Table 1. Of the adult shad captured at the Fabri-

dam, 11 were wild fish, and 4 were hatchery with three individuals having a day 3 or 5 tag indicating the were stocked in the Susquehanna or Juniata; one individual had a day 3,6,9,12, tag indicating it was stocked in the North Branch of the Susquehanna; and one had a day 5,9,13,17 tag indicating it was also stocked in the North Branch of the Susquehanna. Of the 7 adults captured at the base of the Lancaster Water Works Dam, six individuals had a day 3,9,12,15 tag indicating they were stocked in the Conestoga River; one individual had a day 5,9,13,17 tag indicating it was also stocked in the Conestoga River; and one had an anomalous day 3,6 tag indicating it was stocked in the Susquehanna or Juniata river. Of the two adults captured in West Conewago Creek, one individual had a day 3 tag indicating it was stocked in the Susquehanna or Juniata and one was wild. The two adults captured in Muddy Creek were both wild. A single adult blueback herring was captured in the Little Conestoga and was most likely part of a shipment of pre-spawn adults from the Conowingo West Lift.

DISCUSSION

Distribution and Relative Abundance

American Shad

The distribution and abundance of adult American shad in the Susquehanna River basin is influenced by the efficiency of main stem fish passage facilities. Numbers of American shad and river

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

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

The confluence of the Conestoga River with the Susquehanna is located on the west shore below Safe Harbor Dam. Based on fish counts at Holtwood Dam, 109,976 American shad would have access to the Conestoga River. Adult shad captured at the Lancaster Water Supply Dam would have traveled a distance of 32.8 miles up the Conestoga to the base of the dam. In 2000, the fishway at the Lancaster Water Works Dam was completed and saw limited service. Additional shad may have used the fishway and were not available for capture during adult surveys. Catches of adults in the Conestoga increased significantly from 2000 to 2001. Reasons for this increase are most likely associated with increase numbers of adults passed at lower river hydro-electric facilities and the return of multiple year-classes whereas in 2000 only a single year class from the first year of stocking was represented. Despite the number of adult American shad in the Conestoga during 2001, no wild reproduction was documented during juvenile sampling. The only juveniles captured from the Conestoga were hatchery fish stocked well upstream of the Lancaster Water Supply Dam. A threshold number of adults may need to be present before spawning will occur. Enhanced efficiency at main stem fish passage facilities and increases in overall stock abundance may be needed to facilitate successful reproduction in the future.

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

The confluence of Conodoguinet Creek with the Susquehanna is located on the west shore several miles upstream of York Haven Dam. Sampling for adult alosids was conducted at the base of Good Hope Dam which is located some 13.5 miles upstream from the confluence. No adult American shad were observed at the base of the dam during 2001 surveys. Surveys conducted in 2000 also failed to document the presence of adults. Stocking of shad fry in Conodoguinet Creek was first conducted in 1995 and these fish should have begun returning as adults in spring 1998 and 1999. However, prior to 2000, adults did not have access to

Conodoguinet Creek because the fish passage facility at York Haven was not in service. Numbers of fry stocked may be too few to overcome losses associated with downstream fish passage efficiency and would account for the absence of adults in 2000 and 2001. This may diminish in the future as additional year-classes are recruited and the size of the spawning populations increases. Higher stocking rates may be required to insure sufficient numbers are passed at lower river fish passage facilities.

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

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

River Herring

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

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

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

Fidelity to Natal Waters

American shad

Information obtained in 2001 supports findings from previous years and suggests that straying of American shad into tributaries is occurring, however, otolith analysis of adult shad captured in the Susquehanna and Conestoga suggest high fidelity of stocked fry to natal waters.

The presence of a Conestoga River tag on the otolths of 6 of the 7 adult shad captured at the base of the Lancaster Water Supply Dam is strong evidence of stocked fry imprinting to the system. This supports previous evidence of imprinting to the Conestoga obtained in 2000 when a single captured adult was also determined to have a Conestoga tagging sequence. The presence of a Susquehanna or Juniata tag on the remaining adult shad, as well as the origin of other adults captured in West Conewago and Muddy Creek confirms that straying also occurs. Both adult shad captured in Muddy Creek during 2001 were determined to be wild fish and originated from adults passed at Conowingo that strayed into the system.

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

The four hatchery adults collected at the base of the Fabri-dam

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

River Herring

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

in the past. Habitat quality and quantity may also be limiting factors to establishing herring populations in tributaries.

Future Fish Passage Projects and Adult Monitoring Activities

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

apparent lack of success with the herring transport program, it should be discontinued.

SUMMARY

- Adult American shad were captured by electrofishing at the base of the Fabri-dam, Susquehanna River; Lancaster Water Works Dam, Conestoga River; Detter's Mill Dam, West Conewago Creek; and a natural barrier in Muddy Creek.
- Distribution of American shad expanded to include waters where they were not previously documented and abundance of adults increased in tributaries where they were detected in the past.
- Stocked American shad fry will imprint to receiving waters and may be useful management tool in stock restoration efforts.
- Straying of American shad into tributaries is occurring.
- Transport and release of river herring should be discontinued.
- Monitoring main stem and tributaries waters should continue in order to track adult alosid abundance, distribution, wild production, and success of the restoration effort.

Table 1

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

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

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

Table 2

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

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

NA = Not Available.

Table 3

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

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

Table 4

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

Date	Location	Water Temperature (°C)	Start Time (h)	End Time (h)	Number of American Shad	CPUE (No./h)
17 May	Fishing Creek	12.0	0825	0930	0	0
17 May	Peters Creek	13.0	1010	1120	0	0
				Subtotal	***0***	***0***
28 May	Fishing Creek	14.0	0755	0905	0	0
28 May	Peters Creek	15.0	1005	1120	0	0
				Subtotal	***0***	***0***
12 Jun	Fishing Creek	17.0	0810	0921	0	0
12 Jun	Peters Creek	17.0	1005	1117	0	0
				Subtotal	***0***	***0***
				Small Tributary Total	***0***	***0***

Attachment #3

Report on bio-monitoring for juvenile alosids by push-net in Conowingo Reservoir in 2001

Information in this report will address:

Job 8. Push-netting for Juvenile Alosids

REPORT ON BIOMONITORING FOR JUVENILE ALOSIDS BY PUSHNET IN CONOWINGO RESERVOIR IN 2001

TASK 7

Prepared for

PENNSYLVANIA FISH AND BOAT COMMISSION
1225 Shiloh Road
State College, Pennsylvania 16801

Prepared by

NORMANDEAU ASSOCIATES, INC.
1921 River Road
Drumore, Pennsylvania 17518

NAI Job Number 17675

September 2001

1.0 INTRODUCTION

As part of its efforts to detect the occurrence and abundance of adult and juvenile American shad and river herring in the Susquehanna River and its tributaries, the Pennsylvania Fish and Boat Commission (PFBC) contracted Normandeau Associates, Inc. (NAI). The multidisciplinary program identifies several separate tasks to address this broad objective. Task 7 described below seeks to detect the occurrence and abundance of juvenile alosids by pushnet in large Susquehanna River impoundments.

2.0 METHODS AND MATERIALS

Thirteen evening pushnet surveys were conducted in the upper portion of Conowingo Pond between 4 June and 9 July 2001 (Table 1). Ten stations were sampled during each survey. Each station was sampled for five minutes. Surveys began each evening at or near sunset and concluded when all ten stations were sampled. The locations of the Conowingo Pond stations, identified in Figure 1, were concentrated along the shorelines of islands, as well as, sites around Turkey and Deep Water islands, and the Muddy Run Pumped Storage Station.

The pushnet utilized was a 5-foot beam trawl with a 60-inch square mouth opening lashed to a 4 foot 11 inch square steel frame. The net was made of No. 63 knotless 1/4 inch stretch (1/8 inch bar) mesh netting. It was tailored and tapered to a length of 7 feet terminating at a 12-inch canvas collar codend. For each survey the pushnet was suspended in the water and pushed upstream or downstream for five minutes. The net was then retrieved. The collected sample was emptied onto the boat deck and fish were identified, enumerated, and returned to the river. Any American shad collected were frozen for otolith analysis and shipped to the PFBC Benner Spring Research Station in State College, Pennsylvania.

3.0 RESULTS AND DISCUSSION

A total of 2 juvenile American shad and 134 juvenile blueback herring were collected in 2001 (Table 1). Alosids were collected from 7 June through 6 July at water temperatures ranging from 20.0 to 27.5 °C. A total of 13 species was collected; gizzard shad were most abundant (Table 2). Alosids were taken at all stations but were most common at stations 10, 5, and 7, respectively. Each of these stations is located on the west side of an island in areas characterized by reduced flow.

Water temperatures ranged from 19.0 to 27.5 °C and remained relatively stable through the study period (Table 1). Additionally, river flow ranged from 11,400 to 45,800 cfs and averaged 20,446 cfs. Except for a 10-day period between 22 June and 1 July when rain from tropical storm Allison increased the river flow, the river flow was below the long-term median flow averaging less than 15,000 cfs. The flow during this 10-day period averaged nearly 33,000 cfs. Interestingly, the shad catch prior to and following this flow event totaled 69 while the catch during this 10 day period was 67. Also, Holtwood Hydroelectric Station did not spill water for nine of the 13 sample dates; only spilling during the high flow period. Species composition and numbers increased from that reported in 2000.

4.0 RECOMMENDATIONS

Based on experience gained over the past four years we recommend the program continue. It may be necessary to locate areas of known American shad and herring spawning prior to initiating sampling, and then concentrate sampling to those areas.

Table 1

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

Date	Water Temperature (°C)	Secchi Disk (inches)	Number of Replicates	Average Daily River Flow (cfs)*	Start Time (h)	End Time (h)	Number of Alosids	CPUE (No./50 min)
4 Jun	19.0	21	10	18,600	2013	2220	0	0.000
7 Jun	20.0	24	10	19,300	2124	2332	36	0.720
10 Jun	23.0	29	10	13,800	2016	2215	8	0.160
13 Jun	24.7	29	10	11,500	2015	2225	2	0.040
16 Jun	25.0	28	10	11,400	2017	2210	10	0.200
19 Jun	25.7	33	10	13,700	2022	2216	5	0.100
22 Jun	26.0	30	10	23,200	2220	2357	4	0.080
25 Jun	24.5	16	10	45,800	2023	2248	42	0.840
28 Jun	25.0	32	10	40,200	2017	2233	10	0.200
1 Jul	27.5	22	10	22,100	2012	2225	11	0.220
3 Jul	26.0	31	10	17,000	2021	2228	5	0.100
6 Jul	25.0	28	10	16,400	2023	2208	3	0.060
9 Jul	26.0	32	10	12,800	2020	2231	0	0.000
Total			***130***				***136***	***0.209***
Mean	***24.4***	***27.3***		***20,446.2***				

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

Table 2

Summary of fishes collected by pushnet in Conowingo Pond (a main stem impoundment on the Susquehanna River) in spring 2001.

Species	1*	2	3	4	5	6	7	8	9	10	Total
A. shad/herring	1	1	11	7	27	10	19	14	7	39	136
Gizzard shad	305	245	283	439	9,709	1,000	1,095	1,232	400	1,259	15,967
Central stoneroller										1	1
Comely shiner	2	1		2	12	9	93	43	22	16	200
Mimic shiner							1				1
Bluntnose minnow								1			1
Channel catfish						1	4	10	16	7	38
Rock bass		1									1
Smallmouth bass	1	7		2	5	4	7	4	13	6	49
Largemouth bass				1		2				3	6
Tessellated darter					1				2		3
Yellow perch			3	1		1					5
Total	*309*	*255*	*297*	*452*	*9,754*	*1,027*	*1,219*	*1,304*	*460*	*1,331*	***16,408***

* Corresponds to locations presented in Figure 1.

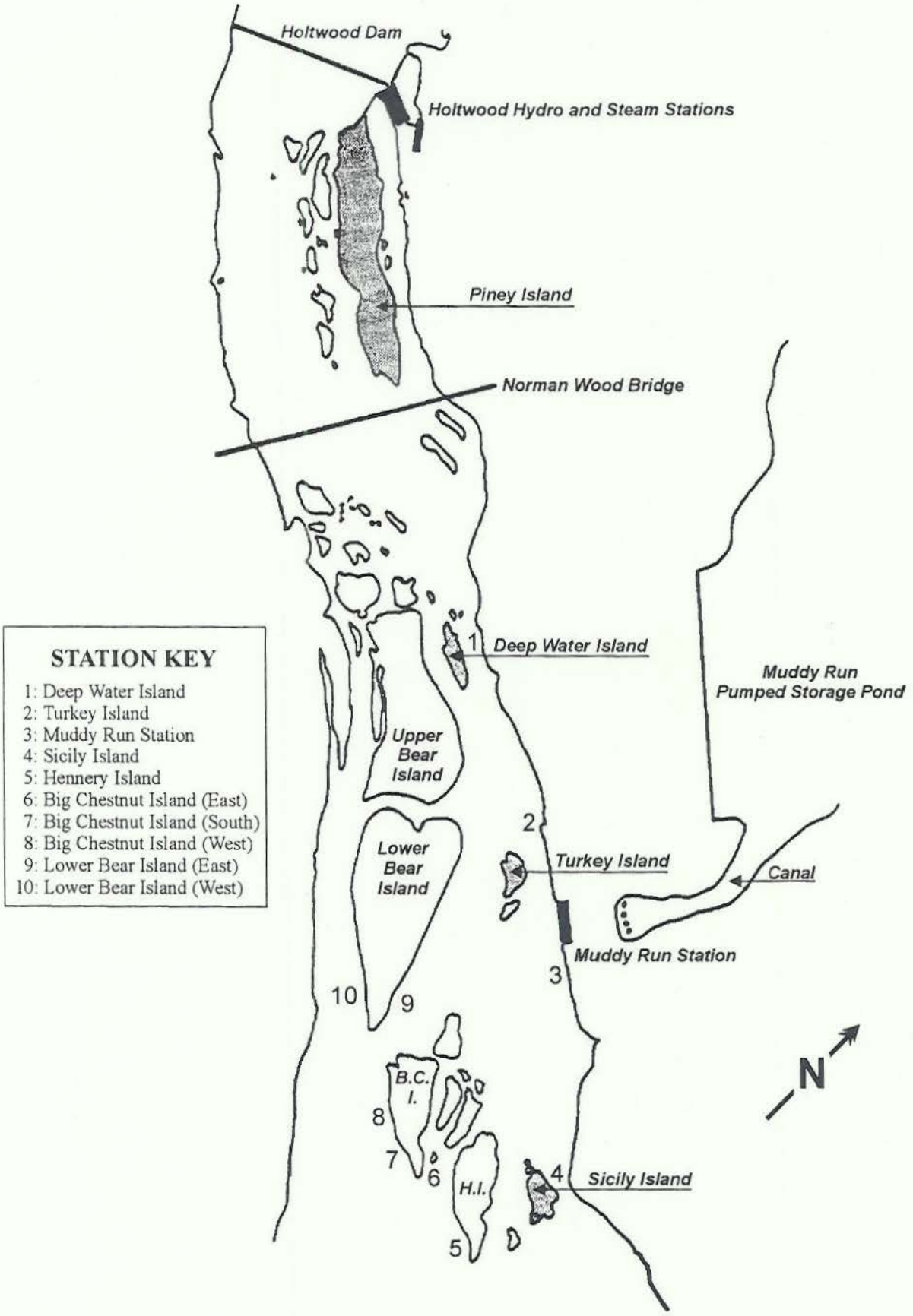


Figure 1

Map of pushnet stations sampled for alosids in Conowingo impoundment, 2001.

Attachment #4

Summary of Conowingo Dam West fish lift operations-2001

Information in this report will address:

Job 9. Conowingo West Lift Operations

SUMMARY OF CONOWINGO DAM WEST FISH LIFT OPERATIONS - 2001

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 2001 (see Part 1). Upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam but Susquehanna Electric Company (SECO) has agreed to keep the West lift operational, to provide a lift operator, and to administer an annual contract for West lift trapping operations. Project details are coordinated with the resource agencies through the Susquehanna River Technical Committee (SRTC). Funding to reimburse SECO for contractor expenses for these operations in 2001 was derived from several sources including upstream utility carryover monies from the 1984 settlement agreement, PA Fish and Boat Commission, and Maryland DNR. These contributed funds are administered by the USFWS Susquehanna River Coordinator.

The objectives of Conowingo West lift operations in 2001 included collection and enumeration of shad, river herring, other migratory and resident fishes; sorting and transportation of up to 10,000 river herring to select tributaries; provision of live adult shad broodfish to the USFWS Northeast Fishery Center at Lamar, PA and to Maryland DNR for tank spawning; and, for on-site tank spawning and shad egg collection at Conowingo Dam. Shad taken here are also monitored for DNR tags and sex ratios, and scale and head samples are taken for age and otolith analysis.

Methods

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

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

Shad and herring collected in the trap were counted and either placed into holding or spawning tanks. Fish in excess of transport or spawning needs were returned alive to the tailrace. When sufficient herring numbers were available they were loaded into truck-mounted 1,000 gallon circular transport tanks and hauled to stocking sites. Live shad were delivered to USFWS Northeast Fishery Center and provided to Maryland DNR for tank spawning. Every 50th shad in the West lift collection was sacrificed for otoliths and a scale sample was taken. Lengths and weights were measured, and sex ratio of shad in daily catches were recorded.

Results

Figure 1 shows daily West lift shad catch, river flow and water temperatures for the 2001 season. Total catch at the West lift amounted to 309,804 fish of 38 taxa (Table 1). Gizzard shad and white perch comprised 85% of this total. Alosid catch included 10,940 American shad, 16,320 blueback herring, 7,824 alewives, and 36 hickory shad. Most American shad (87%) were taken during the four-week period May 3-31 with a peak day catch of 1,240 fish on May 18. All alewives were caught on the first 7 days of operation (April 27- May 3) and most blueback herring were collected before May 6 (Table 2).

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

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

Discussion

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

West lift catch per effort of about 56.5 shad per fishing hour and 26 shad per lift were the highest capture rates ever recorded at this facility. Shad catch per operating day (273) was about average for the past 10 years (Table 6). Operations and fish catch at the West lift during 1985-2001 are summarized in Table 7. Based on analysis of 208 adult shad otolith samples from Conowingo, hatchery-marked fish comprised 62% of the 2001 run, an increase from 53% the previous year. Most marked fish carried the single day tag indicating they were stocked into the Juniata River or mainstem Susquehanna above Clarks Ferry.

Table 1

Catch of fishes at the Conowingo Dam West Fish Lift, 2001.

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

Table 2

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

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

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

Table 2

Continued.

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

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

Table 2

Continued.

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

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

Table 3

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

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

Table 4

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

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

Table 5

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

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

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

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

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

Table 7

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

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

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

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

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

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

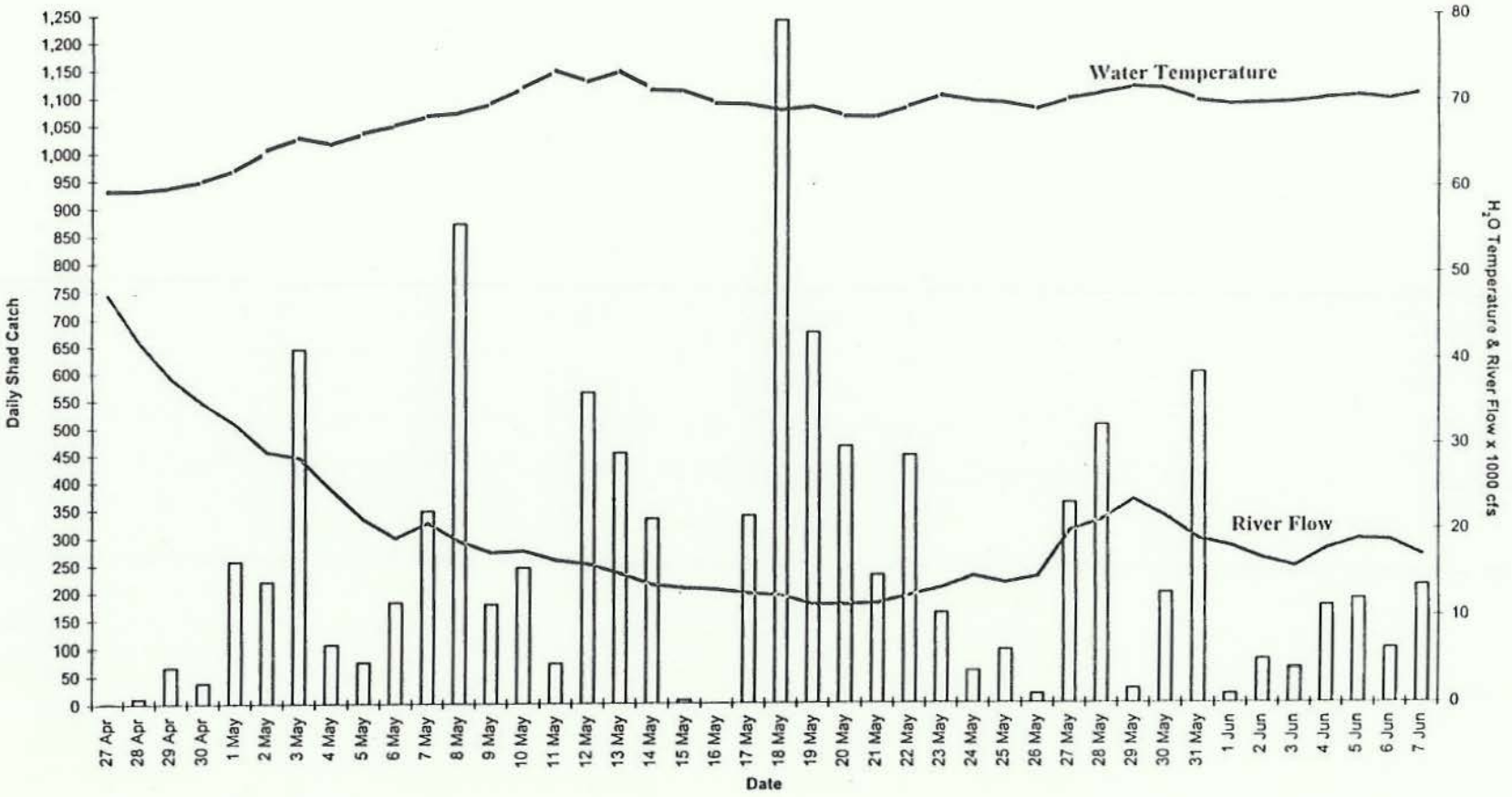


Figure 1

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

Attachment #5

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

Information in this report will partially address:

Job 11. American Shad Otolith Analysis - 2000 Juvenile Year-Class

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

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

Introduction

Development of tetracycline marking has permitted evaluation of the relative success of the hatchery component of the American shad restoration program (Hendricks et al., 1991). Larvae are marked by 4h immersion in 256ppm oxytetracycline hydrochloride. Detectable fluorophore from these marks is visible in the one otolith increment produced on the day of marking. Multiple marks, 3 or 4d apart, have been used to evaluate the relative survival of groups uniquely marked according to release site, egg source river, release time of day, or release habitat (Hendricks et al., 1992, Hendricks et al., 1993).

From 1976 to 1992, American shad larvae reared at the Van Dyke Research Station for Anadromous Fish were stocked into the Juniata River at 18-21d of age. The

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

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

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

As a result, production larvae stocked in 1995 and 1996 were released at 7 days of age. In order to imprint larvae to other areas in the drainage, smaller numbers of larvae were released in tributary streams or other main-stem areas (North Branch and West Branch Susquehanna River) within the Susquehanna River Basin. In order to mark these larvae with unique tetracycline marks, they had to be stocked as older larvae. Recovery rates of these uniquely marked larvae stocked in 1995 and 1996 suggested

that larvae released at 7 days of age may not survive any better than those released later. One explanation for this is that multiple releases at any one site may be attracting predators to that site, resulting in reduced survival. It was theorized that spreading larvae out by stocking at a number of sites may result in improved survival.

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

In 1998, we altered our stocking protocol, spreading larvae out by stocking at various sites with minimal stocking at repeat sites. This paper reports the results of stocking uniquely marked American shad larvae at various sites in 2000 and summarizes results from 1995 to 2000.

Materials and Methods

The majority (63%) of production larvae stocked in 2000 was marked at three days of age and stocked at various sites in the Juniata River and the middle Susquehanna River near Montgomery Ferry. Susquehanna River sites were stocked when high, turbid water prevented stocking in the Juniata River. Sites were generally stocked in succession, moving upriver. Repeated stockings at one site, within a short time interval, were avoided. Smaller numbers of uniquely marked larvae were stocked at other sites,

including the North and West Branches of the Susquehanna River and Conestoga, Conewago, Conodoguinet, and Swatara Creeks. No fingerlings were stocked in 2000.

Juvenile American shad were recaptured during Autumn by lift net (Holtwood Dam), in intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam. Other juvenile samples were collected, but were not used in this analysis because of the potential that they were not representative of the outmigrating population as a whole. Shad were frozen whole and delivered to Benner Spring Fish Research Station for otolith analysis. Otoliths were extracted, mounted, ground and analyzed according to standard procedures (Hendricks et al., 1991). Recovery rates were calculated for each group by dividing the number of fish recovered by the number stocked and multiplying by 10,000. Relative survival was calculated by dividing the recovery rate for each group by the highest recovery rate.

Results and Discussion

Marking and recovery data for 1995 to 2000 are tabulated in tables 1-1 through 1-6, respectively. In 2000, larvae stocked in the Juniata River and middle Susquehanna River near Montgomery Ferry exhibited the best survival (relative survival set to 1.00, Table A1-7). Larvae stocked in Conewago Cr. also survived well (relative survival 0.86). Larvae stocked in the North Branch and in Conodoguinet Cr. did relatively less well with a relative survival of 0.48 and 0.51, respectively. Larvae stocked in the West Branch Susquehanna River and in Conestoga R. did poorly with relative survival of 0.20 and 0.24. No larvae were recovered from the Swatara Cr. release.

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

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

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

Larvae stocked in smaller tributaries did well in some years and poorly in others, for example, Conestoga R. larvae exhibited the best survival in 1995 and 1999, poor relative survival in 1997 (0.35) and 2000 (0.24) and were not detected in 1996 and 1998. The high survival, 1995 and 1999 releases were at the Rt. 322 bridge near Ephrata (river mile 38), as was the low survival release in 2000. The other low survival releases were at Conestoga Pines Park in Lancaster (river mile 22). Larvae stocked in Conodoguinet Creek larvae exhibited good relative survival in 1999 (0.77) fair relative survival in 1996 and 2000(0.50 and 0.51), but poor relative survival in other years (0.18 to 0.25; 1995, 1997 and 1998). Water quality in Conodoguinet Creek is good at the larval stocking site, but low dissolved oxygen may be problematic in the lower reaches of the stream. Larvae stocked in Swatara Cr. did well in 1998 and 1999(relative survival 0.93 and 0.81, respectively), but were not detected in 2000, probably due to the low number stocked (33,000). In Conewago Cr., larvae did well in 1998, poorly in 1999, and well in 2000 (relative survival 1.00 , 0.15, and 0.86 respectively), despite release at the same site. Thus, recovery rate of shad larvae at each stocking site fluctuates from year to year with no one site consistently better than the others. The exception is that the West Branch Susquehanna River exhibits consistently low recovery rates, possibly due low fertility.

Crecco and Savoy (1985) found that survival of 5 day cohorts of American shad larvae in the Connecticut River was highest at low river flow, high water temperature and

high zooplankton density. This dependence on environmental conditions may explain the varying survival of larvae stocked in tributaries of the Susquehanna River, particularly since each tributary receives only one stocking per year. If environmental conditions are ideal at the time of stocking, survival may be good for that release group. If environmental conditions are poor, survival may be poor or zero. Based on the above considerations, I make the following recommendations.

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

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.

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 1-1. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	7-9	5/19-6/16	9,070,000	91%	308	87	0.34	0.27
Conodoguinet Cr.	19	6/6	220,000	2%	5	1	0.23	0.18
mouth of Conodoguinet Cr.	19	6/6	230,000	2%	9	3	0.39	0.31
Conestoga R.	22	6/15	198,000	2%	25	7	1.26	1.00
mouth of Conestoga R.	22	6/15	190,000	2%	8	2	0.42	0.33
Muddy Cr.	22	6/19	93,000	1%	0	0	0.00	0.00
		Total	10,001,000		355		0.35	

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

Table 1-2. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1996.

Stocking Site	Age at Release (days)	Release Dates	Fry Released N	Fry Released %	Juveniles Recovered N	Juveniles Recovered %	Recovery Rate	Relative Survival
Juniata R./ Susq. R. @ Mont. Ferry	6-8	5/24-6/24	5,730,200	77%	45	66	0.08	0.33
Conodoguinet Cr.	16	6/14	171,700	2%	2	3	0.12	0.50
Conestoga R.	17	6/17	277,100	4%	0	0	0.00	0.00
Standing Stone Cr.	21	7/2	42,900	1%	0	0	0.00	0.00
W. Br. Susq. R.	17	6/15	561,100	8%	5	7	0.09	0.38
N. Br. Susq. R.	13	6/19	682,500	9%	16	24	0.23	1.00
		Total	7,465,500		68		0.09	

Table1-3. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1997.

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

Table 1-4. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1998.

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

Table 1-5. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1999.

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

Table 1-6. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 2000.

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

Table A1-7. Annual summary of relative survival of American shad fry stocked at various sites in the Susquehanna River basin. as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995-2000.

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

Attachment #6

Analysis of American shad adult otoliths, 2001

Information in this report will address:

Job 11. American Shad Otolith Analysis - 2001 Spawning Adults

Analysis of adult American shad otoliths, 2001

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

Abstract

A total of 215 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam West Fish Lift in 2001. Based on tetracycline marking 38% of the 208 readable otoliths were identified as wild and 62% hatchery. Double marked fish (released below Conowingo Dam) represented 9.3% of the marked fish in the Conowingo West Lift samples.

Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1986-1995 year classes, stocking of approximately 284 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 134 fingerlings was required to return one adult to the lifts. For wild fish, transport of 0.79 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1995 year classes is not fully recruited. Actual survival is even higher since not all surviving adults enter the lifts.

Introduction

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). Funding for the project was provided by an agreement between the three upstream utilities and the appropriate state and federal agencies. Primary restoration approaches consisted of: 1) trapping of pre-spawn adults at Conowingo Dam and transfer to areas above dams (1972 to 1999), 2) direct fish passage (1997 and beyond), and 3) planting of hatchery-reared fry and fingerlings.

In order to evaluate and improve the program, it was necessary to know the relative contribution of the hatchery program to the overall restoration effort. Toward that end, the Pennsylvania Fish Commission developed a physiological bone mark which could be applied to developing fry prior to release (Lorson and Mudrak, 1987; Hendricks et al., 1991). The mark was produced in otoliths of hatchery-reared fry by immersion in tetracycline antibiotics. Analysis of otoliths of outmigrating juveniles allows discrimination of "wild" vs. hatchery reared fish. The first successful application of tetracycline marking at Van Dyke was conducted in 1984. Marking on a production basis began in 1985 but was only marginally successful (Hendricks, et al., 1986). In

1986, 97.8% tag retention was achieved (Hendricks, et al., 1987) and analysis of outmigrants indicated that 84% of the upstream production (above Conowingo Dam) was of hatchery origin vs 17% wild (Young, 1987). Similar data has been collected in subsequent years.

The contribution to the overall adult population below Conowingo of hatchery-reared and wild fish resulting from restoration efforts was more complicated. The adult population of shad below Conowingo Dam includes: 1) wild upper bay spawning stocks which are a remnant of the formerly abundant Susquehanna River stock; 2) wild fish of upstream origin which are progeny of adults from out-of-basin or Conowingo trap and transfer efforts, 3) hatchery-reared fish originating from stockings in main stem or tributary areas upstream from Conowingo Dam and 4) hatchery-reared fish originating from stockings below the Conowingo Dam. The latter group were fish which received a "double" tetracycline mark and were first planted below Conowingo Dam in 1986.

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

hatchery fish from wild fish. This report presents results of evaluation of otoliths from adult American shad collected in 2001.

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 50th shad to enter the West lift. Adult American shad collected in the upper Chesapeake Bay by Maryland DNR were processed by MDNR and are not reported here.

Each sampled fish was sexed, measured and decapitated. Whole heads were frozen and delivered to the Van Dyke Hatchery. Otoliths (sagittae) were extracted and one otolith was mounted for mark analysis in permount on a microscope slide, while the other was mounted for ageing on clear tape in acrylic.

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

Whole otoliths were aged by viewing with a dissecting microscope and a fiber optic light. The best contrast was obtained by directing the light from the side, parallel to the sagittal plane of the otolith. Ageing was done by a single researcher. After initial

ageing, length at age was analyzed and apparent outliers were re-examined. We have assembled a collection of several hundred otoliths from known aged shad based on the presence of a unique tetracycline mark. These were used as reference material.

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 2001. Age composition data was gathered as follows: for 1996 to 2001, age composition data was collected from the otolith analysis above. For 1991-1995, age composition data was taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1989 and 1990, age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transport mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991).

Recruitment to the lifts by year class was determined for hatchery and wild origin fish by partitioning the lift catch for each year into its component year classes based upon age composition and otolith marking data. Total recruitment by year class was determined for hatchery and wild groups by summing the data for each year class over its recruitment history. The number of larvae required to return one adult to the lifts

(L/A) was determined for each year class by dividing the number of larvae stocked above dams by the total recruitment of adults which originated as hatchery larvae. Similarly, the number of fingerlings required to return one adult (F/A) was determined for each year class by dividing the number of finglerlings stocked above dams by the total recruitment of adults which originated as hatchery fingerlings. The number of transported adults required to return one adult (TA/A) was determined for each year class by dividing the number of adults transported upstream by the total recruitment of unmarked (wild) adults. Overall L/A, F/A and TA/A were caculated by dividing the sum of the number stocked or transported by the sum of the total recruitment of the group, for the cohorts in question.

Results and Discussion

A total of 215 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 2001. No samples were collected from the East lift since it was operated in fish passage mode. For 7 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 208 readable otoliths (Table 1). A total of 79 (38%) otoliths exhibited wild microstructure and no tetracycline mark. One hundred and twenty-nine (62%) exhibited tetracycline marks including single, double, triple, and

quadruple immersion marks. No specimens exhibited feed marks. Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. The contribution of wild (naturally produced) fish to the adult population entering the Conowingo Dam fish lifts during 1989-1999 ranged from 10 to 71% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish have been increasing since 1993 (Figure 2).

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 3). Overall mean age was 4.6 years for males and 5.2 years for females. For wild fish, mean ages were 4.5 for males and 5.0 for females (Table 4). For hatchery fish, mean age was 4.7 for males and 5.4 for females. Overall sex ratio was 0.74 to 1, males to females. Length frequencies and mean length at age are tabulated in Tables 5 to 8. As expected, females were larger than males. Hatchery fish appeared to be slightly older and larger than wild fish.

Fish lift catch, age composition and origin of sacrificed shad are presented in Table 9. Analysis of otoliths to assess hatchery contribution was not conducted prior to 1989. As a result, data for year classes prior to 1986 could not be partitioned into hatchery and wild and are not presented. Year classes after 1995 are not fully recruited

and are not included in the analysis. For the period 1986-1995, the number of hatchery larvae required to produce one returning adult (L/A) ranged from 164 to 620, with an overall value of mean of 284 (Table 10). This is a maximum estimate since the 1995 year class is not fully recruited. L/A was highest (431-620) for the early cohorts (1986 – 1989). During 1990 to 1995, L/A improved to 164-289, presumably due to improvements in fish culture practices. L/A will continue to decrease since L/A for the 1996 and 1997 cohorts is already below the overall.

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

This analysis was repeated for fingerlings stocked above Conowingo Dam (Table 11). For the period 1986-1995, the number of hatchery fingerlings required to produce one returning adult (F/A) ranged from 40 to 386, with an overall value of 134. Again, this is a maximum estimate since the 1995 year class is not fully recruited. At first glance, it would appear that stocking fingerlings is advantageous over stocking larvae,

however, on average, one must stock 100,000 larvae in a pond to harvest 10,000 to 20,000 fingerlings. Therefore, it would take 700 to 1,400 larvae, stocked in a pond, then harvested and stocked in the river as fingerlings to produce one adult. Considering the cost of pond culture, it is clearly better to stock larvae directly. The appearance of 220 recruited adults for the 1995 cohort and 42 for the 1996 cohort, when no fingerlings were stocked, is an artifact of erroneous aging, and highlights the problems with aging American shad.

A similar analysis was tabulated for wild fish (Table 12). For the period 1986 to 1995, transport of an average of 0.79 adults was required to produce one returning adult, above replacement. The actual stock/recruitment ratio of wild fish is unknown since some of the wild fish which entered the lifts would have been of Upper Bay origin and not all recruited fish entered the lifts. These factors may act to cancel each other out, but the magnitude of each is not known.

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

improving for recent years and must continue to do so to allow for successful restoration.

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

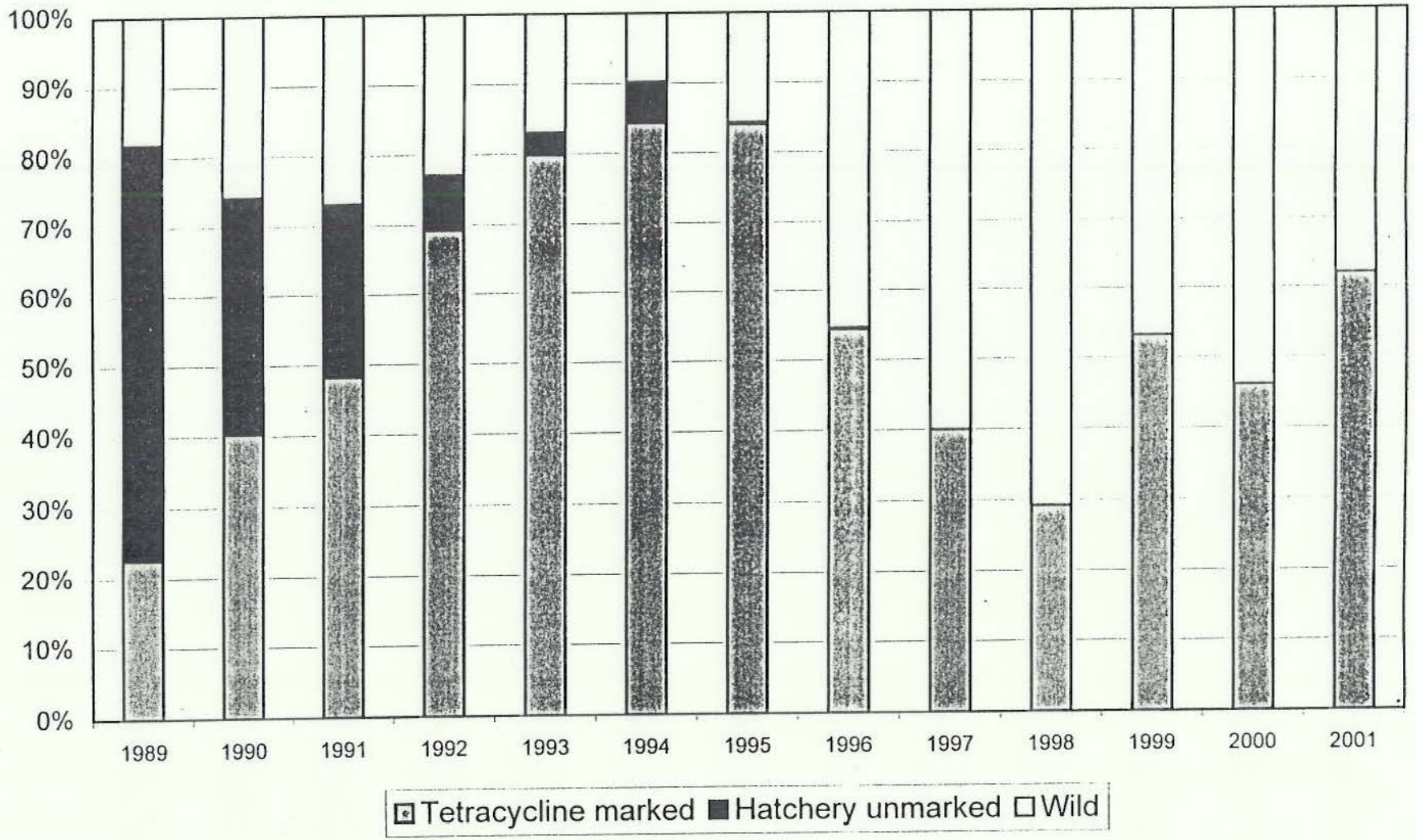


Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts

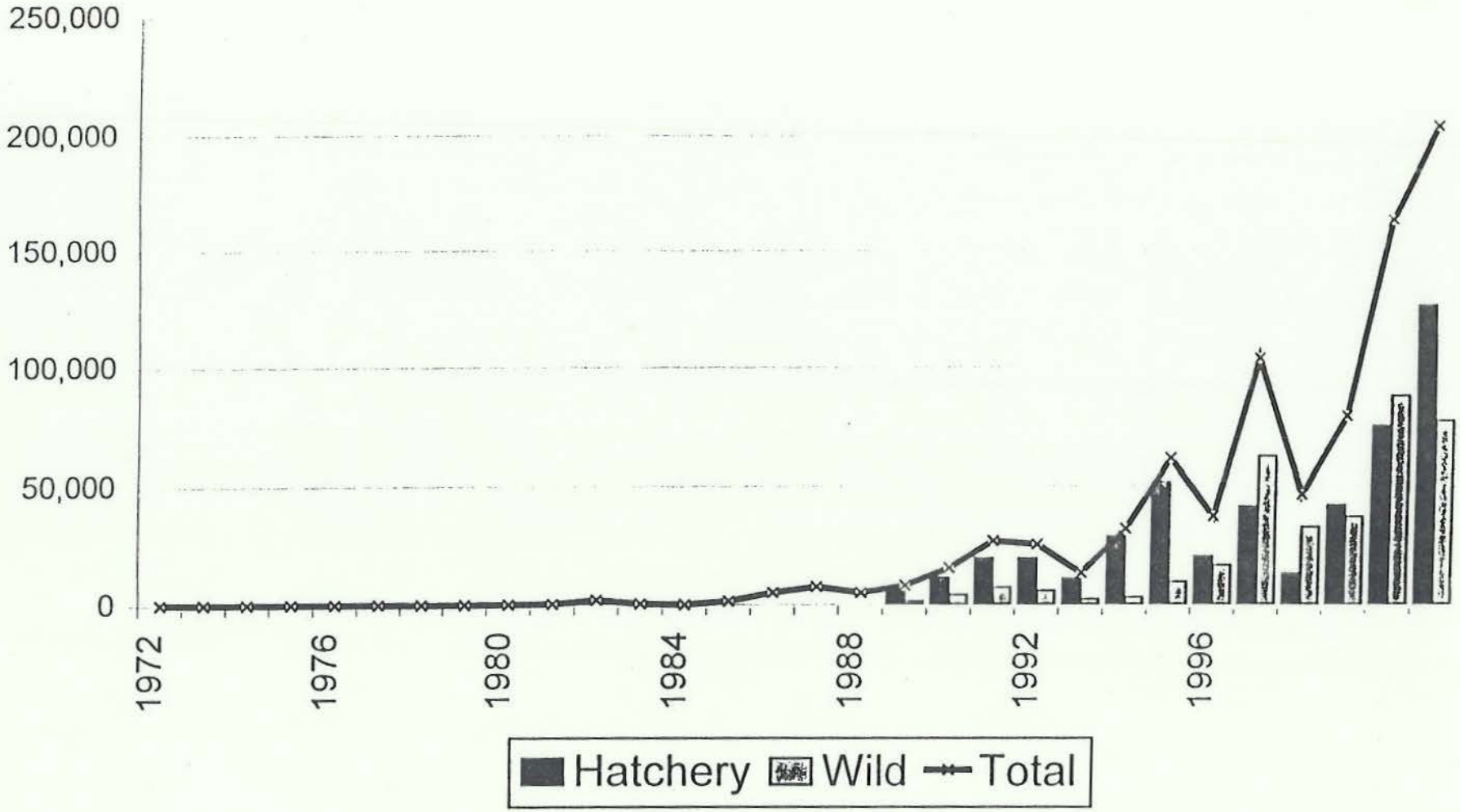


Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Susquehanna River, 2001.
One of every 50 fish collected from the Conowingo West Fish Lift was sacrificed for analysis.

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

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

Table 2. Origin of adult American shad collected at Conowingo Dam Fish Lifts, based on otolith analysis. Every 50th or 100th fish to enter the lifts was sacrificed for analysis.

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

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

Table 3. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 2001.

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

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

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

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

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

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

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

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

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

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

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

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

									Hatchery Release Site			Wild
									Above Dams		Below Dams	
	Fish lift	% Age composition							larvae	fingerlings		
Year	catch	8	7	6	5	4	3	2	%	%	%	%
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4	71% *		6% *	23% *
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%			18%
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%		1%	26%
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	2%	5%	27%
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	1%	4%	23%
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	2%	18%	17%
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	1%	8%	10%
1995	61,650	0.0	3.2	12.4	51.9	28.5	4.0	0.0	77%	1%	6%	16%
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%	1%	6%	45%
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%	2%	5%	60%
1998	46,481	0.0	0.8	10.9	48.1	37.2	3.1	0.0	22%	2%	5%	71%
1999	79,370	0.5	1.1	7.9	32.6	45.3	10.0	0.0	48%	1%	5%	47%
2000	163,331	0.0	1.0	9.9	27.6	51.0	10.4	0.0	40%	0%	6%	54%
2001	203,776	0.0	2.1	22.0	51.8	24.6	2.1	0.0	56%	0%	4%	38%

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

Table 10. Recruitment of hatchery larvae, stocked above dams, to the Conowingo Fish Lifts, 1986- 1996.

	Cohort											
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1988	13											
1989	373	16										
1990	1,706	166	0									
1991	6,956	2,250	307	0								
1992	6,652	6,870	2,181	545	0							
1993	277	1,867	4,563	1,867	69	0						
1994	0	859	5,918	14,318	5,059	0	0					
1995		0	1,517	5,907	24,746	13,570	1,916	0				
1996			0	152	2,881	7,430	6,015	1,365	51			
1997				0	0	3,676	6,363	15,695	9,191	141		
1998					0	80	1,125	4,983	3,858	322	0	
1999						200	400	3,000	12,399	17,198	3,800	0
2000							0	688	6,532	18,221	33,692	6,876
2001								0	2,401	25,205	59,412	28,206
Total recruits to lifts:	15,977	12,028	14,486	22,789	32,755	24,957	15,819	25,730	34,431	61,088	96,904	35,082
Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54	6.42	10.00	7.47	8.02
Number of larvae to return 1 adult:	620	431	445	591	172	289	192	254	186	164	77	229

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

Table 11. Recruitment of hatchery fingerlings, stocked above dams, to the Conowingo Fish Lifts, 1986- 1996.

	Cohort										
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	3 *										
1989	0	0									
1990	0	0	0								
1991	188	61	8	0							
1992	86	89	28	7	0						
1993	7	49	120	49	2	0					
1994	0	12	82	198	70	0	0				
1995		0	24	93	388	213	30	0			
1996			0	3	64	165	134	30	1		
1997				0	0	174	302	744	436	7	
1998					0	6	78	344	266	22	0
1999						2	4	33	138	191	42
2000							0	0	0	0	0
2001								0	0	0	0
Total recruits to lifts:	285	211	262	350	524	560	548	1,152	841	220	42
Fingerlings stocked/10,000:	7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94	13.95	0.00	0.00
ber of fingerlings to return 1 adult:	255	386	244	172	172	97	40	69	166	0	0

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

Table 12. Recruitment of naturally reproduced American shad to the Conowingo Fish Lifts, 1986- 1996.

	Cohort										
Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1988	55 *										
1989	83	4									
1990	607	59	0								
1991	2,811	910	124	0							
1992	2,091	2,159	685	171	0						
1993	73	496	1,211	496	18	0					
1994	0	104	714	1,727	610	0	0				
1995		0	308	1,201	5,029	2,758	389	0			
1996			0	144	2,741	7,069	5,723	1,298	48		
1997				0	0	6,538	11,317	27,914	16,346	251	
1998					0	255	3,570	15,810	12,240	1,020	0
1999						196	391	2,933	12,123	16,816	3,715
2000							0	917	8,710	24,295	44,923
2001								0	1,621	17,019	40,116
Total recruits to lifts:	5,721	3,730	3,043	3,738	8,399	16,816	21,390	48,872	51,088	59,402	88,754
Adults transported/1000:	4.17	7.20	4.74	6.47	15.08	24.66	15.67	11.72	28.68	56.37	33.83
No. of adults transported to return 1 adult:	0.73	1.93	1.56	1.73	1.79	1.47	0.73	0.24	0.56	0.95	0.38

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