Restoration of American Shad to the Susquehanna River

Annual Progress Report 1997

Susquehanna River
Anadromous Fish Restoration Committee

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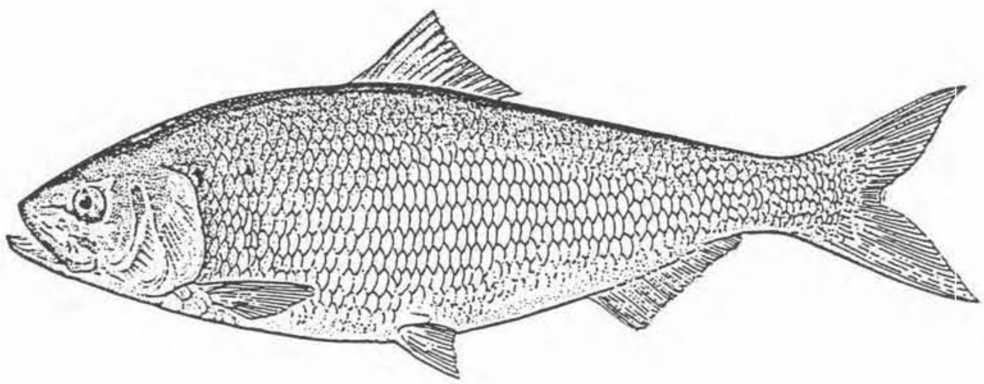
RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



ANNUAL PROGRESS REPORT

1997

SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

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

FEBRUARY 1998

EXECUTIVE SUMMARY

This 1997 Annual Report of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) presents results from activities and studies directed at restoring American shad to the Susquehanna River. This program, largely funded by hydroelectric project operators, is aimed at rebuilding anadromous shad and herring stocks based on hatchery releases and natural reproduction of adult fish collected for transport or directly passed at the Conowingo Dam fish lifts and recently completed passage facilities at Holtwood and Safe Harbor dams. The restoration program represents a continuing commitment among all parties to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The West lift at Conowingo Dam was operated for 44 consecutive days between April 24 through June 6, fishing for 295 hours and making 611 separate lifts. Total catch amounted to 345,983 fish representing 39 taxa including 12,974 American shad, 133,257 blueback herring, 118 hickory shad, and 11 alewives. Sex ratio in the shad run was 1.9 to 1 favoring males and 64 Maryland DNR tags were recovered. Every 50th shad collected during the season was killed for otolith analysis.

A total of 10,528 shad were stocked at Tri-County Boat Club in Middletown with only 53 observed trucking and delayed mortalities. About 1,140 shad were provided to Maryland DNR for tank spawning, 115 fish to the New Jersey Aquarium, and 185 to Safe Harbor for turbine survival studies. Blueback herring were stocked at several upstream areas including 16,672 at Tri-County; 5,003 in Conodoguinet Creek; 3,152 in the Conestoga River; and, 2,956 in the Little Conestoga.

For the first year since built the Conowingo East lift operated to pass all fish into Conowingo Pond. It operated a total of 640 hours and made 652 lifts from April 7 through June 9. Fish were identified and counted as they passed the viewing window and observations were supplemented with video recordings. A record 90,971 American shad and 344,332 blueback herring were counted along with 284,000 other fishes representing 33 taxa. Peak shad passage occurred in early to mid-May with single day totals exceeding 6,000 shad on three occasions. Over 100,000 bluebacks passed in a 3-day period, April 29-May 1.

The tailrace fish lift at Holtwood Dam began operations on April 18 and the spillway lift on April 20. Both facilities operated daily through June 14 except for a 3-day breakdown period on May 21-23. Based on counts at the viewing window, total passage amounted to 225,104 fish of 33 taxa including 28,063 American shad (31% of Conowingo) and 1,042 bluebacks. Of the total shad passed about 15,000 used the tailrace lift and 13,000 used the spillway lift. Peak day shad passage of 2,826 was on May 2.

The new fish lift at Safe Harbor Dam operated for 43 days between April 21 and June 15 with breakdowns occurring on April 29 through May 9 (collapsed attraction water inlet pipe) and June 1-2. Total fish passage as counted at the viewing window was 211,084 fish of 37 taxa including 20,828 American shad and 534 blueback herring. Peak shad day was May 10 at 2,026 fish. Safe Harbor lifts passed 23% of all shad which used the Conowingo East lift and 74% of the Holtwood count.

Maryland DNR conducted a tag and recapture population assessment for the upper Chesapeake Bay and the Conowingo tailrace. During late March through late May 1,775 shad were caught and 1,035 were tagged from upper Bay pound nets and by angling in the Conowingo tailrace. Recaptures included 67 tags in the Conowingo West lift and East lift observations included 81 yellow tags (1997, possible 1995) and 14 blue tags (1996). Using Peterson techniques, population estimates for the upper Bay and tailrace were calculated to be 708,628 and 423,324, respectively - both new records. The increasing population trend recorded in recent years is corroborated by higher catch per effort in both pound nets and by angling. DNR notes that concerns have been expressed regarding the probability that some tags were missed in the East fish passage thus inflating the estimate.

Age analysis and spawning history was derived from scale samples taken from 358 adult shad (264 pound net and 94 angling). Age 4 fish (1993 year-class) made up 52% of the combined sample. Most males were ages 3-5 and females 4-6. The amount of repeat spawning increased substantially from past years, 25% in males and 29% in females.

Based on otolith analysis of 250 adult shad taken at Conowingo West lift in 1997, 100 (40%) were of hatchery origin and 150 (60%) were wild. This was a dramatic increase in wild fish compared to

1995 (16%) and 1996 (45%), representing both the highest percentage and the largest number of wild fish ever collected at Conowingo. The majority of hatchery fish (63%) carried triple tetracycline marks of both Hudson and Delaware River egg sources. Otoliths from 160 shad taken from upper Bay pound nets were also examined and 35 of these (22%) were hatchery fish. This compares to 30% hatchery fish in 1996 and 58% in 1995. Pennsylvania Fish and Boat Commission (PFBC) researchers examined otoliths from 42 shad taken from the Nanticoke River and about 120 from Virginia coastal gill nets and all were wild.

The Wyatt Group was contracted by PFBC to collect shad eggs from the Hudson River in 1997. Between May 6 and June 3 two fishing crews gill netted spawners, stripped and fertilized eggs, and shipped these to Van Dyke hatchery. A total of 11.1 million eggs were taken, mostly from two sites (Cheviot and Coxsackie), with overall viability of 54.5%. Two shipments totalling 2.3 million eggs had very low viabilities (0 and 3.4%) thought to be related to a temperature drop in the shipping containers and poor fertilization due to a shortage of males. Haul seining at Rodgers Island produced no ripe shad or eggs in 1997.

PFBC and Ecology III used anchored gill nets to collect ripe shad and take eggs from the Delaware River near Smithfield Beach on May 13 through June 9. A total of 11.8 million were delivered to Van Dyke in 17 shipments. Overall egg viability was unusually low at 39%, perhaps related to insufficient sperm/egg contact time during fertilization. No Hudson or Delaware River shad eggs were provided to Maryland in 1997.

A total of 22.84 million shad eggs were delivered to Van Dyke with 46.6% viability. Fry survival was 87.4% producing 9.3 million fry of which 2.99 million were stocked at several sites in the Juniata River; 2.80 million were stocked at Montgomery Ferry on the mainstem Susquehanna above Clarks Ferry; 1.2 million into the North Branch at Berwick; 0.62 million in the West Branch at Williamsport; and 0.45 million into two lower river tributaries. Of the remainder, 1.25 million Delaware fry were stocked into the Lehigh River and 32,000 into Benner Springs ponds for mark retention analysis (100%). From the latter, 25,000 fingerlings were later released into Swatara Creek. Fry were released at 7 to 22 days of age and received one to four unique mark combinations. Juniata River stockings were spread out in 1997 in an effort to reduce predation. The Montgomery Ferry site was used when the Juniata was high and turbid.

The Wyatt Group conducted weekly haul seine collections at Columbia, PA during late July through October and caught 879 American shad fingerlings in 90 hauls. The overall catch per effort of 9.7 fish per haul was a record high for this survey. Normandeau Associates conducted lift netting at Holtwood Dam's inner forebay on 16 dates during October 18 through December 2, taking 1,372 juvenile shad in 160 lifts (CPUE = 8.6 fish/lift). Most fish (99%) were taken during the peak of outmigration on November 5-26. PFBC electrofishing at Columbia and other locations also produced some shad. Work performed by Wyatt and Normandeau was done under contract to PFBC.

Peach Bottom water intake screens produced 64 American shad, 358 bluebacks, and 75,500 gizzard shad during three times per week cleanouts from November 7 through December 10. Conowingo strainers were examined twice a week during November 3 through December 8 and took 66 American shad, 14 bluebacks, and 24,000 gizzard shad. Maryland DNR took 29 shad during their summer-fall striper seine survey in the upper Bay. Subsamples of all shad were returned to Benner Spring for otolith analysis.

Otoliths from a total of 600 juvenile shad were examined for hatchery marks from combined collections made above Holtwood. Of these, 516 (86% of total) were hatchery marked of which the majority (95%) carried the single day 5 mark or the multiple mark combinations indicating that they were stocked at Montgomery Ferry and various locations in the Juniata River.

Collections from Holtwood, Peach Bottom, and Conowingo produced 496 otoliths for analysis of which 460 (93%) were hatchery marked. Of these, 377 or 82% were from fry releases in the Juniata River and at Montgomery Ferry. In all collections at and above Conowingo, the North Branch produced 66 juveniles (7% of hatchery total); the West Branch produced 17 fish (2%); and the Conestoga River produced 23 fish (2%). The remaining five hatchery fish originated from Conodoguinet Creek fry (3) and Swatara Creek fingerlings (2). Only two of 29 fish taken in DNR seine collections were hatchery origin, both taken at Havre de Grace and single-marked on day 5.

American shad egg collections, hatchery culture and marking, and otolith mark analysis were funded from the 1993 settlement agreement with upstream utilities. This source (GPU-Genco) committed $273,500 of which about $273,000 was spent in 1997. The PA Fish and Boat Commission funded juvenile shad net and electrofishing collections above Conowingo Dam.

Costs associated with Conowingo West fish lift operations including collection, sorting, and trucking of shad and herring amounted to about $135,000. This was paid from a contributed funds account administered by the U. S. Fish and Wildlife Service and a grant from EPA (Chesapeake Bay Program). SECO and PECO Energy paid for strainer and screen checks for juvenile shad at Conowingo Dam and Peach Bottom. Maryland DNR funded the adult shad population assessment and juvenile shad seining in the upper Chesapeake Bay.

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

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JOB I - Part 1
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INTRODUCTION

Susquehanna Electric Company (SECO), a subsidiary of PECO Energy, has operated a fish passage facility (West lift) at its Conowingo Hydroelectric Station since 1972. Lift operations are part of a cooperative private, state, and federal effort to restore American shad (*Alosa sapidissima*) and other migratory fishes to the Susquehanna River. In accordance with the restoration plan, the operational goal has been to monitor fish populations below Conowingo Dam and transport pre-spawned migratory fishes upriver.

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

With the completion of fishways at Holtwood and Safe Harbor Dam, the East lift was operated to pass fish into Conowingo Pond. To facilitate this mode of operation several capital improvements to the facility were made prior to the season. Objectives of 1997 operation were: (1) monitor passage of migrating and resident fishes through the fishway: and (2) assess fishway and trough effectiveness and make modifications as feasible.

CONOWINGO OPERATION

Project Operation

The Conowingo Hydroelectric Station, built in 1928 is located at river mile 10 on the Susquehanna River (Figure 1). The powerhouse has a peaking generating capacity of 512 MW and a hydraulic capacity of 85,000 cfs. Flows in excess of station draft are spilled over two regulating and 50 crest gates. The powerhouse contains seven vertical Francis (numbered 1 through 7) and four Kaplan (numbered 8 through 11) turbines. The seven Francis units have been equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The four Kaplan turbines installed in 1964 have been recently replaced with a more efficient and fish friendlier mixed flow Kaplan type turbine manufactured by Voith, Inc. The new turbines have been installed in units #8, #10, and #11. Unit #9 turbine replacement project is proceding according to schedule and should be in service by the end of March 1998.

Minimum flow releases from the station during the spring spawning and fishway operating season followed the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500, and 5,000 cfs were maintained from 1 to 30 April, 1 to 31 May, and 1 to 9 June, respectively. Generally, units 5 and 6 were used to meet minimum flow releases in April and May. Either unit 5 or 6 was used in June.

Fishway Operation

East lift operation began on 7 April and it was operated daily through 9 June. Half day lift operation (1100 to 1900 hrs) occurred from 7 April to 18 April. Based on numerous factors including the number of American shad passed and water temperature full day operation began on 19 April and continued (except for 16 to 18 May) through 9 June. Generally, full day operation began between 0700 hrs and 0800 hrs and continued to approximately 1900 hrs. Operation on 16, 17, and 18 May was purposefully shortened with the consent of the USF&WS, Susquehanna River Anadromous Fish Coordinator in an effort to increase the catch of American shad at the west trap and transport facility. Fishway operation was conducted by a staff of three people including a lift operator, supervising biologist, and a biological technician who counted fish.

Work stoppage due to mechanical, electrical, and/or pneumatic failures or maintenance were infrequent and minor in nature and accounted for the loss of just one hour of fishing time. However, on 9 June a sequence of limit switch failures with the crowder system resulted in the termination of lift operation. Based on the review several recommendations were developed and they will be implemented prior to 1998 to prevent this and other control problems from occurring in the future.

The mechanical aspects of East lift operation in 1997 were similar to that described in RMC (1992). Fishing time and/or lift frequency was determined by fish abundance. The hopper was cycled at least hourly throughout the day. As required, mechanical delays at the East lift were reduced by controlling access of fish over the hopper by operation of the crowder screen. This mode of operation "fast fish" involved leaving the crowder in the normal fishing position and raising the hopper frequently to remove fish that accumulate in the holding channel.

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

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

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

The specific entrance(s) used to attract fishes was dictated by the station discharge and which turbine units were operating. For example, when turbine units 8, 9, 10, and 11 were operating, entrance C was the primary entrance used to attract fishes. Under these conditions the attraction flow through the other entrances has been found to be negated or disrupted by flow from the Kaplan turbines. Generally, for the majority of the season when the small units were operating, the primary entrance used to attract fishes was A; under these conditions attraction flow extended across the tailrace. As in previous years, entrance B was not used this season.

Prior to the start of the season, SECO undertook three capital improvements at the East fish lift. They included installation of: (1) a trash chute manufactured by SuperChute, Ltd. The chute was hung on the east side of the trough to facilitate trash removal; (2) a 4 ft high removable aluminum fence installed on the inside of the trough along the west side to prevent fish from jumping out; and (3) a platform addition to the existing walkway around the trough was installed to facilitate trash removal efforts and to provide access to the viewing window area for cleaning and maintenance purposes. All improvements proved to be extremely effective.

Fish Counts

Fish that were lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. The counting area is located in the trough (Figure 2). As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide channel on the east side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to passage from the fishway. Passage from the fishway was controlled by gates located downstream of the window. Generally during the day fish passage was controlled by the technician who opened/closed a set of gates downstream of the viewing window from a controller located in the counting room. To facilitate fish identification during periods of peak passage two people identified and counted fishes.

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

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

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

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

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

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

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed by the Conowingo Dam East fish lift is presented in Table 1. A total of 719,297 fish of 36 taxa were passed upstream into Conowingo Pond. Gizzard shad (344,332) was the dominant fish species passed and comprised almost 48% of the catch. Other predominant fishes passed included blueback herring (242,815), American shad (90,971), white perch (27,312), carp (3,256), quillback (2,488), and walleye (2,334). Alosids (American shad, blueback herring, and alewife) comprised over 46% of the total catch. Peak passage occurred on 30 April when some 89,995 fish, or 12.5% of the season total, were passed. Alosid (American shad and blueback herring) passage total was 83,530 fish or almost 93% of the fish that passed that day.

American Shad Passage

The East lift captured and passed 90,971 American shad in 1997 (Table 1). The first shad was passed on 12 April which was the sixth day of operation. Collection and passage of shad varied daily with over 93.5% (85,277) of the shad captured and passed between 25 April and 1 June. The lift captured and passed over 2,000 American shad per day on 16 occasions and on six of these days more than 4,000 shad were passed. Daily passage exceeded 6,000 shad on three days. Peak passage occurred on 4 May when 6,725 American shad were passed in approximately 11 hours of operation. Some 30.3, 65.8, and 3.9% of the shad passage occurred during operation in April, May, and June, respectively.

American shad were collected at water temperatures of 51.8°F to 69.9°F and at river flows of 20,400 to 53,700 cfs (Table 2 and Figure 3). Over 90% of the shad were collected at water temperatures <65°F (Table 2). Generally, river water temperatures were less than 65°F until 25 May.

The hourly passage of American shad in the East lift is given in Table 3. Most shad passed (70,033) passed through the fishway from 1200 hrs to 1859 hrs. Peak hourly passage of shad (11,715) occurred between 1600 hrs to 1659 hrs. Generally, shad passage declined hourly after the first hour (0800 hrs to 0900 hrs) of operation each day until 1100 hrs when passage increased hourly until it peaked. Following the peak, passage declined steadily until operation ended each night. Typically, upstream movement of shad stopped each evening prior to sunset. This behavior is most likely the reason hourly shad passage rates were slightly higher in the morning since most fish that passed early each day were fish that were captured the preceding day and had remained in the trough overnight.

Other Alosids

Some 242,878 river herring were captured and passed via the East lift (Table 1). No hickory shad were collected. A total of 242,815 blueback herring were captured and passed (Table 1). Most blueback herring (98.3%) were passed between 29 April and 22 May when some 238,774 herring were passed. Passage occurred in three pulses or waves with some 103,799, 42,967, and 79,580 herring captured and passed from 29 April to 2 May, 7 May to 10 May, and 14 to 18 May, respectively. Peak passage occurred at water temperatures of 59°F to 66.2°F and river flows of 21,400 to 34,000 cfs (Table 2). Peak daily passage occurred on 30 April when 77,900 herring were passed in 11 hours of operation.

The hourly passage of blueback herring in the East lift is given in Table 4. Relatively large numbers of herring passed through the fishway hourly from 0900 hrs to 1959 hrs. In contrast, passage during the first hour of operation was limited. Peak hourly passage of herring occurred between 1100 hrs and 1159 hrs. Although the number of herring passed each day varied greatly, a bimodal trend in passage was evident. Generally, passage increased hourly each morning and peaked by noon, it then dropped and leveled off at 16,000 herring per hour until 1700 hrs when passage increased and more than doubled between 1800 hrs and 1859 hrs.

Video Record

A limited review of the video record showed that fish passage was not adequately captured on the tape record. Data in Table 5 lists by date and time the shad count, the number of shad visually estimated from the video count, and the difference between the two counts. The tape count derived from the review of five randomly selected periods was less than that derived from the visual estimate during four of the five periods. The differences between visual counts and tape counts varied from 49 to 61 shad or from 10% to 27%. One video count was reported as being slightly higher than the visual count by some 4% (31 shad). This count was derived based on the consensus of two people, after a frame by frame review of the time period. This detailed review resulted in a count that was some 10% (76 shad) lower than the initial tape count.

Generally, the difference between the video and visual counts resulted from poor tape quality. The majority of video tapes contained images of fish passing the window that were nothing more than grainy silhouettes that were extremely difficult to identify. In general, poor tape quality caused by high turbidity, changing light, and low light conditions made it difficult and practically impossible at times to distinguish fish species. The poor visibility conditions encountered resulted in tape derived counts that were questionable.

Although it was not possible to determine the precision of visual estimates of fish passage the techniques employed were similar to those used at other east coast fishways. Since two people were utilized during periods of increased passage visual estimates of fish passage were considered to accurately reflect the number of fish that passed through the East lift.

SUMMARY

The spring 1997 East lift operating season was very successful. Both the catch and catch per effort of American shad and blueback herring was the highest recorded since operation began in 1991 (Table 6). Passage and survival of fish that utilized the fishway was excellent. Passage effectiveness at the East lift was enhanced by several factors including (1) the elimination of delays caused by sorting and loading of shad for transport; and (2) lift effectiveness was greatly enhanced during April and May by stable low river flows which resulted in improved attraction efficiency. River flows in April and May were generally half of the average median flow which is approximately 62,000 cfs and 42,000 cfs, respectively. In addition, American shad abundance in the Conowingo tailrace was probably at or near an all time high.

RECOMMENDATIONS

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

- Improve visibility conditions at the fish counting window by installation of an adjustable screen capable of reducing the exit channel width from 36 inches down to 18 inches at the counting window. Screen design may also allow intermediate positions between 18 and 36 inches. Channel width would be set daily based on visibility and/or the secchi reading.

- Investigate and install adjustable underwater lighting at the counting window to improve fish counts and the video record of fish passage in the lower third of the water column during periods of low ambient light. Low levels of light, particularly from 1700 hrs to 1900 hrs each evening, made fish identification/counting difficult.

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

- Implement weekly operation checks of all system back-up limits to prevent breakdown caused by control failures.

LITERATURE CITED

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

Table 1

Summary of the daily number of fish passed by the Conowingo Dam East Fish Passage Facility in 1997.

Date	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*
Hours Of Operation	*7.50*	*6.75*	*6.25*	*6.90*	*7.00*	*8.00*	*7.60*	*7.00*
Numbers Of Lifts	*9*	*9*	*7*	*9*	*7*	*9*	*8*	*6*
Water Temperature	*10.0*	*12.0*	*11.5*	*12.0*	*11.5*	*11.5*	*11.5*	*11.0*
American Shad	-	-	-	-	-	44	154	20
Gizzard Shad	11,525	4,596	9,926	12,531	8,287	4,956	8,364	3,415
Blueback Herring	-	-	-	-	-	-	-	-
Alewife	-	-	-	-	-	-	-	-
Striped Bass	-	-	-	-	-	-	-	-
American Eel	-	-	-	-	-	-	-	-
Rainbow Trout	1	-	-	-	-	-	-	-
Brown Trout	-	-	-	-	-	-	-	-
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	1	-	-	-
Muskellunge	2	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	-	-	-	-	1	-	1	-
Quillback	-	-	-	2	1	-	-	-
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	3	1	-
Shorthead Redhorse	2	-	-	-	-	-	-	-
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	7	1	-	1	-	-	-	1
White Perch	-	-	-	-	-	-	-	-
Rock Bass	-	-	-	-	-	-	-	-
Redbreast Sunfish	-	-	-	-	-	-	-	-
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	1	-	-	-	-	-	-	-
Bluegill	2	-	-	-	-	-	-	1
Smallmouth Bass	1	-	-	-	-	-	-	-
Largemouth Bass	-	-	-	-	-	-	1	-
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	1	-	-	-	-
Yellow Perch	-	-	-	-	-	-	-	-
Walleye	1	-	1	1	-	-	-	-
Sea Lamprey	-	-	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***11,542***	***4,597***	***9,927***	***12,536***	***8,290***	***5,003***	***8,521***	***3,437***

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Table 1

Continued.

Date	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*
Hours Of Operation	*8.00*	*8.30*	*7.75*	*7.80*	*11.50*	*9.75*	*11.80*	*11.60*
Numbers Of Lifts	*8*	*9*	*7*	*7*	*10*	*10*	*12*	*12*
Water Temperature	*12.0*	*12.5*	*13.0*	*13.0*	*12.0*	*11.5*	*12.5*	*13.0*
American Shad	86	1,826	748	87	21	283	1,245	943
Gizzard Shad	4,395	2,304	3,528	1,684	2,874	5,500	6,496	7,005
Blueback Herring	-	-	-	-	-	-	-	-
Alewife	1	-	1	-	-	-	-	-
Striped Bass	-	-	-	-	-	-	-	-
American Eel	-	-	-	-	-	-	-	-
Rainbow Trout	-	-	-	-	-	-	-	-
Brown Trout	-	-	-	-	-	-	-	-
Salmo Sp.	-	-	-	-	-	-	1	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	1
Esox Sp.	-	1	-	-	-	-	-	-
Carp	-	1	-	-	-	-	-	-
Quillback	-	11	7	-	-	-	2	1
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	2
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	7	-	-	-	-	-	-
White Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	5	-	35	35	3	-	81	13
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	1	-	-	-	-
White Perch	-	-	-	-	-	-	-	-
Rock Bass	-	-	-	-	-	-	-	-
Redbreast Sunfish	-	-	-	-	-	-	-	-
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	1	-	-	-
Smallmouth Bass	4	6	8	3	1	1	7	2
Largemouth Bass	-	-	-	-	1	1	-	1
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	-	-	-	-	-
Walleye	1	4	-	-	-	-	-	-
Sea Lamprey	-	-	-	-	-	1	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***4,492***	***4,160***	***4,327***	***1,810***	***2,901***	***5,786***	***7,832***	***7,968***

Table 1

Continued.

Date	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*
Hours Of Operation	*11.25*	*11.20*	*11.00*	*11.50*	*10.80*	*11.30*	*11.00*	*10.80*
Numbers Of Lifts	*10*	*11*	*11*	*11*	*11*	*12*	*10*	*11*
Water Temperature	*12.5*	*12.0*	*12.5*	*13.5*	*15.0*	*14.5*	*15.0*	*16.8*
American Shad	627	376	2,788	2,520	5,073	3,168	1,940	5,630
Gizzard Shad	6,939	5,832	1,526	2,492	2,435	4,771	4,360	6,001
Blueback Herring	-	-	-	-	-	97	8,624	77,900
Alewife	-	-	-	-	-	61	-	-
Striped Bass	-	-	1	-	-	-	-	1
American Eel	-	-	-	-	-	-	-	-
Rainbow Trout	-	-	-	-	2	-	-	-
Brown Trout	-	-	-	-	-	-	-	-
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	1	-	-	-	4	14	1	2
Quillback	1	1	-	-	67	687	1	-
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	1	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	5	64	11	77	3	148	265	70
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	6	-	-	-	-
White Perch	-	-	-	-	-	-	-	37
Rock Bass	-	-	-	-	-	-	-	4
Redbreast Sunfish	-	-	-	-	-	-	-	-
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	14
Smallmouth Bass	2	12	-	8	6	21	14	110
Largemouth Bass	2	2	-	-	1	1	3	57
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	-	-	-	2	21
Walleye	-	-	-	-	-	2	11	147
Sea Lamprey	-	-	-	-	-	1	-	1
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***7,577***	***6,287***	***4,327***	***5,103***	***7,591***	***8,971***	***15,221***	***89,995***

Table 1

Continued.

Date	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*
Hours Of Operation	*9.80*	*11.00*	*11.10*	*11.00*	*11.00*	*11.00*	*11.00*	*9.00*
Numbers Of Lifts	*11*	*10*	*10*	*11*	*11*	*11*	*11*	*9*
Water Temperature	*16.6*	*16.5*	*16.0*	*16.5*	*17.0*	*17.0*	*17.0*	*17.0*
American Shad	825	2,300	3,043	6,725	1,031	1,057	3,999	2,666
Gizzard Shad	3,927	1,035	3,210	4,453	7,940	8,381	3,130	4,842
Blueback Herring	14,600	2,675	465	202	167	485	1,914	26,850
Alewife	-	-	-	-	-	-	-	-
Striped Bass	13	19	-	-	-	-	4	3
American Eel	-	-	-	-	-	-	-	1
Rainbow Trout	-	-	-	-	-	-	-	-
Brown Trout	-	1	-	1	-	-	-	-
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	1	-	1	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	196	40	27	2	47	46	64	26
Quillback	190	40	3	-	2	1	19	25
Comely Shiner	-	140	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	1	-	-
Shorthead Redhorse	231	121	16	1	8	7	17	53
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	-	-	-	-	-
White Perch	7,220	1,017	135	43	2	4	5	670
Rock Bass	1	-	-	-	1	-	-	20
Redbreast Sunfish	-	-	-	2	-	-	3	5
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	1	-	-	-
Bluegill	18	7	5	3	4	1	-	-
Smallmouth Bass	182	51	20	3	13	21	34	22
Largemouth Bass	10	3	1	1	-	1	5	18
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	1	-	-	-
Yellow Perch	5	-	4	-	3	-	-	-
Walleye	650	89	40	2	4	8	8	47
Sea Lamprey	-	-	-	-	-	1	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***28,068***	***7,538***	***6,969***	***11,439***	***9,224***	***10,015***	***9,202***	***35,248***

Table 1

Continued.

Date	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*14 May*	*16 May*
Hours Of Operation	*10.30*	*11.00*	*11.00*	*11.00*	*11.20*	*11.20*	*11.00*	*8.00*
Numbers Of Lifts	*12*	*11*	*11*	*11*	*11*	*11*	*11*	*8*
Water Temperature	*17.0*	*16.5*	*15.5*	*16.0*	*17.0*	*16.0*	*16.0*	*16.5*
American Shad	6,395	847	1,490	2,085	658	1,743	2,445	2,010
Gizzard Shad	2,575	5,012	2,361	5,785	3,093	1,825	4,450	4,540
Blueback Herring	11,725	2,478	170	135	107	975	11,780	3,010
Alewife	-	-	-	-	-	-	-	-
Striped Bass	24	3	-	4	1	10	33	16
American Eel	3	-	-	-	-	-	-	-
Rainbow Trout	-	-	-	-	-	-	-	-
Brown Trout	-	-	-	-	-	-	5	3
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	39	6	11	20	146	41	32	32
Quillback	44	1	-	1	40	-	1	5
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	56	3	24	32	3	7	10	25
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	1	-	-	-	-	-	-	-
White Perch	1,845	2,167	1,677	500	160	240	1,203	1,710
Rock Bass	35	2	-	8	-	2	18	2
Redbreast Sunfish	8	2	-	-	1	-	-	-
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-
Bluegill	3	1	1	2	5	7	7	-
Smallmouth Bass	23	11	2	28	7	18	18	6
Largemouth Bass	12	1	-	2	1	5	5	5
White Crappie	-	-	-	-	1	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	3	-	-	-	-	1	4	2
Walleye	60	15	17	26	17	13	27	18
Sea Lamprey	-	1	-	-	-	-	3	6
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***22,851***	***10,550***	***5,753***	***8,628***	***4,240***	***4,887***	***20,041***	***11,390***

Table 1

Continued.

Date	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*
Hours Of Operation	*7.30*	*8.00*	*11.00*	*11.00*	*12.00*	*10.80*	*11.00*	*11.00*
Numbers Of Lifts	*11*	*11*	*11*	*10*	*11*	*11*	*11*	*11*
Water Temperature	*17.0*	*16.5*	*17.0*	*19.0*	*18.3*	*17.5*	*17.0*	*18.0*
American Shad	348	6,481	2,795	1,060	1,015	1,330	1,825	579
Gizzard Shad	4,709	1,220	4,595	4,410	3,870	3,670	5,715	15,280
Blueback Herring	52,590	12,200	2,700	3,202	2,770	1,050	45	43
Alewife	-	-	-	-	-	-	-	-
Striped Bass	-	-	85	31	35	90	31	3
American Eel	-	-	-	1	3	1	-	-
Rainbow Trout	-	1	-	-	-	-	-	-
Brown Trout	-	1	2	-	-	-	4	-
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	7	5	57	59	349	10	14	16
Quillback	1	1	122	1	22	100	5	41
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	2	-	-	-	-
Shorthead Redhorse	1	-	13	8	3	4	-	-
Brown Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	-	6	5	20	-
White Perch	79	470	2,000	1,991	1,090	2,250	475	19
Rock Bass	-	-	18	23	10	8	5	-
Redbreast Sunfish	-	-	13	14	12	5	-	-
Green Sunfish	-	-	-	-	3	-	-	1
Pumpkinseed	-	-	-	-	5	-	-	-
Bluegill	1	1	-	15	29	21	8	3
Smallmouth Bass	3	2	7	16	16	14	7	-
Largemouth Bass	-	-	-	3	-	-	-	-
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	-	-	16	2	12	-	2	-
Walleye	1	9	65	33	118	120	48	7
Sea Lamprey	-	1	-	4	-	-	5	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
TOTAL	***57,740***	***20,392***	***12,488***	***10,875***	***9,368***	***8,678***	***8,209***	***15,992***

Table 1

Continued.

Date	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*
Hours Of Operation	*10.30*	*11.00*	*11.00*	*11.00*	*11.00*	*11.30*	*11.00*	*10.80*
Numbers Of Lifts	*10*	*11*	*11*	*11*	*11*	*11*	*11*	*11*
Water Temperature	*19.0*	*19.0*	*18.8*	*19.0*	*19.0*	*20.0*	*20.0*	*20.5*
American Shad	245	1,224	287	1,170	842	1,085	265	1,097
Gizzard Shad	10,970	14,770	7,830	6,618	8,350	6,280	5,720	1,420
Blueback Herring	36	1,980	1,200	170	150	195	110	5
Alewife	-	-	-	-	-	-	-	-
Striped Bass	3	16	18	170	55	83	32	12
American Eel	-	-	-	-	-	-	-	-
Rainbow Trout	-	1	-	-	-	-	-	1
Brown Trout	-	-	-	-	-	-	-	1
Salmo Sp.	-	-	-	-	-	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	176	82	57	610	205	72	123	266
Quillback	190	25	-	50	73	4	5	9
Comely Shiner	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	5	-	3	4	3	-	+	-
Brown Bullhead	1	-	-	1	-	-	1	-
Channel Catfish	1	25	68	293	228	92	116	5
White Perch	7	4	5	107	20	35	1	37
Rock Bass	1	2	-	4	6	2	4	1
Redbreast Sunfish	2	4	11	15	19	26	-	8
Green Sunfish	-	-	-	-	2	-	-	-
Pumpkinseed	-	-	-	-	7	-	20	1
Bluegill	2	2	9	2	25	37	16	10
Smallmouth Bass	-	2	3	2	11	17	-	2
Largemouth Bass	1	-	-	-	-	2	-	-
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	5	2	5	-	-
Walleye	19	13	21	278	61	98	13	15
Sea Lamprey	-	-	-	-	-	2	-	-
Hybrid Striped Bass	-	-	1	-	-	-	-	-
TOTAL	***11,659***	***18,150***	***9,513***	***9,499***	***10,059***	***8,035***	***6,426***	***2,890***

Table 1

Continued.

Date	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	*TOTAL*
Hours Of Operation	*11.00*	*10.50*	*11.00*	*10.75*	*10.50*	*10.30*	*10.50*	*4.00*	***640.00***
Numbers Of Lifts	*11*	*10*	*11*	*14*	*11*	*10*	*11*	*4*	***652***
Water Temperature	*21.0*	*21.0*	*19.7*	*20.0*	*20.0*	*19.0*	*19.5*	*20.0*	
American Shad	394	80	339	363	597	216	386	50	***90,971***
Gizzard Shad	3,424	5,100	6,130	9,170	7,650	3,530	4,490	1,110	***344,332***
Blueback Herring	2	-	-	-	1	5	2	-	***242,815***
Alewife	-	-	-	-	-	-	-	-	***63***
Striped Bass	22	30	36	29	20	19	38	25	***1,015***
American Eel	-	1	1	1	1	-	-	-	***13***
Rainbow Trout	-	-	-	-	-	-	-	-	***6***
Brown Trout	-	-	-	-	-	1	-	-	***19***
Salmo Sp.	1	-	-	-	-	-	-	-	***2***
Chain Pickerel	-	-	-	-	-	-	-	-	***1***
Muskellunge	-	-	-	-	-	-	-	-	***5***
Esox Sp.	-	-	-	-	-	-	-	-	***1***
Carp	38	118	14	169	3	1	3	2	***3,256***
Quillback	495	116	8	10	50	5	1	1	***2,488***
Comely Shiner	-	-	-	-	-	-	-	-	***140***
Spottail Shiner	-	-	-	-	-	-	-	-	***3***
Spotfin Shiner	-	15	-	-	2	-	-	-	***17***
Notropis Sp.	-	-	-	-	-	-	-	-	***7***
White Sucker	-	-	-	-	-	-	-	-	***7***
Shorthead Redhorse	-	-	-	-	-	-	-	-	***1,475***
Brown Bullhead	-	1	-	-	1	-	-	-	***5***
Channel Catfish	22	62	71	1	120	18	6	1	***1,178***
White Perch	5	-	10	5	30	6	16	15	***27,312***
Rock Bass	1	-	-	24	2	-	-	-	***204***
Redbreast Sunfish	11	2	15	-	9	2	3	3	***195***
Green Sunfish	-	-	-	-	-	-	-	-	***6***
Pumpkinseed	-	-	-	-	-	-	1	-	***36***
Bluegill	12	15	25	-	12	3	2	2	***334***
Smallmouth Bass	2	3	6	3	-	-	1	1	***783***
Largemouth Bass	1	-	-	-	-	-	-	-	***147***
White Crappie	-	-	-	-	-	-	-	-	***1***
Black Crappie	-	-	-	-	-	-	-	-	***2***
Yellow Perch	1	1	-	-	1	-	-	1	***93***
Walleye	20	15	18	13	95	23	15	7	***2,334***
Sea Lamprey	-	-	-	4	-	-	-	-	***30***
Hybrid Striped Bass	-	-	-	-	-	-	-	-	***1***
TOTAL	***4,451***	***5,559***	***6,673***	***9,792***	***8,594***	***3,829***	***4,964***	***1,218***	***719,297***

Table 2

Summary of American shad catch, Maryland DNR recaptures, daily average river flow, water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Conowingo Dam East Fish Passage Facility in 1997.

Date	American Shad catch	MD DNR Recaptures	River Flow (CFS)	Water Temp (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
7 Apr	0	0	63,300	50.0	24	11	C	310	22.0-23.0	107.2-107.9
8 Apr	0	0	58,800	53.6	24	11	C	310	22.0-23.0	108.4-108.7
9 Apr	0	0	53,100	52.7	24	11	C	310	22.5	106.9-107.1
10 Apr	0	0	48,800	53.6	24	11	C	310	20.5-22.0	107.2-108.2
11 Apr	0	0	43,700	52.7	22	11	C	310	21.0-22.5	106.0-107.0
12 Apr	44	0	39,200	52.7	22	8	C	310	16.0-21.0	107.6-108.3
13 Apr	154	0	38,100	52.7	32	6	C	310	18.0-20.0	108.1-108.7
14 Apr	20	0	34,800	51.8	22	11	C	310	19.0-22.5	107.3-107.6
15 Apr	86	0	34,300	53.6	24	9	C	310	19.5-21.5	107.8-108.2
16 Apr	1,826	0	34,800	54.5	32	9	C	310	19.0-22.0	107.8-108.3
17 Apr	748	0	32,700	55.4	26	8	C, A	310	18.5-21.0	107.6-108.8
18 Apr	87	0	32,100	55.4	24	9	C, A	310	18.0-22.0	107.3-107.8
19 Apr	21	0	29,200	53.6	22	6	C, A	310	17.0-21.5	106.5-107.5
20 Apr	283	0	28,300	52.7	24	4	A	310	17.0-18.0	107.5-108.1
21 Apr	1,245	0	27,000	54.5	24	11	C, A	310	17.0-22.5	107.2-108.3
22 Apr	943	0	26,800	55.4	28	11	C, A	310	17.0-22.5	107.3-108.4
23 Apr	627	0	25,400	54.5	24	11	C, A	310	17.0-22.5	106.8-108.2
24 Apr	376	0	24,200	53.6	24	11	C, A	310	17.0-22.5	106.9-108.8
25 Apr	2,788	0	25,100	54.5	26	10	C, A	310	17.0-22.5	106.2-107.9
26 Apr	2,520	1B	23,200	56.3	26	6	C, A	310	17.0-20.0	107.1-107.6
27 Apr	5,073	0	21,800	59.0	34	2	A	310	17.0	106.4-107.7
28 Apr	3,168	2Y	21,200	58.1	32	8	C, A	310	17.0-21.5	107.7-108.6
29 Apr	1,940	0	22,500	59.0	32	8	C, A	310	17.0-21.5	107.4-108.3
30 Apr	5,630	3Y,1B	21,400	62.3	36	6	C, A	310	17.0-20.0	107.0-108.6
1 May	825	0	23,000	61.9	32	6	C	310	20.0	107.3-107.9
2 May	2,300	3Y,2B	24,200	61.7	24	8	C, A	310	18.0-21.5	106.5-108.4
3 May	3,043	1Y	26,900	60.8	24	7	C, A	310	17.0-21.5	107.6-108.1
4 May	6,725	2Y,1B	26,400	61.7	36	4	A	310	17.0-19.5	107.2-108.8
5 May	1,031	0	27,400	62.6	28	8	C, A	310	17.0-21.5	106.6-107.5
6 May	1,057	0	30,600	62.6	32	8	C, A	310	18.5-21.5	106.6-107.8
7 May	3,999	0	32,700	62.6	24	8	C, A	310	18.0-21.5	107.7-108.6
8 May	2,666	7Y	34,000	62.6	28	8	C	310	20.0-21.5	107.5-108.2

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Table 2

Continued.

Date	American Shad catch	MD DNR Recaptures	River Flow (CFS)	Water Temp (°F)	Secchi (in)	Maximum Units in Operation	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
9 May	6,395	10Y,3B	32,300	62.6	30	7	C	310	18.5-21.0	107.0-107.8
10 May	847	0	30,100	61.7	32	6	C, A	310	17.0-20.0	106.8-108.2
11 May	1,490	0	28,500	60.0	28	6	A, C	310	17.0-20.0	107.8-108.6
12 May	2,085	2Y	28,100	60.8	32	9	C	310	18.0-21.5	107.7-108.6
13 May	658	0	25,800	62.6	36	8	C	310	18.0-21.5	107.3-108.5
14 May	1,743	7Y	24,700	60.8	36	8	C, A	310	17.0-21.5	107.3-108.5
15 May	2,445	1Y	25,700	60.8	32	6	C	310	18.0-20.0	107.7-108.1
16 May	2,010	9Y	24,800	61.7	36	9	C	310	18.0-22.0	107.5-108.0
17 May	348	0	22,900	62.6	36	2	A	310	17.0	106.4-107.7
18 May	6,481	3Y	21,700	61.7	36	4	A	310	17.0-18.0	107.4-108.7
19 May	2,795	1Y,1B	22,000	62.6	36	8	C	310	18.0-22.0	107.7-108.7
20 May	1,060	1Y	20,400	66.2	36	8	A, C	310	18.0-21.5	107.2-108.1
21 May	1,015	3Y,3B	21,100	65.0	36	6	A, C	310	17.0-20.0	108.8-108.9
22 May	1,330	4Y,2B	29,300	63.5	36	6	C	310	18.0-20.0	107.5-108.4
23 May	1,825	6Y	44,300	62.6	36	8	C	310	20.2-21.5	107.8-108.4
24 May	579	0	39,000	64.4	36	8	C	310	18.0-21.5	107.3-108.3
25 May	245	0	38,100	66.2	36	6	C	310	20.0	108.1-108.5
26 May	1,224	2Y	39,400	66.2	37	8	C	310	18.0-21.5	107.4-108.6
27 May	287	0	47,300	65.9	37	10	C	310	21.0-22.0	106.8-107.9
28 May	1,170	8Y0	49,700	66.2	32	10	C	310	21.5-22.0	106.0-107.2
29 May	842	0	48,200	66.2	34	11	C	310	22.0-22.5	105.7-106.5
30 May	1,085	4Y	38,700	68.0	32	9	C	310	19.0-22.0	106.4-108.0
31 May	265	0	32,700	68.0	28	6	A, C	310	17.0-20.0	107.3-107.9
1 Jun	1,097	0	29,500	68.9	34	6.0	A, C	310	16.5-20.0	107.3-108.3
2 Jun	394	1Y	29,700	69.9	36	8.0	C, A	310	18.0-21.5	107.5-108.4
3 Jun	80	0	37,600	69.9	32	8	C	310	18.0-21.5	107.0-108.3
4 Jun	339	1Y	47,800	67.5	30	10	C	310	21.0-22.5	108.1-108.3
5 Jun	363	0	51,000	68.0	28	9	C	310	21.0-22.0	107.7-108.0
6 Jun	597	0	53,700	68.0	20	10	C	310	22.0	107.1-108.5
7 Jun	216	0	46,800	66.2	24	8	A, C	310	18.0-21.5	107.9-109.0
8 Jun	386	0	37,300	67.1	28	8	A, C	310	18.0-22.0	107.9-108.7
9 Jun	50	0	32,200	68.0	32	7	C	310	22.0	107.7-108.0

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Table 3

Hourly summary of American shad passage at the Conowingo Dam East Fish Passage Facility in 1997.

Date	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*
Observation Time - Start	*1130*	*1202*	*1225*	*1050*	*1101*	*1100*	*1100*	*1116*	*1110*	*1109*	*1106*	*1056*	*719*
Observation Time - End	*1911*	*1857*	*1850*	*1759*	*1807*	*1847*	*1832*	*1816*	*1848*	*1929*	*1905*	*1850*	*1843*
Military Time (hrs)													
0700 to 0759	-	-	-	-	-	-	-	-	-	-	-	-	1
0800 to 0859	-	-	-	-	-	-	-	-	-	-	-	-	1
0900 to 0959	-	-	-	-	-	-	-	-	-	-	-	-	4
1000 to 1059	-	-	-	0	-	-	-	-	-	-	-	0	0
1100 to 1159	0	-	-	0	0	0	4	14	3	0	206	32	0
1200 to 1259	0	0	0	0	0	0	0	3	14	10	45	15	0
1300 to 1359	0	0	0	0	0	3	0	0	5	105	65	9	0
1400 to 1459	0	0	0	0	0	4	0	0	7	245	88	2	0
1500 to 1559	0	0	0	0	0	6	9	3	19	277	59	6	0
1600 to 1659	0	0	0	0	0	17	70	0	27	318	65	17	6
1700 to 1759	0	0	0	0	0	11	54	0	11	343	165	2	8
1800 to 1859	0	0	0	-	-	3	17	0	-	389	49	4	1
1900 to 1959	0	-	-	-	-	-	-	-	-	139	6	-	-
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
No time stamp	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***0***	***0***	***0***	***0***	***0***	***44***	***154***	***20***	***86***	***1,826***	***748***	***87***	***21***

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Table 3

Continued.

Date	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*
Observation Time - Start	*900*	*656*	*616*	*752*	*739*	*800*	*800*	*815*	*754*	*755*	*813*	*750*	*800*
Observation Time - End	*1845*	*1845*	*1753*	*1909*	*1843*	*1903*	*1921*	*1901*	*1910*	*1859*	*1904*	*1906*	*1859*
Military Time (hrs)													
0700 to 0759	-	2	316	-	-	-	-	-	1	0	-	0	-
0800 to 0859	-	47	128	4	1	-	-	0	474	110	860	0	0
0900 to 0959	-	15	99	85	4	13	447	12	467	40	640	300	40
1000 to 1059	6	4	38	57	0	1	174	55	269	50	175	0	310
1100 to 1159	0	3	2	12	9	9	95	214	125	120	300	100	700
1200 to 1259	6	16	13	11	16	22	141	299	114	255	550	50	400
1300 to 1359	58	188	72	166	42	413	551	505	69	170	750	50	265
1400 to 1459	27	78	42	77	28	212	409	530	86	170	400	50	165
1500 to 1559	20	25	20	49	37	224	142	640	791	120	555	65	181
1600 to 1659	12	66	32	11	14	275	218	705	384	190	150	100	78
1700 to 1759	68	145	54	40	54	548	66	990	-	370	750	50	101
1800 to 1859	48	213	127	41	99	364	175	1,113	-	345	200	60	60
1900 to 1959	38	348	-	47	72	656	54	10	-	-	300	-	-
2000 to 2059	-	-	-	27	-	51	48	-	-	-	-	-	-
No time stamp	-	95	-	-	-	-	-	-	388	-	-	-	-
Total	*283*	*1,245*	*943*	*627*	*376*	*2,788*	*2,520*	*5,073*	*3,168*	*1,940*	*5,630*	*825*	*2,300*

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Table 3

Continued.

Date	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Observation Time - Start	*755*	*800*	*805*	*800*	*800*	*801*	*800*	*800*	*800*	*800*	*751*	*748*	*803*
Observation Time - End	*1904*	*1902*	*1859*	*1859*	*1909*	*1905*	*1903*	*1902*	*1904*	*1906*	*1859*	*1901*	*1902*
Military Time (hrs)													
0700 to 0759	0	-	-	-	-	-	-	-	-	-	0	0	-
0800 to 0859	20	122	32	100	37	140	100	245	195	125	10	60	50
0900 to 0959	60	110	44	124	163	15	50	24	55	105	20	15	30
1000 to 1059	40	333	63	110	238	100	155	28	0	150	40	145	80
1100 to 1159	135	255	110	85	582	45	510	36	50	250	50	400	100
1200 to 1259	180	770	80	50	209	90	150	51	10	310	50	170	100
1300 to 1359	555	910	113	63	193	455	405	18	0	190	50	150	515
1400 to 1459	580	1,250	141	70	529	258	265	23	5	195	40	190	415
1500 to 1559	515	1,150	99	209	580	314	370	1	0	300	40	210	310
1600 to 1659	400	950	198	30	562	557	1,280	151	170	225	80	96	410
1700 to 1759	415	750	89	141	248	355	635	150	565	150	190	138	225
1800 to 1859	135	100	62	75	625	325	2,375	110	170	80	88	167	150
1900 to 1959	8	25	-	-	33	12	100	10	270	5	-	2	60
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
No time stamp	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***3,043***	***6,725***	***1,031***	***1,057***	***3,999***	***2,666***	***6,395***	***847***	***1,490***	***2,085***	***658***	***1,743***	***2,445***

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Table 3

Continued.

Date	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*
Observation Time - Start	*754*	*800*	*1100*	*800*	*802*	*800*	*809*	*800*	*800*	*800*	*800*	*800*	*800*
Observation Time - End	*1601*	*1518*	*1907*	*1902*	*1905*	*1902*	*1904*	*1902*	*1902*	*1821*	*1904*	*1904*	*1902*
Military Time (hrs)													
0700 to 0759	0	-	-	-	-	-	-	-	-	-	-	-	-
0800 to 0859	0	42	-	0	200	0	-	5	106	6	68	30	0
0900 to 0959	90	6	-	320	0	170	35	25	12	6	46	5	15
1000 to 1059	10	12	-	50	15	100	30	10	12	34	42	5	40
1100 to 1159	320	10	100	150	5	200	60	40	7	30	159	7	115
1200 to 1259	555	64	75	180	100	70	120	195	5	17	135	23	25
1300 to 1359	530	35	400	100	180	50	280	260	34	11	125	10	140
1400 to 1459	215	131	575	220	250	50	220	315	56	15	225	115	185
1500 to 1559	290	48	1,350	260	35	130	155	140	126	26	150	35	125
1600 to 1659	-	-	1,500	510	100	50	100	370	122	65	150	0	135
1700 to 1759	-	-	1,750	360	115	50	200	180	70	20	50	40	45
1800 to 1859	-	-	250	450	0	85	80	200	24	15	50	10	185
1900 to 1959	-	-	481	195	60	60	50	85	5	-	24	7	160
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
No time stamp	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***2,010***	***348***	***6,481***	***2,795***	***1,060***	***1,015***	***1,330***	***1,825***	***579***	***245***	***1,224***	***287***	***1,170***

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Table 3

Continued.

Date	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	
Observation Time - Start	*800*	*800*	*800*	*809*	*800*	*812*	*752*	*800*	*823*	*808*	*830*	*805*	
Observation Time - End	*1910*	*1859*	*1903*	*1902*	*1901*	*1821*	*1900*	*1846*	*1857*	*1824*	*1859*	*1558*	*TOTAL*
Military Time (hrs)													
0700 to 0759	-	-	-	-	-	-	2	-	-	-	-	-	*322*
0800 to 0859	100	-	70	8	95	0	5	1	-	15	-	-	*3,612*
0900 to 0959	35	25	20	242	15	10	0	3	50	0	0	15	*4,126*
1000 to 1059	25	10	17	400	15	5	15	16	25	10	7	5	*3,531*
1100 to 1159	50	2	10	100	30	5	22	41	75	20	8	10	*6,132*
1200 to 1259	35	25	17	100	20	25	25	32	70	35	9	0	*6,157*
1300 to 1359	200	255	7	50	10	5	21	30	25	20	50	0	*9,931*
1400 to 1459	146	183	10	60	35	10	33	92	95	30	80	0	*9,927*
1500 to 1559	81	0	29	40	5	5	77	65	70	20	30	10	*10,648*
1600 to 1659	50	260	10	40	25	5	19	3	50	30	100	10	*11,568*
1700 to 1759	60	40	15	25	75	5	73	52	70	30	40	-	*11,246*
1800 to 1859	30	285	57	25	45	5	47	28	67	6	45	-	*9,759*
1900 to 1959	30	-	3	7	24	-	-	-	-	-	17	-	*3,403*
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	*126*
No time stamp	-	-	-	-	-	-	-	-	-	-	-	-	*483*
Total	*842*	*1,085*	*265*	*1,097*	*394*	*80*	*339*	*363*	*597*	*216*	*386*	*50*	*90,971*

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Table 4

Hourly summary of blueback herring passage at the Conowingo Dam East Fish Passage Facility in 1997.

Date	*7 Apr*	*8 Apr*	*9 Apr*	*10 Apr*	*11 Apr*	*12 Apr*	*13 Apr*	*14 Apr*	*15 Apr*	*16 Apr*	*17 Apr*	*18 Apr*	*19 Apr*
Observation Time - Start	*1130*	*1202*	*1225*	*1050*	*1101*	*1100*	*1100*	*1116*	*1110*	*1109*	*1106*	*1056*	*719*
Observation Time - End	*1911*	*1857*	*1850*	*1759*	*1807*	*1847*	*1832*	*1816*	*1848*	*1929*	*1905*	*1850*	*1843*
Military Time (hrs)													
0700 to 0759	-	-	-	-	-	-	-	-	-	-	-	-	0
0800 to 0859	-	-	-	-	-	-	-	-	-	-	-	-	0
0900 to 0959	-	-	-	-	-	-	-	-	-	-	-	-	0
1000 to 1059	-	-	-	0	-	-	-	-	-	-	-	0	0
1100 to 1159	0	-	-	0	0	0	0	0	0	0	0	0	0
1200 to 1259	0	0	0	0	0	0	0	0	0	0	0	0	0
1300 to 1359	0	0	0	0	0	0	0	0	0	0	0	0	0
1400 to 1459	0	0	0	0	0	0	0	0	0	0	0	0	0
1500 to 1559	0	0	0	0	0	0	0	0	0	0	0	0	0
1600 to 1659	0	0	0	0	0	0	0	0	0	0	0	0	0
1700 to 1759	0	0	0	0	0	0	0	0	0	0	0	0	0
1800 to 1859	0	0	-	-	0	0	0	0	0	0	0	0	0
1900 to 1959	0	-	-	-	-	-	-	-	-	0	0	-	-
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***

Table 4

Continued.

Date	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*
Observation Time - Start	*900*	*656*	*616*	*752*	*739*	*800*	*800*	*815*	*754*	*755*	*813*	*750*	*800*
Observation Time - End	*1845*	*1845*	*1753*	*1909*	*1843*	*1903*	*1921*	*1901*	*1910*	*1859*	*1904*	*1906*	*1859*
Military Time (hrs)													
0700 to 0759	-	0	0	-	-	-	-	-	0	0	-	0	-
0800 to 0859	-	0	0	0	0	-	-	0	0	0	2,880	0	0
0900 to 0959	-	0	0	0	0	0	0	0	5	5	2,660	6,600	700
1000 to 1059	0	0	0	0	0	0	0	0	0	0	4,250	0	975
1100 to 1159	0	0	0	0	0	0	0	0	0	2	5,460	2,850	500
1200 to 1259	0	0	0	0	0	0	0	0	0	2	3,250	600	450
1300 to 1359	0	0	0	0	0	0	0	0	0	0	12,000	350	50
1400 to 1459	0	0	0	0	0	0	0	0	7	1	4,300	100	0
1500 to 1559	0	0	0	0	0	0	0	0	53	400	7,600	0	0
1600 to 1659	0	0	0	0	0	0	0	0	13	210	2,750	2,500	0
1700 to 1759	0	0	0	0	0	0	0	0	9	3,002	12,500	50	0
1800 to 1859	0	0	0	0	0	0	0	0	10	5,002	15,750	1,000	0
1900 to 1959	0	0	-	0	0	0	0	0	0	-	4,500	550	-
2000 to 2059	-	-	-	0	0	0	0	-	-	-	-	-	-
Total	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***97***	***8,624***	***77,900***	***14,600***	***2,675***

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Table 4

Continued.

Date	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*
Observation Time - Start	*755*	*800*	*805*	*800*	*800*	*801*	*800*	*800*	*800*	*800*	*751*	*748*	*803*
Observation Time - End	*1904*	*1902*	*1859*	*1859*	*1909*	*1905*	*1903*	*1902*	*1904*	*1906*	*1859*	*1901*	*1902*
Military Time (hrs)													
0700 to 0759	0	-	-	-	-	-	-	-	-	-	20	-	-
0800 to 0859	0	5	1	0	0	25	380	17	0	5	10	30	75
0900 to 0959	0	10	0	32	0	0	1,250	824	10	5	0	0	40
1000 to 1059	0	0	33	50	0	1,235	1,200	267	0	0	0	75	10
1100 to 1159	0	20	15	25	5	55	2,820	230	0	5	10	110	65
1200 to 1259	45	10	38	30	0	2,890	700	25	30	10	10	130	-
1300 to 1359	305	45	28	155	81	7,530	860	175	35	5	50	465	-
1400 to 1459	25	10	12	35	1,083	1,680	850	780	30	15	0	80	30
1500 to 1559	20	0	2	108	360	4,070	125	15	0	20	5	50	50
1600 to 1659	65	52	38	25	204	1,860	920	30	40	50	0	5	3,800
1700 to 1759	5	37	0	25	112	2,045	120	45	20	20	0	0	1,810
1800 to 1859	0	13	0	0	64	5,370	2,100	20	0	0	2	20	4,350
1900 to 1959	0	0	-	-	5	90	400	50	5	0	-	10	1,550
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	*465*	*202*	*167*	*485*	*1,914*	*26,850*	*11,725*	*2,478*	*170*	*135*	*107*	*975*	*11,780*

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Table 4

Continued.

Date	16 May	17 May	18 May	19 May	20 May	21 May	22 May	23 May	24 May	25 May	26 May	27 May	28 May
Observation Time - Start	*754*	*800*	*1100*	*800*	*802*	*800*	*809*	*800*	*800*	*800*	*800*	*800*	*800*
Observation Time - End	*1601*	*1518*	*1907*	*1902*	*1905*	*1902*	*1904*	*1902*	*1902*	*1821*	*1904*	*1904*	*1902*
Military Time (hrs)													
0700 to 0759	0	-	-	-	-	-	-	-	-	-	-	-	-
0800 to 0859	0	20	-	0	100	0	0	0	0	0	1	5	0
0900 to 0959	910	35	-	1,200	275	500	150	20	16	3	119	310	105
1000 to 1059	550	3,255	-	250	200	180	50	20	0	0	1,300	32	65
1100 to 1159	210	30,260	5	600	525	150	20	5	0	3	390	23	0
1200 to 1259	300	8,160	1,300	290	100	110	50	0	1	24	50	80	0
1300 to 1359	60	4,530	450	200	100	250	60	0	0	0	35	110	0
1400 to 1459	300	5,230	1,445	50	300	20	110	0	8	2	30	105	0
1500 to 1559	670	1,100	1,000	10	55	410	110	0	5	0	20	360	0
1600 to 1659	10	-	2,750	50	350	650	50	0	7	0	30	150	0
1700 to 1759	-	-	1,550	20	795	200	250	0	1	4	5	25	0
1800 to 1859	-	-	750	30	200	300	100	0	5	0	0	0	0
1900 to 1959	-	-	2,950	0	202	0	100	0	0	-	0	0	0
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	***3,010***	***52,590***	***12,200***	***2,700***	***3,202***	***2,770***	***1,050***	***45***	***43***	***36***	***1,980***	***1,200***	***170***

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Table 4

Continued.

Date	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*	
Observation Time - Start	*800*	*800*	*800*	*809*	*800*	*812*	*752*	*800*	*823*	*808*	*830*	*805*	
Observation Time - End	*1910*	*1859*	*1903*	*1902*	*1901*	*1821*	*1900*	*1846*	*1857*	*1824*	*1859*	*1558*	*Total*
Military Time (hrs)													
0700 to 0759	-	-	-	-	-	-	-	-	-	-	-	-	***20***
0800 to 0859	0	0	3	2	0	0	0	0	0	0	-	-	***3,559***
0900 to 0959	25	5	30	0	0	0	0	0	0	0	0	0	***15,844***
1000 to 1059	10	0	15	0	0	0	0	0	0	5	2	0	***14,029***
1100 to 1159	0	5	20	0	0	0	0	0	1	0	0	0	***44,389***
1200 to 1259	35	15	20	0	0	0	0	0	0	0	0	0	***18,755***
1300 to 1359	30	120	5	1	2	0	0	0	0	0	0	0	***28,087***
1400 to 1459	5	0	0	2	0	0	0	0	0	0	0	0	***16,645***
1500 to 1559	20	50	1	0	0	0	0	0	0	0	0	0	***16,689***
1600 to 1659	15	0	1	0	0	0	0	0	0	0	0	0	***16,625***
1700 to 1759	10	0	15	0	0	0	0	0	0	0	0	-	***22,675***
1800 to 1859	0	0	0	0	0	0	0	0	0	0	0	-	***35,086***
1900 to 1959	0	0	0	0	0	-	-	-	-	-	0	-	***10,412***
2000 to 2059	-	-	-	-	-	-	-	-	-	-	-	-	***0***
Total	***150***	***195***	***110***	***5***	***2***	***0***	***0***	***0***	***1***	***5***	***2***	***0***	***242,815***

Table 5

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 1997 Conowingo Dam East lift fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
26 Apr	26	0800 to 0900	458	397	61 (13%)
28 Apr	32	0756 to 0906	482	425	57 (12%)
18 May	36	1527 to 1608	750	781*	-31 -(4%)
19 May	36	0820 to 0912	500	449	51 (10%)
26 May	36	1101 to 1212	179	130	49 (27%)

* Video count higher than visual count

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Table 6

Summary of selected operation and fish catch statistics at the Conowingo Dam East Fish Passage Facility, 1991 to 1997.

Year	Number of Days Operated	Number of Lifts	Operating Time (hrs)	Catch (millions)	Number of Taxa	American shad	Blueback herring	Alewife	Hickory shad
1991	60	1168	647.2	0.651	42	13,897	13,149	323	0
1992	49	599	454.1	0.492	35	26,040	261	3	0
1993	42	848	463.5	0.530	29	8,203	4,574	0	0
1994	55	955	574.8	1.062	36	26,715	248	5	1
1995	68	986	706.2	1.796	36	46,062	4,004	170	1
1996	49	599	454.1	0.492	35	26,040	261	3	0
1997	64	652	640.0	0.719	36	90,971	242,815	63	0

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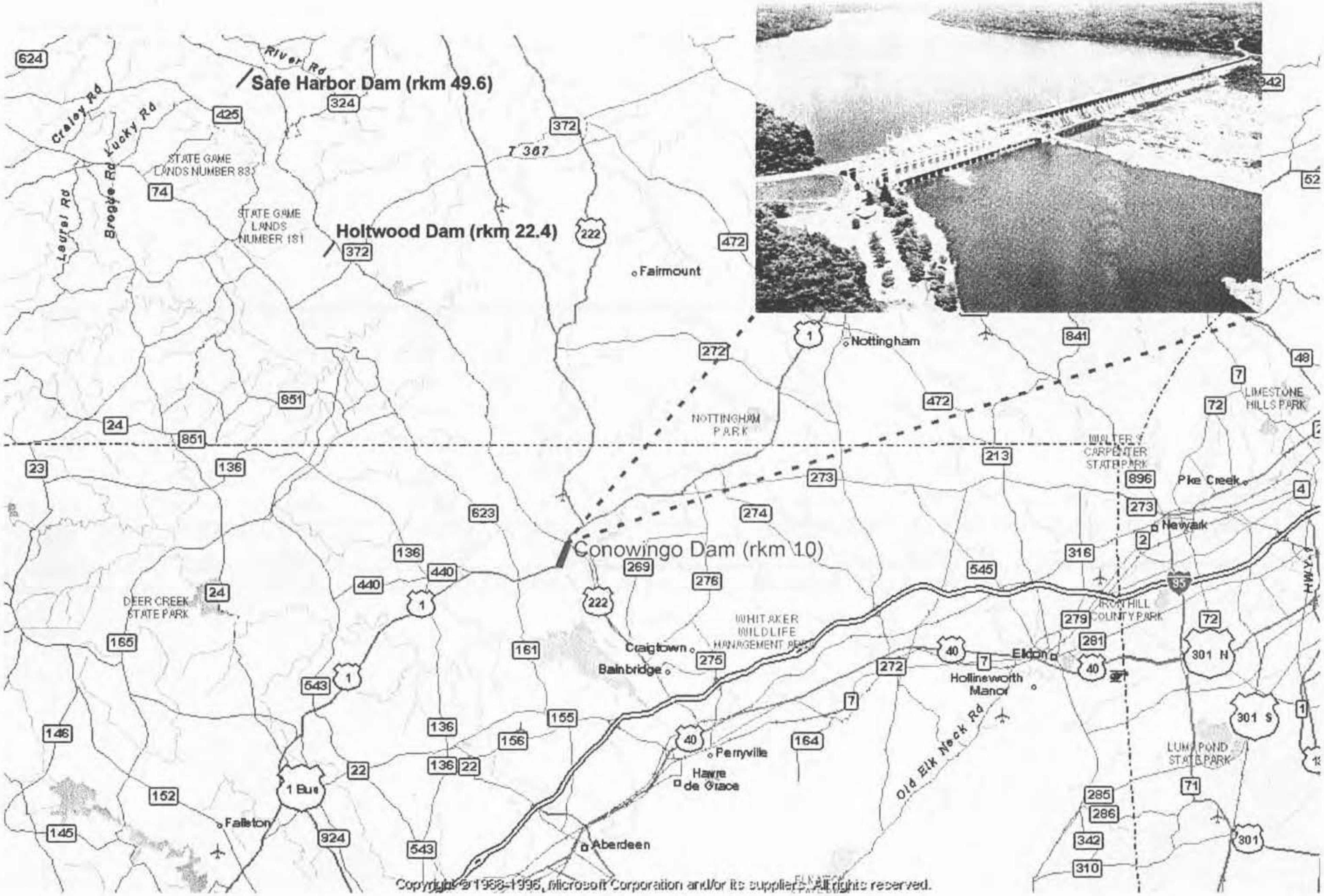
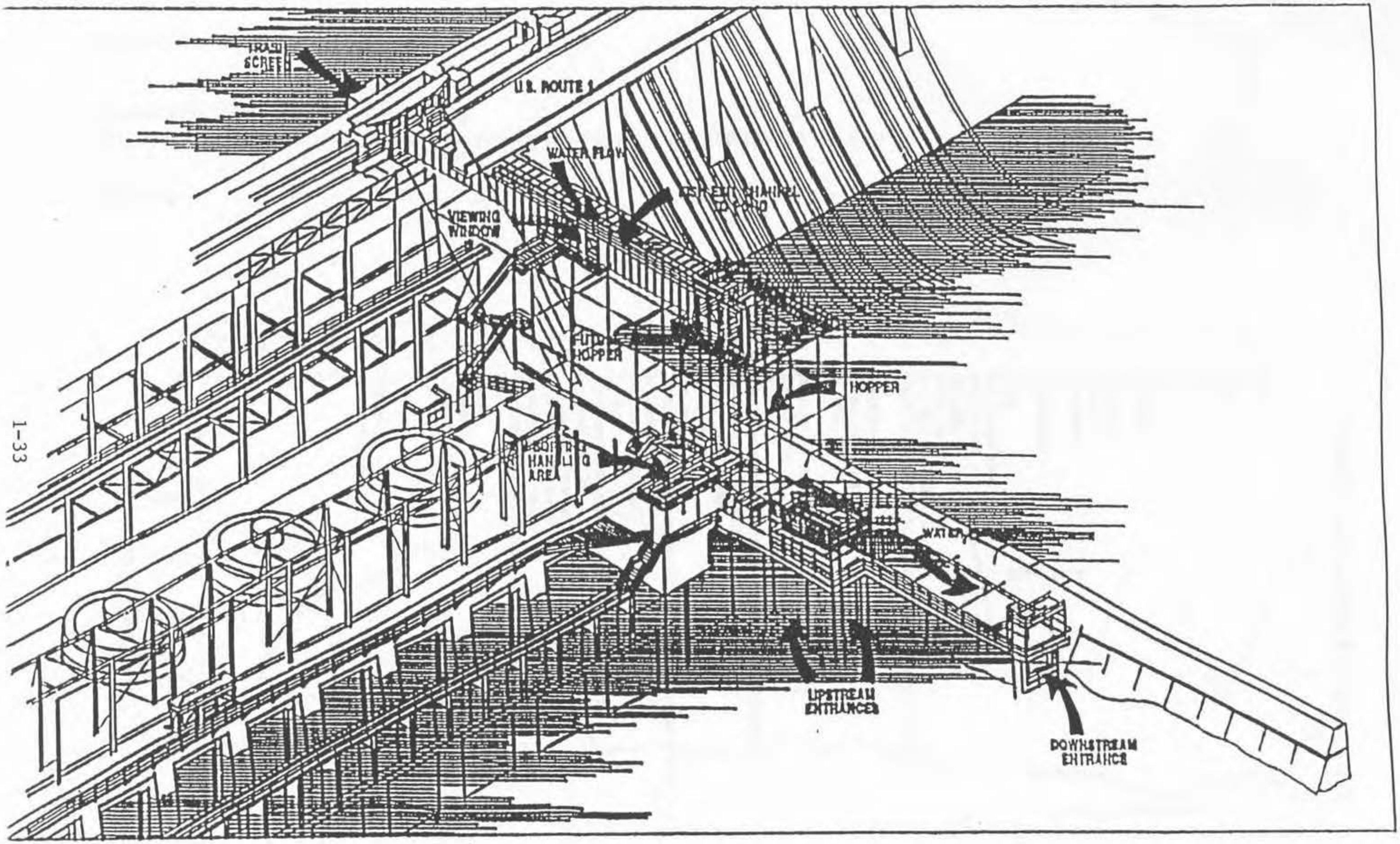


Figure 1

General location of the Conowingo Dam, Susquehanna River.



igure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

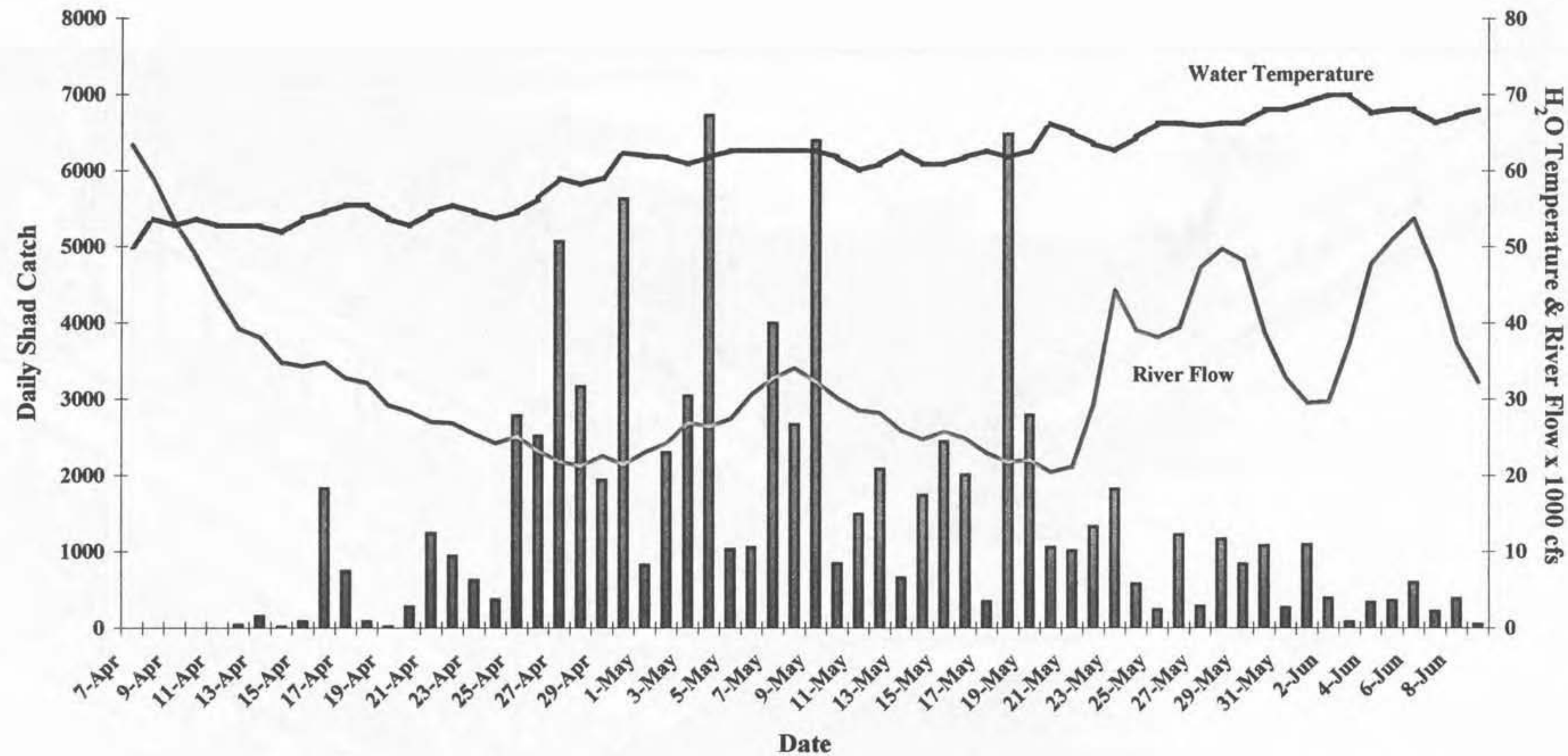


Figure 3

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Conowingo East Fish Lift, spring 1997.

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Job I - Part 2
Summary of Conowingo Dam West Fish Lift Operations - 1997

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Introduction

The shore-based trapping device at Conowingo Dam known as the West fish lift has operated every spring since 1972 for the purpose of collecting and counting American shad, river herring, other migratory species and resident fishes in the tailrace. Since 1985, most shad collected here have been sorted from the daily catch, placed into circular transport tanks, and stocked into suitable spawning waters above the mainstem hydroelectric dams. During the spring runs of 1991 through 1996 the newer East fish lift at Conowingo Dam also served this same primary purpose.

With completion of fish elevators at the upstream Holtwood and Safe Harbor dams, the Conowingo East lift was operated to enable passage of all fish into the project head pond in 1997 (see Job I, part 1). Under terms of the 1993 settlement agreement which resulted in the Holtwood and Safe Harbor fish passage construction, upstream licensees are no longer obligated to pay for trap and transport activities from Conowingo Dam. However, in negotiations with the Susquehanna River Technical Committee (SRTC), Susquehanna Electric Company (SECO) did agree to rehabilitate the aging West lift, to keep it operational for five years after cessation of East lift sorting and trucking, to provide a lift operator, and to administer an annual contract in coordination with the resource agencies for West lift trapping operations.

Funding to reimburse SECO for contractor expenses (about $135,000 in 1997) is derived from several sources including utility carryover monies from the 1984 settlement agreement, the EPA Chesapeake Bay Program, PA Fish and Boat Commission, and Maryland DNR. These contributed funds are administered by the U.S. Fish and Wildlife Service's Susquehanna River Coordinator.

The objectives of Conowingo West lift operations in 1997 included collection and enumeration of shad, river herring, other migratory and resident fishes; sorting and transportation of 10,000 shad to the mainstem above York Haven Dam and 10,000 river herring to select tributaries; providing live shad for Maryland DNR tank spawning and other approved purposes; recording of DNR tags, sex ratios and archiving scale samples; and sacrificing shad samples for otolith analysis.

Methods

In order to stay within the designated budget several operational adjustments were adopted by the SRTC. These included (1) limiting the period of operation to the peak six weeks of the run (late April through the first week in June); (2) limiting daily lift operations to 8 hours (1100-1900 hrs.); and, (3) operation of only three transport units with seasonal stocking targets of 10,000 shad and 10,000 herring. Within these parameters the West lift was operated as it has in past years, maintaining appropriate entrance velocities and curbing use of adjacent units 1 and 2 whenever river flow dropped below 60,000 cfs.

Normandeau Associates, Inc. (NAI) was contracted by SECO to operate both Conowingo fish lifts and to arrange for appropriate transport and stocking from the West lift. At the time of the pre-selected start date of April 24th, 6,000 shad had already passed the East lift and water temperature had warmed to 12.3°C. Operations continued daily through June 6 with 10-18 lifts per day. NAI used a PC-based data management and reporting system which has been described in earlier SRAFRC reports.

Shad and herring collected in the trap were counted and placed into holding tanks. When sufficient numbers were available, typically 100-200 shad and/or 500-1000 herring, these were loaded into truck-mounted 1,000 gallon circular transport tanks and hauled to stocking sites. Shad were stocked at Tri-County Marina at Middletown, PA and herring were placed both at Tri-County and in three tributaries, the Conestoga River, Little Conestoga Creek and Conodoguinet Creek. Fish that died during transport were recovered at the stocking site upon release. Delayed transport mortalities were recovered at Tri-County five times each week during the stocking season. Live shad were also provided to Maryland DNR for tank spawning on nine occasions, and to New Jersey Aquarium twice.

Every 50th shad in the West lift collection was sacrificed for its otoliths. In addition, a scale sample was taken. The sex ratio of shad was determined from daily subsamples ranging from about 60-160 fish and totalling 4,531 fish, 35% of the catch.

Results

During the period April 24 through June 6, the West lift operated for 44 consecutive days making 611 separate lifts with a total fishing time of 295 hours. Total catch amounted to 345,983 fish representing 39 taxa (Table 1). During this operational period average daily water temperature gradually rose from 12.3 to 20.8°C and river flows remained unusually low, exceeding 40,000 cfs on only six days (Figure 1).

American shad - A total of 12,974 American shad were collected at the West lift in 1997. Catch ranged without trend from 45 to 936 fish with a daily average of 295 shad (Table 2). Sex ratios switched from as high as 4:1 favoring males in the early and middle parts of the run to about 1:1 at the end of the run. For the season male/female sex ratio was 1.9:1. A total of 64 Maryland DNR first time 1997 tags were collected.

Most shad, 10,528, were transported and stocked at Tri-County Boat Club in Middletown, PA. Typical truckloads included 150-180 fish early in the season and 100-150 late in the season as water temperature warmed. Only 26 trucking mortalities were observed at the time of stocking and an additional 27 dead shad were later recovered at the release site. One hundred eighty-five shad were delivered to Safe Harbor forebay, 115 were provided to the New Jersey Aquarium, and Maryland DNR hauled 1,139 shad to Manning Hatchery for tank spawning. The upstream stocking summary is shown in Table 3. A total of 257 shad were sacrificed for otolith extraction by PA Fish and Boat Commission.

River herring - Herring catch in 1997 amounted to 11 alewives (all in the first 4 days of operation) and 133,257 bluebacks. Blueback abundance was extremely variable with 3,000 or more herring taken on 15 dates between April 29 and May 26. The peak 7-day collection period was May 13-19 with 60,200 fish. A total of 27,783 blueback herring were stocked at upstream locations with an observed transport mortality of only 47 fish (Table 4). New Jersey Aquarium took 1,016 herring for display. Specific Susquehanna River and tributary stocking numbers and sites were:

4/29-5/4	Little Conestoga	2,956 fish
4/30-5/7	Conestoga River	3,152 fish
5/8-5/10	Conodoguinet Cr.	5,003 fish
4/29-5/26	Tri-County Marina	16,672 fish

Other species - A total of 118 hickory shad were collected at the West lift with most of them occurring on four consecutive days - April 28 through May 1. The 2,665 striped bass handled at the West lift in 1997 mostly occurred after May 9 in relatively small numbers of 20-200 fish per day. Other common species included gizzard shad (126,570), white perch (58,685), shorthead redhorse (3,134), and common carp (2,281). These species, along with alosids and stripers comprised over 98% of the total catch of 345,983 fish taken in 1997.

Discussion

Although the 1997 West lift season was shortened by design due to funding constraints, all objectives of the program were met or exceeded. The relatively high and uniform catch of target species in the West lift in 1997 was enhanced by consistently low river flows throughout the season which improved attraction efficiency.

Catch per effort of about 44 shad per trap fishing hour was the second highest capture rate recorded at this facility, exceeded only by the shortened and concentrated 1996 season (Table 5). Blueback herring abundance was the largest season total recorded since the early 1970s but alewife catch was at a near record low. Lack of alewife in the catch is largely related to the late season start of West lift operations. Although shad and blueback herring numbers were high, total catch of fish at the West lift was the second lowest recorded since 1985 (Table 6) due to the relative paucity of gizzard shad numbers.

Shad catch of 12,974 fish in 44 trap days might suggest a somewhat average year as this number has been exceeded on three occasions. But unlike all past years, passage effectiveness was greatly enhanced at the East lift in 1997 (no sorting or loading), and overall shad abundance in the Conowingo tailrace was probably at an all time high. Based on analysis of 250 otoliths, hatchery-marked shad comprised 40% of the 1997 run, the lowest such fraction recorded since 1989. Of the total shad collected, 83% were hauled to upstream spawning waters above York Haven Dam with an observed mortality rate of less than 0.5%. Blueback herring upstream stocking comprised 21% of the total collection and was limited only by availability of trucks and cost constraints.

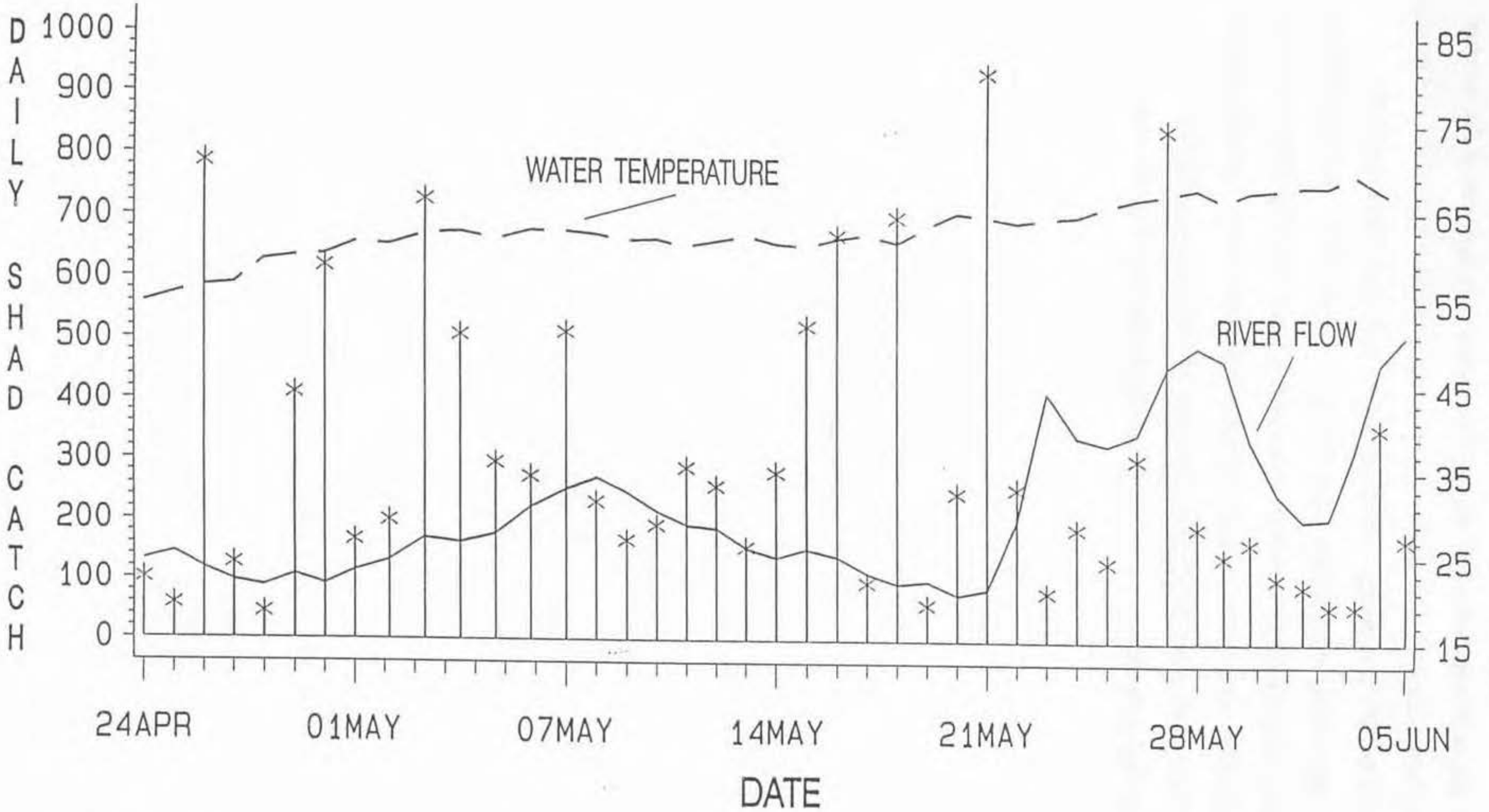

FIGURE 1

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, 1997.

TABLE 1. CATCH OF FISHES AT THE CONOWINGO DAM WEST FISH LIFT, 24 APRIL THROUGH 6 JUNE 1997.

OF DAYS	44
NO. OF LIFTS	611
OPERATING TIME (HRS)	348.6
FISHING TIME (HRS)	295.1
NO. OF TAXA	39
American eel	110
BLUEBACK HERRING	133257
HICKORY SHAD	118
ALEWIFE	11
AMERICAN SHAD	12974
GIZZARD SHAD	126570
Rainbow trout	1
Brown trout	14
Muskellunge	2
Common carp	2281
Golden shiner	1
Comely shiner	576
Spottail shiner	1041
Spotfin shiner	1
Quillback	780
White sucker	7
Shorthead redhorse	3134
White catfish	140
Yellow bullhead	37
Brown bullhead	27
Channel catfish	977
White perch	58685
STRIPED BASS	2665
Rock bass	280
Redbreast sunfish	430
Green sunfish	6
Pumpkinseed	51
Bluegill	277
Smallmouth bass	251
Largemouth bass	55
White crappie	30
Black crappie	19
Tessellated darter	5
Yellow perch	102
Walleye	1063
Atlantic needlefish	1
Sea lamprey	2
Striped bass x white bass	1
Greenside darter	1
TOTAL	345983

TABLE 2. DAILY SUMMARY OF FISHES COLLECTED AT THE CONOWINGO DAM WEST LIFT, 24 APRIL THROUGH 6 JUNE 1997.

DATE	24APR	25APR	26APR	27APR	28APR	29APR	30APR	01MAY	02MAY	03MAY
NO OF LIFTS	13	15	10	14	14	12	10	14	14	12
FIRST LIFT	11:02	11:08	11:10	10:52	11:20	11:08	11:15	11:12	10:48	11:20
LAST LIFT	18:45	19:00	19:00	18:55	18:58	19:00	18:45	18:50	18:55	19:22
OPERATING TIME (HRS)	7.7	7.9	7.8	8.1	7.6	7.9	7.5	7.6	8.1	8.0
FISHING TIME (HRS)	6.4	6.7	7.0	6.7	6.5	7.0	7.1	6.7	7.0	6.0
AVG WATER TEMP (C)	12.3	12.9	13.4	13.5	15.0	15.2	15.4	16.1	.	16.7
BLUEBACK HERRING					42	3479	4810	1323	4	3137
HICKORY SHAD					1	65	27	4		
ALEWIFE	1		1	9						
AMERICAN SHAD	101	58	783	127	45	412	620	167	200	728
GIZZARD SHAD	1935	6060	2140	1957	2045	14690	2470	723	2460	4753
COMMON CARP						6				
STRIPED BASS					2			3		2
OTHER SPP	182	335	171	221	700	185	693	1036	2081	977
TOTAL	2219	6453	3095	2314	2835	18837	8620	3256	4745	9597

DATE	04MAY	05MAY	06MAY	07MAY	08MAY	09MAY	10MAY	11MAY	12MAY	13MAY
NO OF LIFTS	14	16	16	14	14	15	14	14	14	14
FIRST LIFT	10:50	11:08	11:02	11:00	11:17	10:57	11:00	10:55	11:07	11:06
LAST LIFT	18:50	18:50	19:04	18:55	18:55	18:50	18:50	18:50	18:55	18:50
OPERATING TIME (HRS)	8.0	7.7	8.0	7.9	7.6	7.9	7.8	7.9	7.8	7.7
FISHING TIME (HRS)	6.7	6.5	7.0	6.8	6.6	6.8	6.8	6.7	6.3	6.8
AVG WATER TEMP (C)	16.8	16.4	16.9	16.9	16.7	16.3	16.4	16.0	16.3	16.7
BLUEBACK HERRING	840	22	400	3095	10488	2324	1842	1180	1879	4989
HICKORY SHAD								1	3	5
ALEWIFE										
AMERICAN SHAD	509	297	274	514	232	167	193	289	258	156
GIZZARD SHAD	4630	9047	2970	865	4760	3335	4115	1591	5767	3035
COMMON CARP	5	23	113							
STRIPED BASS	1	7	14	5	36	138	32	36	50	81
OTHER SPP	2439	2324	6349	3146	766	2266	2813	3701	3612	4865
TOTAL	8424	11720	10120	7625	16282	8230	8995	6798	11569	13131

TABLE 2. CONTINUED.

DATE	14MAY	15MAY	16MAY	17MAY	18MAY	19MAY	20MAY	21MAY	22MAY	23MAY
NO OF LIFTS	14	15	15	17	18	12	16	12	15	10
FIRST LIFT	10:55	10:50	11:00	11:03	7:57	11:00	10:53	11:00	10:48	10:55
LAST LIFT	18:50	18:55	18:55	18:15	18:45	18:55	18:55	18:35	18:55	19:00
OPERATING TIME (HRS)	7.9	8.1	7.9	7.2	10.8	7.9	8.0	7.6	8.1	8.1
FISHING TIME (HRS)	6.6	7.1	7.5	6.3	8.8	7.0	6.6	6.1	6.9	4.0
AVG WATER TEMP (C)	16.2	16.0	16.5	16.8	16.3	17.3	18.2	17.9	17.6	17.8
BLUEBACK HERRING	3865	3245	8815	19400	14550	5329	350	1300	2905	4028
HICKORY SHAD										
ALEWIFE										
AMERICAN SHAD	281	525	672	97	702	60	248	936	256	82
GIZZARD SHAD	1685	1739	385	196	4840	618	2510	904	1255	1408
COMMON CARP							64		1	
STRIPED BASS	14	52	14	71	211	181	70	94	145	94
OTHER SPP	999	2326	1766	442	4540	3000	8208	368	622	618
TOTAL	6844	7887	11652	20206	24843	9188	11450	3602	5184	6230

DATE	24MAY	25MAY	26MAY	27MAY	28MAY	29MAY	30MAY	31MAY	01JUN	02JUN
NO OF LIFTS	14	15	16	15	12	15	15	15	15	12
FIRST LIFT	11:00	10:57	10:50	11:20	11:00	11:00	11:01	10:43	10:57	10:52
LAST LIFT	18:55	18:35	19:00	18:17	18:50	18:50	18:50	19:00	18:55	18:55
OPERATING TIME (HRS)	7.9	7.6	8.2	7.0	7.8	7.8	7.8	8.3	8.0	8.1
FISHING TIME (HRS)	6.8	6.5	7.0	6.9	5.4	6.6	6.4	7.2	6.8	7.1
AVG WATER TEMP (C)	18.0	18.7	19.1	19.4	19.8	19.0	19.7	19.8	20.0	20.0
BLUEBACK HERRING	1880	3305	10900	30	250	2221	1190	928	1704	2710
HICKORY SHAD										
ALEWIFE										
AMERICAN SHAD	190	133	306	846	193	144	167	108	95	60
GIZZARD SHAD	4110	2580	614	8050	2435	1395	3985	2713	867	758
COMMON CARP	1			1230	704	9	3	45	4	19
STRIPED BASS	108	72	100	22	76	215	118	142	107	69
OTHER SPP	441	255	333	800	440	463	675	388	422	457
TOTAL	6730	6345	12253	10978	4098	4447	6138	4324	3199	4073

TABLE 2. CONTINUED.

DATE	03JUN	04JUN	05JUN	06JUN	Total
NO OF LIFTS	11	13	13	13	611
FIRST LIFT	10:50	10:57	10:52	10:52	.
LAST LIFT	18:45	18:50	18:50	18:55	.
OPERATING TIME (HRS)	7.9	7.9	8.0	8.1	348.6
FISHING TIME (HRS)	7.0	6.9	7.0	6.9	295.1
AVG WATER TEMP (C)	20.8	19.8	19.0	18.5	.
BLUEBACK HERRING	1730	743	1898	127	133257
HICKORY SHAD			12		118
ALEWIFE					11
AMERICAN SHAD	60	360	173	150	12974
GIZZARD SHAD	243	944	717	2271	126570
COMMON CARP	2	9	4	39	2281
STRIPED BASS	54	96	52	81	2665
OTHER SPP	308	566	360	448	68107
TOTAL	2397	2718	3216	3116	345983

Table 3 Summary of American shad transported from the Conowingo Dam West Fish Lift, 1997.

DATE	NO. COLLECTED	WATER TEMP (C)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (C) AT STOCKING LOCATION
26APR	783	15.0	161	Tri-County Marina	0	100.0	13.8	14.2	15.0
		14.9	177	Tri-County Marina	1	99.4	9.8	15.6	16.0
		15.0	173	Tri-County Marina	0	100.0	10.0	13.6	16.0
		14.2	165	Tri-County Marina	1	99.4	14.0	12.2	15.8
27APR	127	13.9	144	Tri-County Marina	0	100.0	18.4	13.9	15.5
29APR	412	15.5	114	Tri-County Marina	0	100.0	12.0	11.0	15.8
30APR	620	15.8	147	Tri-County Marina	0	100.0	12.5	13.4	16.0
		16.2	175	Tri-County Marina	0	100.0	12.0	11.8	17.5
		16.0	168	Tri-County Marina	0	100.0	15.0	12.0	17.0
30APR	620	16.1	159	Tri-County Marina	0	100.0	17.5	11.0	17.0
01MAY	167	16.3	131	Tri-County Marina	0	100.0	15.5	10.2	16.9
02MAY	200	17.2	157	Tri-County Marina	1	99.4	13.2	10.8	17.0
		17.0	163	Tri-County Marina	1	99.4	13.0	10.8	17.0
		17.3	167	Tri-County Marina	1	99.4	15.8	9.2	16.2
		17.2	180	Tri-County Marina	0	100.0	13.9	10.5	16.8
		17.1	158	Tri-County Marina	0	100.0	14.8	14.4	17.2
04MAY	509	17.0	175	Tri-County Marina	0	100.0	13.8	13.2	17.1
		17.5	179	Tri-County Marina	3	98.3	13.3	11.1	16.1
05MAY	297	17.0	175	Tri-County Marina	0	100.0	11.0	12.0	15.2
06MAY	274	17.5	150	Tri-County Marina	0	100.0	13.9	11.2	16.3
		18.0	118	Tri-County Marina	0	100.0	13.1	10.5	16.0
07MAY	514	18.0	175	Tri-County Marina	0	100.0	15.6	13.8	17.0
		17.2	174	Tri-County Marina	0	100.0	13.0	15.0	17.0
		17.8	140	Tri-County Marina	1	99.3	12.0	11.9	15.9
08MAY	232	17.0	154	Tri-County Marina	0	100.0	17.2	13.8	17.0
		16.0	55	Tri-County Marina	2	96.4	9.5	10.4	13.5
09MAY	167	16.2	130	Tri-County Marina	0	100.0	15.2	11.7	14.2
		16.8	30	Tri-County Marina	0	100.0	10.5	10.0	14.0
10MAY	193	17.1	86	Tri-County Marina	0	100.0	13.1	11.6	13.9
		16.5	98	Tri-County Marina	0	100.0	15.0	13.0	14.4
11MAY	289	17.2	44	Tri-County Marina	0	100.0	10.5	12.2	15.5
		17.2	48	Tri-County Marina	0	100.0	12.8	11.6	16.0
12MAY	258	17.0	56	Tri-County Marina	0	100.0	17.2	12.0	17.0
		17.1	93	Tri-County Marina	1	98.9	13.2	12.6	17.5
		16.5	89	Tri-County Marina	0	100.0	16.0	9.0	15.5
13MAY	156	17.5	36	Tri-County Marina	0	100.0	12.2	14.2	16.0
		17.2	22	Tri-County Marina	0	100.0	13.2	11.4	15.9
		17.2	60	Tri-County Marina	0	100.0	12.2	10.0	15.5
		17.5	28	Tri-County Marina	0	100.0	13.5	10.8	15.2
14MAY	281	17.0	76	Tri-County Marina	0	100.0	11.6	14.2	17.0
		17.0	155	Tri-County Marina	0	100.0	15.0	12.4	16.0
		16.8	42	Tri-County Marina	0	100.0	13.5	10.5	15.9
15MAY	525	16.0	175	Tri-County Marina	0	100.0	12.2	15.2	16.0
		17.0	99	Tri-County Marina	1	99.0	12.0	14.3	16.2
		17.0	150	Tri-County Marina	1	99.3	15.0	14.0	16.0
		15.6	74	Tri-County Marina	0	100.0	15.0	12.8	15.2

Table 3. Summary of American shad transported from the Conowingo Dam West Fish Lift, 1997.

(continued)

DATE	NO. COLLECTED	WATER TEMP (C)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (C) AT STOCKING LOCATION
16MAY	672	17.0	45	Tri-County Marina	0	100.0	12.7	12.5	16.2
		17.1	177	Tri-County Marina	0	100.0	15.8	12.2	16.5
		16.8	175	Tri-County Marina	1	99.4	17.4	12.0	16.0
		16.8	143	Tri-County Marina	0	100.0	14.5	11.8	16.0
		16.8	111	Tri-County Marina	0	100.0	12.8	11.2	16.0
17MAY	97	17.1	94	Tri-County Marina	0	100.0	15.9	11.0	16.0
18MAY	702	17.5	169	Tri-County Marina	0	100.0	12.0	13.6	16.8
		17.9	185	Tri-County Marina	0	100.0	12.2	11.8	17.5
		17.2	145	Tri-County Marina	0	100.0	14.2	11.8	16.2
19MAY	60	17.0	2	Tri-County Marina	0	100.0	11.0	14.4	18.5
		18.9	13	Tri-County Marina	0	100.0	15.8	13.4	19.5
		17.5	43	Tri-County Marina	0	100.0	11.8	12.0	17.8
20MAY	248	20.0	161	Tri-County Marina	0	100.0	14.8	11.2	20.0
21MAY	936	19.2	180	Tri-County Marina	0	100.0	12.8	12.6	19.0
		19.0	177	Tri-County Marina	0	100.0	11.8	11.2	18.5
		18.2	180	Tri-County Marina	1	99.4	10.8	11.0	17.2
		18.5	180	Tri-County Marina	2	98.9	14.2	9.4	17.5
22MAY	256	19.0	172	Tri-County Marina	0	100.0	14.2	10.0	18.0
		18.4	72	Tri-County Marina	0	100.0	14.8	10.4	17.0
23MAY	82	19.0	76	Tri-County Marina	0	100.0	13.0	11.0	18.0
24MAY	190	19.0	162	Tri-County Marina	2	98.8	9.0	11.0	20.0
25MAY	133	19.0	121	Tri-County Marina	0	100.0	15.5	8.0	18.0
26MAY	306	20.0	184	Tri-County Marina	1	99.5	13.0	8.0	19.0
		19.9	90	Tri-County Marina	0	100.0	13.7	8.4	18.7
27MAY	846	20.0	186	Tri-County Marina	0	100.0	11.3	9.7	18.5
		20.6	183	Tri-County Marina	1	99.5	12.5	10.2	19.0
		20.0	193	Tri-County Marina	1	99.5	11.2	9.4	19.0
		19.8	181	Tri-County Marina	0	100.0	8.8	9.0	18.1
28MAY	193	20.2	20	Safe Harbor Forebay	0	100.0	12.0	11.0	20.0
		21.0	117	Tri-County Marina	0	100.0	20.0	12.4	21.0
29MAY	144	20.0	142	Tri-County Marina	1	99.3	14.2	9.8	18.2
30MAY	167	21.0	151	Tri-County Marina	0	100.0	12.8	18.4	18.2
31MAY	108	20.1	87	Tri-County Marina	0	100.0	13.0	10.0	20.0
01JUN	95	20.8	76	Tri-County Marina	0	100.0	11.8	8.1	20.8
02JUN	60	20.5	49	Tri-County Marina	1	98.0	10.5	8.0	18.4
03JUN	60	21.0	51	Tri-County Marina	0	100.0	13.4	8.6	15.0
04JUN	360	20.0	124	Tri-County Marina	0	100.0	13.0	9.0	16.9
		20.0	103	Tri-County Marina	0	100.0	13.6	9.8	16.0
05JUN	173	20.5	165	Safe Harbor Forebay	0	100.0	11.2	10.0	20.0
		21.0	90	Tri-County Marina	1	98.9	13.4	8.8	18.0
06JUN	150	20.1	113	Tri-County Marina	0	100.0	13.5	8.8	18.9
LOCATION			10713		26				

Table 4. Summary of transports of river herring from the Conowingo Dam West Fish Lift, 24 April through 6 June, 1997.

DATE	SPECIES	NO. COLLECTED	WATER TEMP (C)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (C) AT STOCKING LOCATION
26APR	ALEWIFE	1	15.0	1	Tri-County Marina	0	100.0	10.0	13.6	16.0
29APR	BLUEBACK HERRING	3479	15.0	1000	Little Contestoga Cr	0	100.0	16.0	15.8	16.8
			15.5	289	Tri-County Marina	0	100.0	12.0	11.0	15.8
30APR	BLUEBACK HERRING	4810	15.8	982	Conestoga Hartmann & Lapp	9	99.1	12.0	12.4	16.0
			15.8	103	Tri-County Marina	0	100.0	12.5	13.4	16.0
			16.2	1170	Conestoga Hartmann & Lapp	1	99.9	14.2	14.1	17.2
01MAY	BLUEBACK HERRING	1323	16.2	910	Little Contestoga Cr	5	99.5	15.2	9.9	15.9
			16.3	79	Tri-County Marina	0	100.0	15.5	10.2	16.9
02MAY	BLUEBACK HERRING	4	17.2	2	Tri-County Marina	0	100.0	13.2	10.8	17.0
04MAY	BLUEBACK HERRING	840	17.5	1046	Little Contestoga Cr	7	99.3	11.2	11.5	15.0
			17.0	12	Tri-County Marina	0	100.0	13.8	13.2	17.1
06MAY	BLUEBACK HERRING	400	17.5	90	Tri-County Marina	0	100.0	13.9	11.2	16.3
			18.0	144	Tri-County Marina	0	100.0	13.1	10.5	16.0
07MAY	BLUEBACK HERRING	3095	17.0	1000	Conestoga Hartmann & Lapp	0	100.0	14.0	12.0	15.0
08MAY	BLUEBACK HERRING	10488	17.0	900	Conodoguinet Cr	5	99.4	16.0	14.0	14.0
			16.9	1003	Conodoguinet Cr	2	99.8	15.4	11.9	14.1
			16.0	110	Tri-County Marina	0	100.0	9.5	10.4	13.5
09MAY	BLUEBACK HERRING	2324	17.0	1000	Conodoguinet Cr	4	99.6	18.2	12.4	17.2
			16.7	1100	Conodoguinet Cr	2	99.8	12.5	13.3	14.7
			16.2	243	Tri-County Marina	1	99.6	15.2	11.7	14.2
			16.8	494	Tri-County Marina	1	99.8	10.5	10.0	14.0
10MAY	BLUEBACK HERRING	1842	16.5	1000	Conodoguinet Cr	1	99.9	15.0	12.8	13.5
			17.1	679	Tri-County Marina	0	100.0	13.1	11.6	13.9
10MAY	BLUEBACK HERRING	1842	16.5	163	Tri-County Marina	0	100.0	15.0	13.0	14.4
11MAY	BLUEBACK HERRING	1180	17.2	911	Tri-County Marina	0	100.0	10.5	12.2	15.5
			17.2	162	Tri-County Marina	0	100.0	12.8	11.6	16.0
12MAY	BLUEBACK HERRING	1879	17.0	772	Tri-County Marina	0	100.0	17.2	12.0	17.0
			17.1	663	Tri-County Marina	3	99.5	13.2	12.6	17.5
			16.5	444	Tri-County Marina	1	99.8	16.0	9.0	15.5
13MAY	BLUEBACK HERRING	4989	17.5	1000	Tri-County Marina	1	99.9	12.2	14.2	16.0
			17.2	1060	Tri-County Marina	0	100.0	13.2	11.4	15.9
			17.2	884	Tri-County Marina	0	100.0	12.2	10.0	15.5
			17.5	679	Tri-County Marina	0	100.0	13.5	10.8	15.2
14MAY	BLUEBACK HERRING	3865	17.0	775	Tri-County Marina	1	99.9	11.6	14.2	17.0
			17.0	110	Tri-County Marina	0	100.0	15.0	12.4	16.0
			16.8	900	Tri-County Marina	1	99.9	13.5	10.5	15.9
15MAY	BLUEBACK HERRING	3245	17.0	590	Tri-County Marina	1	99.8	12.0	14.3	16.2
			15.6	424	Tri-County Marina	0	100.0	15.0	12.8	15.2
16MAY	BLUEBACK HERRING	8815	17.0	1000	Tri-County Marina	0	100.0	12.7	12.5	16.2
			16.8	400	Tri-County Marina	1	99.8	12.8	11.2	16.0
17MAY	BLUEBACK HERRING	19400	17.1	500	Tri-County Marina	0	100.0	15.9	11.0	16.0
19MAY	BLUEBACK HERRING	5329	17.0	1000	Tri-County Marina	0	100.0	11.0	14.4	18.5
			18.9	1000	Tri-County Marina	0	100.0	15.8	13.4	19.5
			17.5	579	Tri-County Marina	0	100.0	11.8	12.0	17.8
22MAY	BLUEBACK HERRING	2905	18.4	200	Tri-County Marina	0	100.0	14.8	10.4	17.0
			19.9	210	Tri-County Marina	0	100.0	13.7	8.4	18.7
TOTAL				27783		47				

Table 5. Conowingo West Fish Lift Catch and Effort of American Shad during Primary Collection Periods in 1985-1997.

Year	No. Lifts	Fishing Hrs.	No. Shad	Shad/Hour
1985	839	328.6	1,518	4.6
1986	737	431.5	5,136	11.9
1987	1295	506.5	7,659	15.1
1988	1166	471.7	5,137	10.9
1989	1034	447.2	8,216	18.4
1990	1247	541.0	15,958	29.5
1991	1123	478.5	13,273	27.7
1992	1517	566.0	10,323	18.2
1993	971	398.0	5,328	13.4
1994	918	414.0	5,595	13.5
1995	1216	632.2	15,588	24.7
1996	441	245.2	11,458	46.7
1997	**611**	**295.1**	**12,974**	**43.8**

Table 6. Operations and Fish Catch at Conowingo West Lift, 1985-1997

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

JOB I - Part 3

SUMMARY OF OPERATION AT THE HOLTWOOD FISH PASSAGE FACILITY IN 1997

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INTRODUCTION

On June 1, 1993 representatives of PPL, Inc. (PPL), two upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed Holtwood, Safe Harbor, and York Haven Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. A major element of this agreement was for PPL, the owner/operator of the Holtwood Hydroelectric Project (Holtwood), to construct and place in operation a fishway, including spillway and tailrace lifts, by April 1, 1997. This agreement was reached based on numerous factors including, but not limited to, an increasing Susquehanna River American shad (*Alosa sapidissima*) population and completion of a permanent fish passage facility at Conowingo Dam in 1991.

The Holtwood fish passage facility has both upstream and downstream passage capabilities. The upstream facility includes a tailrace and spillway lift. It was designed according to United States Fish and Wildlife Service (USFWS) guidelines and specifications which resulted from extensive study, design review, hydraulic modeling, and discussion(s) with resource agencies. Although construction of the lifts began in April 1995, operation in 1997 would not have been possible without a major commitment by PPL. A 100 year flood that began on January 20, 1996 caused extensive damage to the fish passage project and resulted in a six month delay to construction. As a result of PPL's commitment, fishway operation started at the beginning of the 1997 spring spawning migration as scheduled.

On March 21, prior to the start of fishway operation, a meeting of the Holtwood Fish Passage Technical Advisory Committee (FPTAC) comprised of PPL, USFWS, Maryland Department of Natural Resources (MDDNR), and the Pennsylvania Fish and Boat Commission (PFBC) representatives was held by PPL at Holtwood. The meeting included an updated construction schedule, a tour of the fishway, and discussions and consensus on operation of the fishway during the 1997 spring migration season. Objectives of 1997 operation were: (1) monitor passage of migratory and resident fishes through the newly installed fishway; and (2) assess fishway efficiency and effectiveness and make modifications as feasible.

HOLTWOOD OPERATIONS

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (Figure 1). It is the second upstream hydroelectric facility on the river. The project consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, a powerhouse with ten turbine units with a combined generating capacity of 102 MW, and a reservoir of 2,400 acres surface area. Each unit is capable of passing approximately 3,000 cfs. Natural river flows in excess of 32,000 cfs are spilled over the dam.

Fishway design at Holtwood incorporated numerous criteria established by the USFWS and the resource agencies. Physical design parameters for the lift included: (1) tailrace and spillway lifts with a cycle time of 10 minutes; (2) operation of the tailrace lift at tailwater elevations between 104 ft and 122 ft and spillway lift operation at tailwater elevations between 114 ft and 138 ft; (3) three adjustable entrances from which water velocity was adjustable to 5 or 6 ft/sec; (4) a total of 800 cfs attraction flow; (5) a river flow operating limit of 150,000 cfs; and (6) operation at forebay water elevations between 165 ft and 174 ft. In addition, the fishway was sized to pass a design population of 2.7 million American shad and 10 million river herring.

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (Figure 2). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system which includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into the trough through which fish swim into Lake Aldred. Attraction flow, in, through, and from the lifts is supplied through a piping system and five diffusers that are gravity fed from two trough intakes. Generally, water conveyance and attraction flow is controlled by regulating the three entrance gates and seven motor operated valves. Fish that enter the tailrace and/or spillway entrances are attracted by water flow into the mechanically operated crowder chambers. Once inside, fish are crowded over the hopper(s) (6,700 gal capacity). Fish are then lifted in the hopper(s) and sluiced into the trough. Fish swim upstream through a counting facility and into the forebay through a pre-existing 14 ft wide debris chute. Since the trough was attached to the debris chute it was designed with debris sluicing capabilities.

Two inflatable rubber dams were installed during fishway construction to enhance the effectiveness of the spillway lift. A 40 ft long, 10 ft high rubber crest dam was installed on the east end of the dam crest adjacent to the exit of the trough. A 300 ft long, 4 ft 9 in high rubber crest dam was installed adjacent to the 10 ft high rubber crest dam section to assist with control spill and improve conditions in the east spillway channel.

Conceptual design guidelines for fishway operation included three entrance combinations. They were: (1) entrance A, B, and C; (2) entrance A and B; and (3) entrance C. Construction delays and equipment availability problems resulted in the development of a guideline for 1997 that utilized a combination of entrance A and C.

Fish Lift Operation

The 1997 operation of the Holtwood fishway was managed in a flexible fashion due to the dynamic nature of conditions experienced. Fishway operation occurred with and around the completion of numerous construction activities and punch list items. Daily management by PPL ensured that construction activities and mechanical and electrical problems that were encountered were dealt with in a fashion so interruptions to fishway operation were minimized. Fishway operation was conducted by a staff of three people including a lift operator and supervising biologist who received fishway training on 1 and 2 April, and a biological technician who counted fish.

Fishway operation began on April 18 when the tailrace lift was placed in service. The spillway lift was placed in service on April 21 and both lifts operated daily through May 20. The fishway was shut down from 21 to 23 May due to structural problems that resulted from screen clogging by maple seeds. Operation resumed on May 24 and continued daily through June 14. The fishway was operated from 1100 hrs to 1900 hrs from 18 April to 3 May. Generally, for the remainder of the season the fishway was operated from 0800 hrs to 1900 hrs.

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

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

6 and entrance gate C controlled hydraulics of the spillway lift. Valve 5 controlled flow of water through the crowder channel. Valve 6 regulated the volume of attraction water to a diffuser upstream of entrance C. Position of gate C controlled the velocity of water from the spillway entrance.

Initially, the volume of attraction flow utilized in the fishway varied from 300 to 600 cfs. However, starting on 30 April lift operation occurred at discharges of 300 cfs following implementation of a conservative approach to operation and control of the fishway's attraction water system. The conservative approach to operation resulted from a combination of factors including several unexplained problems with several motor operated valves, the closed/open operation of valves 2 and 3, and the failure of the Safe Harbor Fishway water conveyance system.

Water velocity in the fishway was a function of the total volume of water utilized, project hydraulics (*i.e.*, tailwater and forebay elevation), and valve and gate position. Initially, velocities at the fishway exit, in the trough, crowder channels, and at the entrance were maintained at approximately 6.0, 1.0, 1.0, and 6.0 ft/sec, respectively. Based on visual observations of fish movements, operating experience, and equipment limitations and availability, velocities were modified as feasible throughout the spring to facilitate the collection and passage of clupeids. Velocities that appeared to be most effective at the exit, in the trough, crowder channels, and at the entrances ranged from 2.0 to 4.0, 0.75 to 1.0, 1.0 to 1.5, and 4.0 to 6.0 ft/sec, respectively.

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

Since debris management was considered during fishway design it was a relatively simple task to sluice debris from the fishway. Debris was sluiced from the fishway at two locations, the exit/entrance of the trough and the downstream end of the trough. Small floating debris that entered the fishway was sluiced out of the trough through gate 6 and into the tailrace on an as needed basis throughout the operation each day. Large wood debris that accumulated at the exit of the fishway on the 4 inch adjustable trash screen and/or the 12 inch fixed trash screen was sluiced into the spillway through gate 9. Normally, sluicing debris from the exit/entrance of the fishway was conducted on an as needed basis every few days prior to the start of lift operation. Although it was easy, it required about 1½ hours to complete since it involved a series of seven steps and sounding the Hydro Station Warning System.

Fish Counts

Fish that were lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. The counting area is located immediately downstream of the main attraction water supply area in the trough (Figure 2). As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide and 12 ft long channel on the west side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to passage from the fishway. Passage from the fishway was controlled by two different gates. Generally, during the day fish passage was controlled by the technician who opened/closed a set of gates downstream of the viewing window from a controller located in the counting room. Initially, at night fish were denied passage from the fishway by closing these gates downstream of the window. However, after several weeks of operation a gate located approximately 2 ft upstream of the viewing window was closed to limit potential damage to the window from debris that entered the trough each evening with the 100 cfs fish maintenance flow.

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

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

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

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

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

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

RESULTS

Relative Abundance

The relative abundance of fishes collected and passed by the Holtwood fishway is presented in Table 1. A total of 225,104 fish of 32 taxa passed upstream into Lake Aldred. Gizzard shad (167,916) was the dominant fish species passed and comprised nearly 75% of the catch. Some 28,063 American shad were collected and passed upstream through the fishway. Other predominant fishes passed included shorthead redhorse (8,342), quillback (7,088), walleye (4,652), and channel catfish (4,060). Peak passage occurred on 24 May when some 13,728 fish were passed.

American Shad Passage

The Holtwood fishway captured and passed 28,063 American shad in the first season of operation (Table 1). Both the tailrace and spillway lifts captured and passed shad on their first day of operation which were 18 and 21 April, respectively. Collection and passage of shad varied daily with approximately 84% (24,180) of the shad captured and passed between 26 April and 31 May. The fishway captured and passed over 1,000 American shad per day on eight occasions and on two of these days more than 2,750 shad were passed. Peak shad passage occurred on 2 May when 2,826 shad were captured and passed in six hours of operation. Some 10.9%, 76.5%, and 12.6% of the shad passage occurred during operation in April, May, and June, respectively.

American shad were collected and passed at water temperatures of 53.0°F to 77.2°F and river flows of 19,900 to 53,700 cfs (Table 2 and Figure 4). Nearly 88% of the shad were passed prior to 1 June at water temperatures <68.0°F.

The hourly passage of American shad in the Holtwood fishway is given in Table 3. Most shad (23,710) passed through the fishway between 1000 hrs and 1800 hrs. Peak hourly passage of shad (6,818) occurred between 1500 hrs and 1559 hrs. Although the number of shad passed each day varied greatly a trend in daily passage was evident. Normally, shad passage increased hourly each day, peaked by 1600 hrs, and declined steadily until operation was ended each evening.

A qualitative assessment of the relative number of shad collected in the tailrace and spillway lift was undertaken by viewing each hopper of fish and estimating the number of shad in each lift as they were sluiced into the trough. This information was summed by lift and applied to the daily shad passage count in an effort to determine the number of shad that was captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 15,151 and 12,912 shad (54% and 46%), were captured in the tailrace and spillway lift, respectively (Table 4). The contribution of each lift's catch to daily passage varied considerably throughout the season. Both lifts appeared to catch shad very effectively based on visual observations of fish movement up to and/or in the vicinity of the entrances to the lifts.

Catch of shad in the spillway lift was dependent on flow conditions in the east spillway channel. Hydraulic conditions in the spillway channel was controlled by river flow and operation of the inflatable dam. Spills did not occur when river flow was less than station capacity. Over 8,000 shad (63%) were collected by the spillway lift during operation conducted without spill (Table 4).

Spillway lift operation occurred on 17 days during three periods of spill. Varying amounts of spill occurred from 7 to 9 May, 25 to 31 May, and 3 to 9 June (Table 3 and Figure 4). From 7 to 9 May most shad were captured prior to spill that started at approximately 1230, 1400, and 1600 hrs when the rubber dam was lowered. Generally, during this period once the 300 ft rubber dam was lowered the shad catch was reduced to just a few shad. The catch of shad from 25 to 31 May totaled 3,217 fish with approximately equal numbers of shad collected in the tailrace and spillway lifts. Although the overall catch during this time period at both lifts was similar the spillway lift was not operated on 26 May and limited to four lifts on 25 May (Table 1). Visual observations during this period indicated that spill in the east channel with the rubber dam deflated precluded shad from reaching the spillway entrance. In an effort to improve the catch the rubber dam was inflated. The shad catch appeared to improve and this observation was supported by collection of a larger number of shad in the spillway lift during the final period of spill. The catch from 3 to 9 June totaled 1,959 shad; 1,146 and 817 were estimated to be captured by the spillway and tailrace lifts, respectively (Table 4).

Other Alosids

A total of 1,042 blueback herring was collected (Table 1). Blueback herring were collected from 5 May to 13 June. Most (45%) blueback herring were passed on 18 and 19 May when 164 and 305 herring were passed, respectively. Although passage of blueback herring was extremely low (<0.5%) compared to the 242,815 herring passed at Conowingo Dam, visual observations made during daily walk downs in the vicinity of the entrances to the spillway and tailrace lifts indicated few herring made it to the project area. Observations indicated those that did migrate to the project area were effectively captured by both lifts. One hickory shad was passed on 1 May. No alewife were observed.

Passage Evaluation

In 1997, fishway monitoring efforts focused on visual observations of immigrating fish movements below and in the tailrace and spillway lifts to optimize safe and efficient utilization of the fishway. In general, numbers of fish observed in the tailrace was higher than those in the spillway. Most of the fish were observed in the tailrace. Observations indicated that alosids entered the area in pulses over the spawning period. Generally, fish survival in the fishway was excellent as few mortalities were observed.

Debugging of the fishway occurred daily throughout the season and operation was modified based on equipment availability and visual observations of fish movement. Throughout the season operating personnel made modifications to lift operation based on visual observations of fish movement into and through the fishway to enhance capture and passage.

Throughout the season improvements to systems and/or equipment were identified that could be implemented to enhance fishway operation. As feasible, they were implemented during the season or scheduled for completion after the end of the operation. Improvements identified included: (1) reset positions for fish handling equipment; (2) installation of a dead band in the PLC(s) to prevent continuous opening/closing of equipment; and (3) installation of staff gauges to facilitate manual operation of fishway hydraulics if/when tailrace, spillway, or forebay elevation signal was lost.

From 7 May to 20 May fishway operation was plagued by problems caused by maple seeds. Maple seeds clogged picket and crowder screens in the trough causing interruption to and/or the cancellation of fishway operation on numerous occasions. Following an unwatered inspection of the trough at the end of operation on 19 May lift operation was cancelled. During the inspection of the trough several beams that supported the screens above the main water attraction supply were found pulled away from their mounts and all of the beams had deflected; some as much as nine inches. Repairs were completed ahead of schedule and the fishway was back in operation at 1100 hrs on 24 May.

Nine surveys were conducted in the east channel of the spillway following spill events. The surveys were conducted by two people on an opportunistic basis. Few fish were observed during these surveys and those observed were primarily gizzard shad. Just one shad was observed in the east channel during these surveys.

Video Record

A limited review of the video record showed that fish passage was not adequately captured on the tape record. Data in Table 5 lists by date and time the shad count, the number of shad visually estimated count, and the difference between the two counts. The tape count derived from the review of the six periods was always less than that derived from the visual estimate. The differences between visual counts and tape counts varied from 22 to 780 shad. Poor tape quality caused by high turbidity and changing light conditions often made it difficult to distinguish fish species. Generally, the poor visibility conditions resulted in tape derived counts that consistently underestimated the numbers of shad passing through the fishway.

SUMMARY

The spring 1997 Holtwood fishway operating season was very successful even though construction activities and equipment availability limited several aspects of fishway operation. Relatively large numbers of American shad utilized the tailrace and spillway lifts. Except for alewife, all anadromous fish species targeted for restoration utilized the fishway. Passage and survival of fish that utilized the fishway was excellent. Some 28,063 American shad were passed into Lake Aldred. Few blueback herring were captured and passed the Holtwood fishway. Daily observations indicated that anadromous fish that reached the project area were effectively captured and passed upstream.

Lift operation in April and most of May 1997 occurred during a period of low river flow. Median flows in April and May are roughly 62,000 cfs and 42,000 cfs, respectively. The number of shad and other fishes that reached the spillway lift entrance appeared to be limited by the volume of spill that flows in and through the east channel. Reconnaissance surveys of flow conditions in the east channel revealed that a velocity barrier was formed in the steep sided channel(s) which are located some 1,500 ft downstream of the spillway lift entrance. A rough approximation of the volume of flow that forms the velocity barrier was derived by subtracting the estimated volume of flow that appeared to be flowing into the east channel from the known volume of spill. Based on this method of calculation developed by station personnel the velocity barrier develops when the volume of flow in the east channel reaches 20,000 cfs to 25,000 cfs.

Numerous insights into efficient fishway operation were gained during the 1997 season. Many of these will be utilized in future fishway operation. However, completion of fishway construction after the season including completion of the water conveyance system will require the development of a new set of matrix settings to control hydraulic conditions in and from the fishway. In addition, removal of the construction access bridge from the tailrace should result in an improvement to tailrace hydraulics and fishway effectiveness. Although fishway operation was successful it is anticipated that completion of all fishway construction activities will result in significant improvements relative to fish passage in the future.

RECOMMENDATIONS

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

- As part of the 1998 operation guideline develop a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel, nightly inspections of picket screen; and weekly lubrication of hopper doors. Based on 1997 operation implementation of these routine maintenance activities should minimize disruption of fishway operation.

- Design and install secondary limits in the crowder drive system to prevent damage to the equipment.

- Design and install a surface skimmer boom in front of the fishway exit channel to deflect maple seeds in an effort to reduce or avoid screen clogging problems which occurred in May 1997.

- Improve visibility conditions at the fish counting window by installation of a screen capable of reducing exit channel width from 36 inches down to a minimum of 18 inches at the counting window. Screen design should also allow several intermediate positions between 18 and 36 inches. Channel width should be set daily based on visibility and/or the secchi reading.

- Install underwater lighting at the counting window to improve fish counts and the video record of fish passage during periods of low lights (*i.e.*, cloudy days and/or rainy days). Light intensity should be adjustable.

- Investigate use of the 24 inch drain valve for fishway maintenance flows at night to minimize debris loading at the fishway exit and in other parts of the fishway.

Table 1

Summary of the daily number of fish passed by the Holtwood fish passage facility in 1997.

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*
Hours of Operation - Spillway:	*0*	*0*	*2*	*5.5*	*8.3*	*7.75*	*9.3*	*8.5*	*9*	*8*	*9*	*9*
Hours of Operation - Tailrace:	*5*	*8*	*8*	*7.75*	*8.3*	*7.75*	*9.3*	*8.5*	*9*	*8*	*9*	*9*
Number of Lifts - Spillway:	*0*	*0*	*2*	*6*	*12*	*9*	*9*	*8*	*13*	*8*	*5*	*10*
Number of Lifts - Tailrace:	*10*	*14*	*12*	*12*	*10*	*11*	*8*	*7*	*13*	*14*	*10*	*14*
Water Temperature (°F):	*54.7*	*52.6*	*51.6*	*50.9*	*51.3*	*53*	*54.3*	*56*	*57.4*	*58.9*	*59.8*	*60.3*
American Shad	2	1	3	17	20	20	100	189	1,331	77	64	768
Gizzard Shad	302	1,781	522	225	524	893	1,117	1,310	3,360	2,521	1,503	4,280
Hickory Shad	-	-	-	-	-	-	-	-	-	-	-	-
Blueback Herring	-	-	-	-	-	-	-	-	-	-	-	-
Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow Trout	-	1	1	-	-	1	4	-	-	1	1	-
Brown Trout	-	-	-	-	-	-	-	-	1	-	-	-
Brook Trout	-	-	-	-	-	-	-	-	-	-	-	-
Salmo Sp.	-	-	-	-	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-	-	-
Carp	-	-	-	-	-	-	-	1	-	-	4	-
Quilback	1	-	2	-	-	-	1	17	10	109	129	146
Spottail Shiner	-	-	-	-	1	-	-	-	-	-	-	-
White Sucker	6	10	-	-	-	6	16	1	1	19	26	8
Shorthead Redhorse	-	3	5	-	6	28	15	105	289	508	390	578
White Catfish	-	-	-	-	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	4	-	-	-	-	-	-	4	13
White Perch	-	-	-	-	-	-	-	-	-	-	-	-
Rock Bass	-	-	2	-	-	-	-	-	-	5	5	13
Redbreast Sunfish	-	-	-	-	-	-	-	-	-	-	-	-
Green Sunfish	-	-	-	-	-	-	-	-	-	-	-	1
Pumpkinseed	-	-	-	-	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	-	-	-	-	-	4
Smallmouth Bass	4	11	1	-	2	7	4	20	25	41	71	78
Largemouth Bass	4	-	-	-	2	-	-	-	3	3	2	5
White Crappie	-	-	-	-	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	-	-	-	-	-	-	2	1	-
Walleye	4	5	4	1	1	12	10	18	90	54	151	174
Sea Lamprey	-	-	-	-	-	-	-	-	-	-	1	-
Hybrid Striped Bass	-	-	-	-	-	-	1	-	-	-	-	-
Tiger Muskie	-	-	-	-	-	-	-	-	-	-	-	-
Total	***323***	***1,812***	***540***	***247***	***556***	***967***	***1,268***	***1,661***	***5,110***	***3,340***	***2,352***	***6,068***

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Table 1

Continued.

Date:	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*
Hours of Operation - Spillway:	*5.5*	*7*	*6*	*11*	*10.5*	*9.5*	*10*	*7.5*	*9*	*9.5*	*9*	*10*
Hours of Operation - Tailrace:	*5.5*	*7*	*6*	*11*	*10.5*	*9.5*	*10*	*7.5*	*9*	*9.5*	*9*	*10*
Number of Lifts - Spillway:	*21*	*4*	*8*	*9*	*12*	*12*	*20*	*7*	*12*	*17*	*21*	*23*
Number of Lifts - Tailrace:	*11*	*5*	*14*	*15*	*15*	*13*	*20*	*11*	*13*	*16*	*15*	*17*
Water Temperature (°F):	*61.1*	*61.4*	*61.4*	*62.5*	*63.1*	*62*	*62.6*	*61.1*	*61*	*60.2*	*59*	*58.1*
American Shad	477	409	2,826	204	348	1,189	281	102	1,740	804	532	783
Gizzard Shad	2,791	1,925	4,815	6,136	5,140	3,615	3,270	1,920	2,095	4,122	3,629	2,672
Hickory Shad	-	1	-	-	-	-	-	-	-	-	-	-
Blueback Herring	-	-	-	-	-	1	9	-	14	10	6	26
Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow Trout	-	-	-	1	1	-	-	-	2	-	1	2
Brown Trout	-	-	-	1	2	8	6	-	-	-	1	-
Brook Trout	-	-	-	-	-	-	-	-	-	-	-	1
Salmo Sp.	-	-	-	-	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-	-	-
Carp	1	1	8	44	57	17	21	3	35	65	33	11
Quilback	37	32	83	267	349	220	16	5	716	53	1,103	476
Spottail Shiner	-	50	-	-	-	-	-	-	-	-	-	-
White Sucker	12	-	5	5	6	-	-	-	-	-	-	-
Shorthead Redhorse	276	71	740	948	668	320	65	20	100	178	115	154
White Catfish	-	-	-	-	-	-	1	-	-	-	-	-
Channel Catfish	6	207	13	32	106	24	30	30	80	80	-	15
White Perch	-	-	-	-	-	-	-	-	-	1	-	-
Rock Bass	3	12	11	17	18	14	6	6	7	5	4	3
Redbreast Sunfish	3	-	6	-	-	-	13	5	6	-	1	2
Green Sunfish	-	-	-	-	-	-	-	-	-	1	1	3
Pumpkinseed	-	5	-	1	1	-	-	-	-	-	-	-
Bluegill	5	-	-	1	1	1	5	5	3	1	-	2
Smallmouth Bass	41	9	13	36	46	20	15	5	20	17	11	9
Largemouth Bass	3	3	-	2	8	3	1	-	2	2	4	-
White Crappie	-	-	-	-	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	1	1	-	-	-	-	-	-
Yellow Perch	-	-	-	-	1	-	-	-	-	-	-	-
Walleye	173	44	247	226	178	105	116	75	76	85	52	58
Sea Lamprey	-	-	-	-	-	-	1	-	-	2	1	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Tiger Muskie	-	-	-	1	-	-	-	-	-	-	-	-
Total	*3,828*	*2,769*	*8,767*	*7,922*	*6,931*	*5,538*	*3,856*	*2,176*	*4,896*	*5,426*	*5,494*	*4,217*

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Table 1

Continued.

Date:	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*24 May*	*25 May*	*26 May*
Hours of Operation - Spillway:	*9*	*1*	*6.5*	*8.5*	*2.5*	*9.5*	*10.5*	*11*	*10.75*	*0*	*5*	*0*
Hours of Operation - Tailrace:	*9*	*1*	*6.5*	*4.5*	*6*	*9.5*	*10.5*	*11*	*10.75*	*6*	*9.5*	*9.5*
Number of Lifts - Spillway:	*12*	*1*	*11*	*10*	*5*	*15*	*16*	*18*	*15*	*0*	*4*	*0*
Number of Lifts - Tailrace:	*15*	*1*	*9*	*7*	*10*	*11*	*12*	*15*	*18*	*12*	*18*	*15*
Water Temperature (°F):	*58.5*	*58.9*	*59.8*	*61.6*	*61.3*	*61.3*	*61.8*	*62.4*	*63.1*	*64.2*	*65.5*	*67*
American Shad	277	31	545	2,790	875	361	896	1,197	650	1,406	872	93
Gizzard Shad	1,315	1	2,505	1,694	1,526	2,489	860	625	844	11,496	11,377	10,975
Hickory Shad	-	-	-	-	-	-	-	-	-	-	-	-
Blueback Herring	12	4	197	43	15	22	164	305	40	23	23	20
Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow Trout	-	-	-	-	1	2	-	-	-	-	-	2
Brown Trout	7	-	-	-	-	-	1	-	-	-	-	-
Brook Trout	-	-	-	-	-	-	-	-	-	-	-	-
Salmo Sp.	-	-	-	3	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	1	1	1
Carp	17	-	-	4	3	14	15	4	6	13	10	32
Quilback	21	-	10	92	90	42	65	95	255	85	282	94
Spottail Shiner	-	-	-	-	-	-	-	-	-	-	-	-
White Sucker	-	-	-	-	-	-	-	-	-	6	-	-
Shorthead Redhorse	86	1	95	245	100	201	190	506	340	195	160	85
White Catfish	-	-	-	-	-	-	-	-	-	-	-	-
Channel Catfish	10	-	8	2	30	-	-	-	5	150	81	221
White Perch	1	-	22	19	8	2	16	4	3	28	27	292
Rock Bass	-	-	5	10	5	4	1	12	3	21	8	9
Redbreast Sunfish	1	-	7	4	4	3	19	13	15	40	22	12
Green Sunfish	-	-	2	2	1	-	-	1	-	2	9	7
Pumpkinseed	1	-	-	-	-	-	1	-	-	2	1	1
Bluegill	6	-	2	-	-	-	5	6	9	28	5	6
Smallmouth Bass	8	-	6	13	13	17	28	21	20	8	14	4
Largemouth Bass	3	-	1	-	1	1	1	-	3	-	-	-
White Crappie	-	-	1	1	-	1	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-	-	-	-	1
Yellow Perch	-	-	-	-	-	1	1	1	-	4	1	1
Walleye	68	1	115	113	49	110	101	131	92	220	255	270
Sea Lamprey	-	-	-	-	-	1	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Tiger Muskie	-	-	-	-	-	-	-	-	-	-	-	-
Total	*1,833*	*38*	*3,521*	*5,035*	*2,721*	*3,271*	*2,364*	*2,921*	*2,285*	*13,728*	*13,148*	*12,126*

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Table 1

Continued.

Date:	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*
Hours of Operation - Spillway:	*7*	*8*	*10*	*10*	*10.5*	*10.5*	*10*	*9*	*10.5*	*10.5*	*8.5*	*10.5*
Hours of Operation - Tailrace:	*8.5*	*8*	*10*	*10*	*10.5*	*10.5*	*10*	*9*	*10.5*	*10.5*	*8.5*	*10.5*
Number of Lifts - Spillway:	*8*	*12*	*8*	*11*	*20*	*21*	*12*	*10*	*9*	*11*	*11*	*13*
Number of Lifts - Tailrace:	*13*	*13*	*14*	*12*	*18*	*18*	*15*	*11*	*9*	*11*	*9*	*12*
Water Temperature (°F):	*67.5*	*67.5*	*67.4*	*67.5*	*67.8*	*68.4*	*68.8*	*69*	*67.9*	*65.9*	*66.7*	*68.1*
American Shad	58	32	505	471	1,186	508	180	239	313	237	629	88
Gizzard Shad	10,890	5,243	6,898	7,638	8,620	5,020	2,572	1,910	1,339	793	1,103	1,406
Hickory Shad	-	-	-	-	-	-	-	-	-	-	-	-
Blueback Herring	5	-	-	11	21	32	5	-	-	-	-	4
Striped Bass	-	-	-	-	-	-	-	-	-	-	1	-
Rainbow Trout	3	-	-	1	5	5	-	3	4	-	-	-
Brown Trout	1	-	-	-	1	1	-	-	-	-	37	8
Brook Trout	-	-	-	-	-	-	-	-	-	-	-	-
Salmo Sp.	-	5	-	-	-	-	5	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-	-	-	-	-
Carp	14	14	18	18	55	41	16	9	4	27	4	23
Quilback	17	2	109	101	262	432	79	63	25	17	62	290
Spottail Shiner	-	-	-	-	-	-	-	50	-	-	20	-
White Sucker	-	-	-	-	-	-	-	-	-	-	-	-
Shorthead Redhorse	35	25	110	70	100	85	4	31	20	-	7	8
White Catfish	-	-	-	-	2	2	-	-	-	-	-	-
Channel Catfish	306	875	218	156	36	30	79	79	289	81	118	257
White Perch	66	7	21	16	34	17	15	9	1	2	1	2
Rock Bass	11	6	3	7	5	11	7	3	3	3	10	-
Redbreast Sunfish	18	15	18	11	22	10	5	5	7	21	24	8
Green Sunfish	8	5	7	-	2	8	2	-	-	-	4	4
Pumpkinseed	-	4	1	3	10	2	1	-	-	-	3	-
Bluegill	12	3	8	5	2	7	7	-	2	22	9	12
Smallmouth Bass	4	1	1	10	30	42	6	1	3	5	2	20
Largemouth Bass	-	-	4	2	2	4	1	1	3	1	2	-
White Crappie	-	-	-	-	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	-	2	1	-	-	-	-	-	-
Walleye	81	33	95	60	151	165	93	85	53	38	38	65
Sea Lamprey	-	-	-	-	-	-	-	-	-	2	-	2
Hybrid Striped Bass	-	-	-	-	-	-	-	-	-	-	-	-
Tiger Muskie	-	-	-	-	-	-	-	-	-	-	-	-
Total	***11,529***	***6,270***	***8,016***	***8,580***	***10,548***	***6,423***	***3,077***	***2,488***	***2,066***	***1,249***	***2,074***	***2,197***

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Table 1

Continued.

Date:	*8 Jun*	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*	
Hours of Operation - Spillway:	*10*	*10*	*10.25*	*10*	*10*	*11.5*	*9.75*	
Hours of Operation - Tailrace:	*10*	*10*	*10.25*	*10*	*10*	*11.5*	*9.75*	
Number of Lifts - Spillway:	*13*	*11*	*10*	*12*	*10*	*11*	*11*	
Number of Lifts - Tailrace:	*12*	*13*	*11*	*12*	*9*	*10*	*10*	
Water Temperature (°F):	*67.8*	*67.7*	*68.9*	*70.9*	*73.7*	*76.1*	*77.2*	**TOTAL**
American Shad	216	237	207	347	198	54	78	**28,063**
Gizzard Shad	2,802	1,761	1,331	1,215	795	269	136	**167,916**
Hickory Shad	-	-	-	-	-	-	-	**1**
Blueback Herring	12	11	2	-	-	5	-	**1,042**
Striped Bass	2	-	1	-	-	-	-	**4**
Rainbow Trout	2	-	-	-	-	6	7	**57**
Brown Trout	-	-	2	2	2	9	3	**93**
Brook Trout	-	-	-	-	-	-	-	**1**
Salmo Sp.	-	-	-	-	-	-	-	**13**
Muskellunge	-	1	-	-	-	-	-	**4**
Carp	92	18	1	40	40	11	13	**877**
Quilback	589	113	9	-	2	4	9	**7,088**
Spottail Shiner	-	-	-	-	-	-	-	**121**
White Sucker	-	-	-	-	-	-	-	**127**
Shorthead Redhorse	14	27	9	6	5	-	-	**8,342**
White Catfish	-	-	-	-	-	-	-	**5**
Channel Catfish	137	16	27	113	51	19	22	**4,060**
White Perch	2	4	4	7	4	-	2	**637**
Rock Bass	1	3	-	2	-	1	-	**285**
Redbreast Sunfish	11	10	5	15	9	22	11	**423**
Green Sunfish	-	-	4	2	3	8	5	**92**
Pumpkinseed	-	5	1	-	-	3	-	**46**
Bluegill	4	5	7	1	2	9	4	**216**
Smallmouth Bass	2	6	8	5	2	8	3	**817**
Largemouth Bass	-	-	-	-	1	3	2	**83**
White Crappie	-	-	-	-	-	-	-	**3**
Black Crappie	-	-	-	-	-	-	-	**3**
Yellow Perch	-	-	-	-	1	2	2	**21**
Walleye	29	44	34	51	26	17	10	**4,652**
Sea Lamprey	-	-	-	-	-	-	-	**10**
Hybrid Striped Bass	-	-	-	-	-	-	-	**1**
Tiger Muskie	-	-	-	-	-	-	-	**1**
Total	***3,915***	***2,261***	***1,652***	***1,806***	***1,141***	***450***	***307***	**225,104**

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Table 2

Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in 1997.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs) A	B	C	Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
18 Apr	32,100	54.7	22	9	300	-	-	116.5-117.4	-	166.0-168.5
19 Apr	29,200	52.6	20	9	180-300	-	-	117.1-117.3	-	166.2-168.2
20 Apr	28,300	51.6	26	5 to 9	180-300	-	70	111.2-117.3	117	164.1-166.8
21 Apr	27,000	50.9	22	9	300	-	90	117.2-117.6	117	166.1-167.0
22 Apr	26,800	51.3	20	9	300	-	300	117.2-117.3	117	166.1-167.7
23 Apr	25,400	53.0	20	9	300	-	300	117.3-117.4	117	167.0-168.6
24 Apr	24,200	54.3	20	7 to 9	300	-	300	115.2-117.6	117	166.1-169.4
25 Apr	25,100	56.0	18	9	300	-	300	117.2-117.3	117	166.9-169.0
26 Apr	23,200	57.4	20	9	300	-	300	117.0-117.1	117	166.6-168.2
27 Apr	21,800	58.9	20	9	200	-	300	117.0-117.2	117	166.0-166.8
28 Apr	21,200	59.8	20	5 to 9	200	-	200	112.9-117.4	117	166.4-167.9
29 Apr	22,500	60.3	20	7 to 9	300	-	200	115.4-117.2	117	166.5-167.5
30 Apr	21,400	61.1	20	5 to 9	150	-	150	113.5-117.3	117	166.7-167.3
1 May	23,000	61.4	18	5 to 9	150	-	150	113.4-117.1	117	166.0-167.3
2 May	24,200	61.4	22	7 to 9	150	-	150	115.1-117.2	117	166.0-166.5
3 May	26,900	62.5	20	9	150	-	150	117.0-117.3	117	165.9-168.9
4 May	26,400	63.1	20	5 to 9	150	-	150	113.7-117.3	117	166.3-168.3
5 May	27,400	62.0	20	9	150	-	150	116.9-117.2	117	165.0-167.5
6 May	30,600	62.6	20	9	150	-	150	117.0-117.5	117	165.0-170.2
7 May	32,700	61.1	20	9	150	-	150	116.7-117.4	117-125	165.3-169.1
8 May	34,000	61.0	20	7 to 9	150	-	150	115.3-117.5	116-126	165.4-169.3
9 May	32,300	60.2	20	9 to 10	150	-	150	117.1-118.4	117-126	165.0-169.2
10 May	30,100	59.0	28	10	150	-	150	118.0-118.4	117	166.0-169.3
11 May	28,500	58.1	28	6 to 10	150	-	150	114.3-118.3	116-117	165.3-167.2
12 May	28,100	58.5	24	9 to 10	150	-	150	117.1-118.4	116-117	165.5-169.0
13 May	25,800	58.9	26	6	150	-	150	113.3-114.2	115	165.3-166.6
14 May	24,700	59.8	28	6 to 10	150	-	150	112.4-118.2	115-117	165.0-167.0
15 May	25,700	61.6	28	6 to 10	150	-	150	112.4-118.3	115-117	164.2-168.3
16 May	24,800	61.3	28	6 to 10	150	-	150	112.2-118.8	116-117	163.9-168.0
17 May	22,900	61.3	28	10	150	-	150	118.2-118.4	117	167.9-169.3
18 May	21,700	61.8	26	8 to 10	150	-	150	116.2-118.3	117	167.8-168.2
19 May	22,000	62.4	26	10	150	-	150	118.3-118.4	116-117	167.5-169.0
20 May	20,400	63.1	26	5 to 10	150	-	150	114.0-118.4	116-117	167.4-169.6

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Table 2

Continued.

Date	River Flow (cfs)	Water Temp. (°F)	Secchi (in)	Number Of Units	Weir Gate Operation (cfs)			Tailrace El. (ft)	Spillway El. (ft)	Forebay El. (ft)
					A	B	C			
21 May	21,100	63.5	-	-	-	-	-	-	-	-
22 May	29,300	64.1	-	-	-	-	-	-	-	-
23 May	44,300	64.9	-	-	-	-	-	-	-	-
24 May	39,000	64.2	30	10	150	-	-	118.6	-	170.1-170.2
25 May	38,100	65.5	28	10	150	-	150	118.3-118.7	117-129	168.3-170.5
26 May	39,400	67.0	29	10	150	-	-	118.2-118.7	-	168.6-170.5
27 May	47,300	67.5	28	10	150	-	150	118.4-119.0	130-133	169.8-171.9
28 May	49,700	67.5	26	10	150	-	150	118.5-119.0	132	170.2-171.7
29 May	48,200	67.4	26	10	150	-	150	118.3-118.7	121-129	170.1-172.0
30 May	38,700	67.5	20	10	150	-	150	118.1-118.7	118-127	169.5-172.1
31 May	32,700	67.8	20	10	150	-	150	117.5-118.2	118-120	168.1-170.8
1 Jun	29,500	68.4	22	10	150	-	150	118.0-118.4	116-117	167.9-168.7
2 Jun	29,700	68.8	20	10	150	-	150	118.2-118.5	119-117	167.8-170.8
3 Jun	37,600	69.0	26	10	150	-	150	118.4-118.7	117-125	169.2-171.5
4 Jun	47,800	67.9	22	10	150	-	150	118.5-118.8	124-129	170.6-172.2
5 Jun	51,000	65.9	20	10	150	-	150	118.4-118.7	118-129	170.3-171.7
6 Jun	53,700	66.7	20	10	150	-	150	118.4-118.7	119-127	170.3-171.7
7 Jun	46,800	68.1	20	10	150	-	150	118.4-118.7	124-127	170.2-171.7
8 Jun	37,300	67.8	20	10	150	-	150	118.6-118.8	117-124	171.4-171.7
9 Jun	32,200	67.7	18	10	150	-	150	118.2-118.6	117-121	167.8-171.2
10 Jun	28,500	68.9	20	10	150	-	150	118.3-118.5	117	167.9-170.7
11 Jun	24,100	70.9	20	9 to 10	150	-	150	116.8-117.8	117	167.6-168.8
12 Jun	23,100	73.7	20	8 to 10	150	-	150	116.4-118.4	117	167.6-169.1
13 Jun	22,300	76.1	20	10	150	-	150	117.5-117.7	117	167.8-168.1
14 Jun	19,900	77.2	20	8 to 10	150	-	150	116.5-117.8	117	167.6-168.8

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Table 3

Hourly summary of American shad passage at the Holtwood fish passage facility in 1997.

Date:	*18 Apr*	*19 Apr*	*20 Apr*	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*
Observation Time - Start:	*1030*	*1030*	*1035*	*1046*	*1125*	*1004*	*1005*	*1024*	*1006*	*1008*
Observation Time - End:	*1830*	*1829*	*1842*	*1846*	*1838*	*1858*	*1915*	*1903*	*1910*	*1840*
Military Time (hours)										
0700 - 0759	-	-	-	-	-	-	-	-	-	-
0800 - 0859	-	-	-	-	-	-	-	-	-	-
0900 - 0959	-	-	-	-	-	-	-	-	-	-
1000 - 1059	0	0	-	0	-	0	0	8	5	3
1100 - 1159	0	0	-	0	0	0	0	1	19	18
1200 - 1259	0	0	0	2	0	0	0	0	15	11
1300 - 1359	0	1	0	3	2	2	0	13	35	8
1400 - 1459	0	0	2	5	3	5	4	31	212	10
1500 - 1559	1	0	1	4	7	8	4	41	383	1
1600 - 1659	1	0	0	0	6	3	27	49	342	10
1700 - 1759	0	0	0	3	2	0	36	29	252	13
1800 - 1859	0	0	0	0	0	2	27	17	57	3
1900 - 1959	-	-	-	-	-	-	2	0	11	-
2000 - 2059	-	-	-	-	-	-	-	-	-	-
Total Catch	*2*	*1*	*3*	*17*	*20*	*20*	*100*	*189*	*1,331*	*77*

Date :	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*
Observation Time - Start :	*1000*	*1000*	*1034*	*1033*	*1302*	*740*	*735*	*739*	*816*	*845*
Observation Time - End :	*1902*	*1901*	*1901*	*1735*	*1901*	*1825*	*1913*	*1838*	*1815*	*1826*
Military Time (hours)										
0700 - 0759	-	-	-	-	-	1	0	0	-	-
0800 - 0859	-	-	-	-	-	10	16	3	0	0
0900 - 0959	-	-	-	-	-	19	32	3	0	0
1000 - 1059	2	1	0	1	-	28	39	17	30	0
1100 - 1159	0	0	2	2	-	14	22	31	35	7
1200 - 1259	0	2	55	44	-	19	39	50	23	4
1300 - 1359	19	193	15	1	116	19	87	83	26	15
1400 - 1459	3	241	32	306	1,299	31	60	224	24	14
1500 - 1559	6	147	202	55	1,175	26	23	378	72	38
1600 - 1659	7	49	132	-	123	12	22	277	25	12
1700 - 1759	9	84	37	-	69	20	3	108	40	10
1800 - 1859	18	50	2	-	44	5	5	15	6	2
1900 - 1959	0	1	0	-	-	-	-	-	-	-
2000 - 2059	-	-	-	-	-	-	-	-	-	-
Total Catch	*64*	*768*	*477*	*409*	*2,826*	*204*	*348*	*1,189*	*281*	*102*

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Table 3

Continued.

Date :	*8 May*	*9 May*	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Observation Time - Start :	*841*	*842*	*1042*	*835*	*838*	*953*	*1227*	*1010*	*1000*	*800*
Observation Time - End :	*1819*	*1817*	*1836*	*1839*	*1843*	*1156*	*1850*	*1849*	*1905*	*1842*
Military Time (hours)										
0700 - 0759	-	-	-	-	-	-	-	-	-	-
0800 - 0859	0	3	-	0	10	-	-	-	-	3
0900 - 0959	315	88	-	25	10	4	-	-	-	9
1000 - 1059	130	256	31	94	23	11	-	0	0	12
1100 - 1159	95	220	150	47	7	16	-	1	0	16
1200 - 1259	305	31	98	41	8	-	20	180	2	29
1300 - 1359	450	35	84	41	18	-	115	195	20	19
1400 - 1459	370	56	52	142	59	-	80	153	1	7
1500 - 1559	60	36	37	118	62	-	160	1,905	431	26
1600 - 1659	0	35	29	170	35	-	70	188	263	74
1700 - 1759	15	42	17	83	21	-	80	116	100	114
1800 - 1859	0	2	4	22	24	-	20	52	58	52
1900 - 1959	-	-	30	-	-	-	-	-	-	-
2000 - 2059	-	-	-	-	-	-	-	-	-	-
Total Catch	***1,740***	***804***	***532***	***783***	***277***	***31***	***545***	***2,790***	***875***	***361***

Date :	*18 May*	*19 May*	*20 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*
Observation Time - Start :	*827*	*805*	*814*	*1300*	*902*	*810*	*907*	*805*	*811*	*814*
Observation Time - End :	*1906*	*1906*	*1858*	*1911*	*1827*	*1840*	*1831*	*1815*	*1812*	*1753*
Military Time (hours)										
0700 - 0759	-	-	-	-	-	-	-	-	-	-
0800 - 0859	4	20	5	-	-	32	-	1	0	11
0900 - 0959	32	2	21	-	47	6	1	0	6	300
1000 - 1059	70	25	5	-	63	1	1	0	7	56
1100 - 1159	60	75	3	-	308	3	2	6	6	24
1200 - 1259	65	74	13	-	96	12	8	2	14	10
1300 - 1359	70	46	69	0	76	9	4	8	78	9
1400 - 1459	50	87	77	465	103	12	7	2	290	13
1500 - 1559	80	233	146	330	66	7	7	4	48	16
1600 - 1659	130	395	210	261	43	6	17	7	34	16
1700 - 1759	215	165	79	191	43	3	11	2	20	16
1800 - 1859	70	70	22	142	27	2	0	0	2	-
1900 - 1959	50	5	-	17	-	-	-	-	-	-
2000 - 2059	-	-	-	-	-	-	-	-	-	-
Total Catch	***896***	***1,197***	***650***	***1,406***	***872***	***93***	***58***	***32***	***505***	***471***

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Table 3

Continued.

Date :	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*	*9 Jun*
Observation Time - Start :	*830*	*814*	*808*	*922*	*805*	*806*	*936*	*810*	*808*	*815*
Observation Time - End :	*1910*	*1822*	*1810*	*1817*	*1856*	*1842*	*1816*	*1759*	*1816*	*1825*
Military Time (hours)										
0700 - 0759	-	-	-	-	-	-	-	-	-	-
0800 - 0859	14	42	4	-	24	18	-	6	6	3
0900 - 0959	195	135	3	0	60	72	5	11	48	11
1000 - 1059	230	105	10	17	37	41	12	2	55	11
1100 - 1159	135	50	10	36	23	41	35	10	16	6
1200 - 1259	55	34	10	28	26	15	64	10	12	9
1300 - 1359	136	65	26	47	45	10	83	8	14	3
1400 - 1459	127	31	46	39	25	16	205	10	4	39
1500 - 1559	105	28	22	42	35	10	76	13	24	54
1600 - 1659	69	10	23	19	25	7	125	10	24	56
1700 - 1759	46	7	25	8	8	2	23	8	12	43
1800 - 1859	72	1	1	3	5	5	1	-	1	2
1900 - 1959	2	-	-	-	-	-	-	-	-	-
2000 - 2059	-	-	-	-	-	-	-	-	-	-
Total Catch	*1,186*	*508*	*180*	*239*	*313*	*237*	*629*	*88*	*216*	*237*

Date :	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*	
Observation Time - Start :	*810*	*808*	*815*	*823*	*802*	
Observation Time - End :	*1827*	*1821*	*1830*	*1801*	*1743*	**TOTAL**
Military Time (hours)						
0700 - 0759	-	-	-	-	-	**1**
0800 - 0859	2	23	0	5	3	**268**
0900 - 0959	13	72	1	6	7	**1,559**
1000 - 1059	20	58	78	8	7	**1,610**
1100 - 1159	13	32	40	3	5	**1,645**
1200 - 1259	7	36	27	2	1	**1,608**
1300 - 1359	25	49	16	8	14	**2,533**
1400 - 1459	31	25	16	5	7	**5,158**
1500 - 1559	7	17	5	9	27	**6,818**
1600 - 1659	49	5	7	2	7	**3,518**
1700 - 1759	28	19	6	6	-	**2,289**
1800 - 1859	12	11	2	0	-	**938**
1900 - 1959	-	-	-	-	-	**118**
2000 - 2059	-	-	-	-	-	**0**
Total Catch	*207*	*347*	*198*	*54*	*78*	**28,063**

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Table 4

Visually derived estimate of the American shad catch in the tailrace and spillway lifts at the Holtwood Power Station in 1997.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
18 Apr	2	2		100	
19 Apr	1	1		100	
20 Apr	3	3		100	
21 Apr	17	12	5	70	30
22 Apr	20	0	20	0	100
23 Apr	20	14	6	70	30
24 Apr	100	50	50	50	50
25 Apr	189	76	113	40	60
26 Apr	1,331	1,198	133	90	10
27 Apr	77	54	23	70	30
28 Apr	64	32	32	50	50
29 Apr	768	730	38	95	5
30 Apr	477	429	48	90	10
1 May	409	245	164	60	40
2 May	2,826	1,696	1,130	60	40
3 May	204	153	51	75	25
4 May	348	174	174	50	50
5 May	1,189	595	594	50	50
6 May	281	140	141	50	50
7 May	102	51	51	50	50
8 May	1,740	522	1,218	30	70
9 May	804	80	724	10	90
10 May	532	106	426	20	80
11 May	783	39	744	5	95
12 May	277	55	222	20	80
13 May	31	3	28	10	90
14 May	545	136	409	25	75
15 May	2,790	2,093	697	75	25
16 May	875	700	175	80	20
17 May	361	36	325	10	90
18 May	896	358	538	40	60
19 May	1,197	479	718	40	60
20 May	650	390	260	60	40
21 May					
22 May					
23 May					
24 May	1,406	1,406		100	
25 May	872	349	523	40	60

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Table 4

Continued.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
26 May	93	93		100	
27 May	58	58	0	100	0
28 May	32	32	0	100	0
29 May	505	76	429	15	85
30 May	471	118	353	25	75
31 May	1,186	890	296	75	25
1 Jun	508	76	432	15	85
2 Jun	180	135	45	75	25
3 Jun	239	191	48	80	20
4 Jun	313	250	63	80	20
5 Jun	237	190	47	80	20
6 Jun	629	63	566	10	90
7 Jun	88	84	4	95	5
8 Jun	216	11	205	5	95
9 Jun	237	24	213	10	90
10 Jun	207	21	186	10	90
11 Jun	347	174	173	50	50
12 Jun	198	158	40	80	20
13 Jun	54	41	13	75	25
14 Jun	78	59	19	75	25
Total	*28,063*	*15,151*	*12,912*		

Table 5

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 1997 Holtwood fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
26 Apr	24 in	1413 to 1511	311	159	152 (49%)
2 May	22 in	1342 to 1441	1078	298	780 (72%)
15 May	28 in	1448 to 1511	922	496	426 (46%)
19 May	28 in	1058 to 1157	75	53	22 (29%)
24 May	30 in	1400 to 1502	425	377	48 (11%)
31 May	20 in	901 to 1004	217	145	72 (33%)

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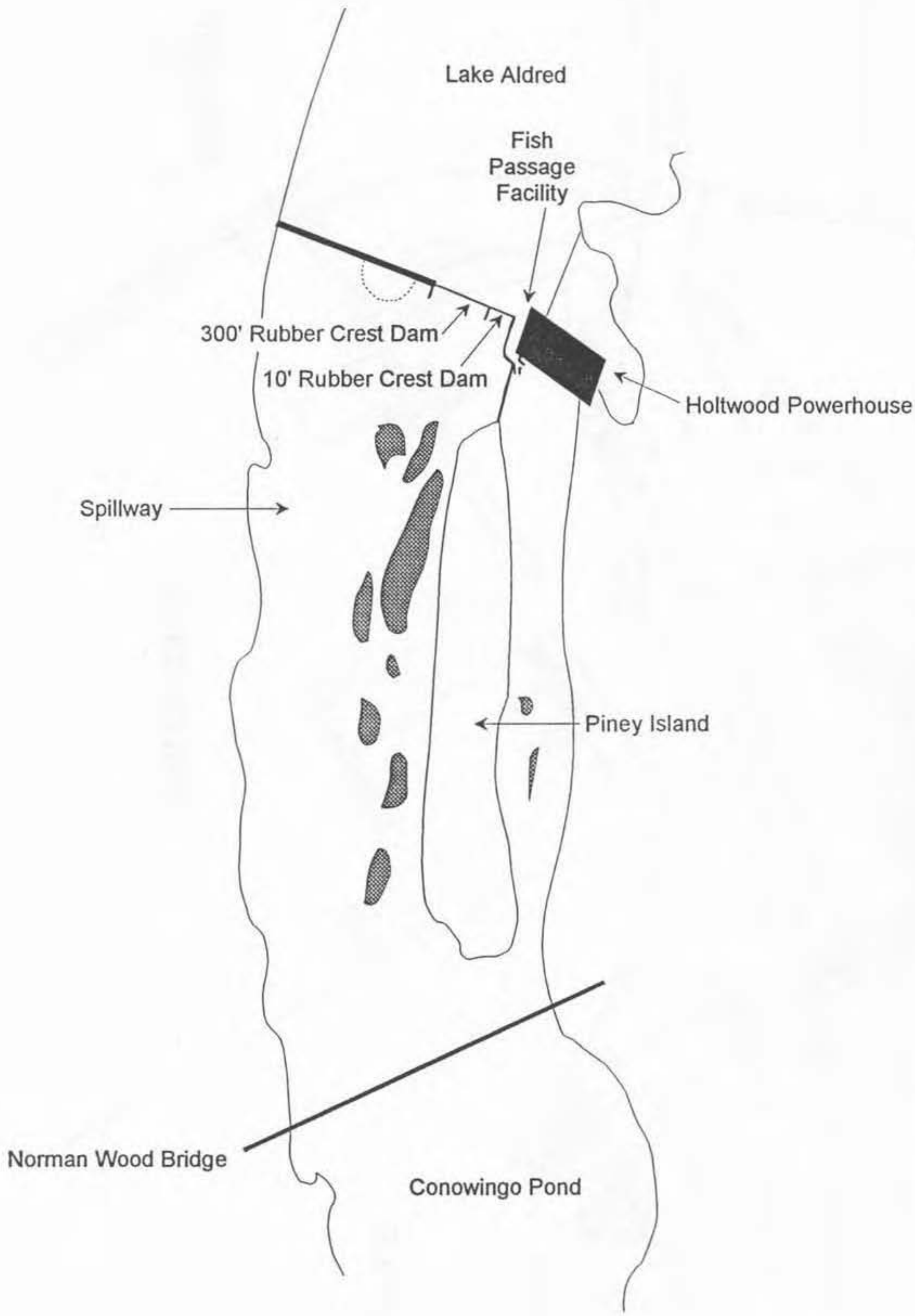

Figure 1

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

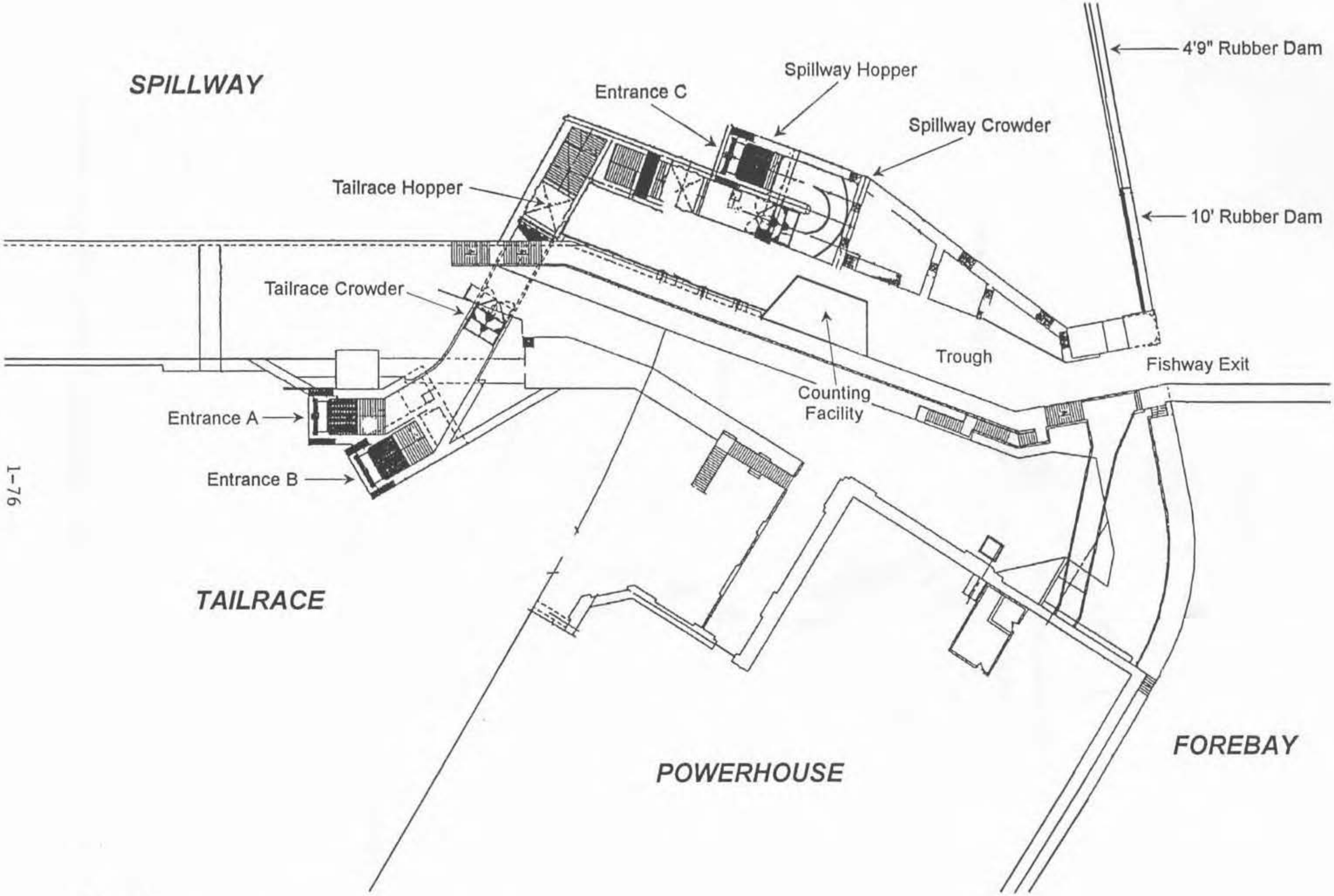

Figure 2

General layout of the Holtwood fish passage facility.

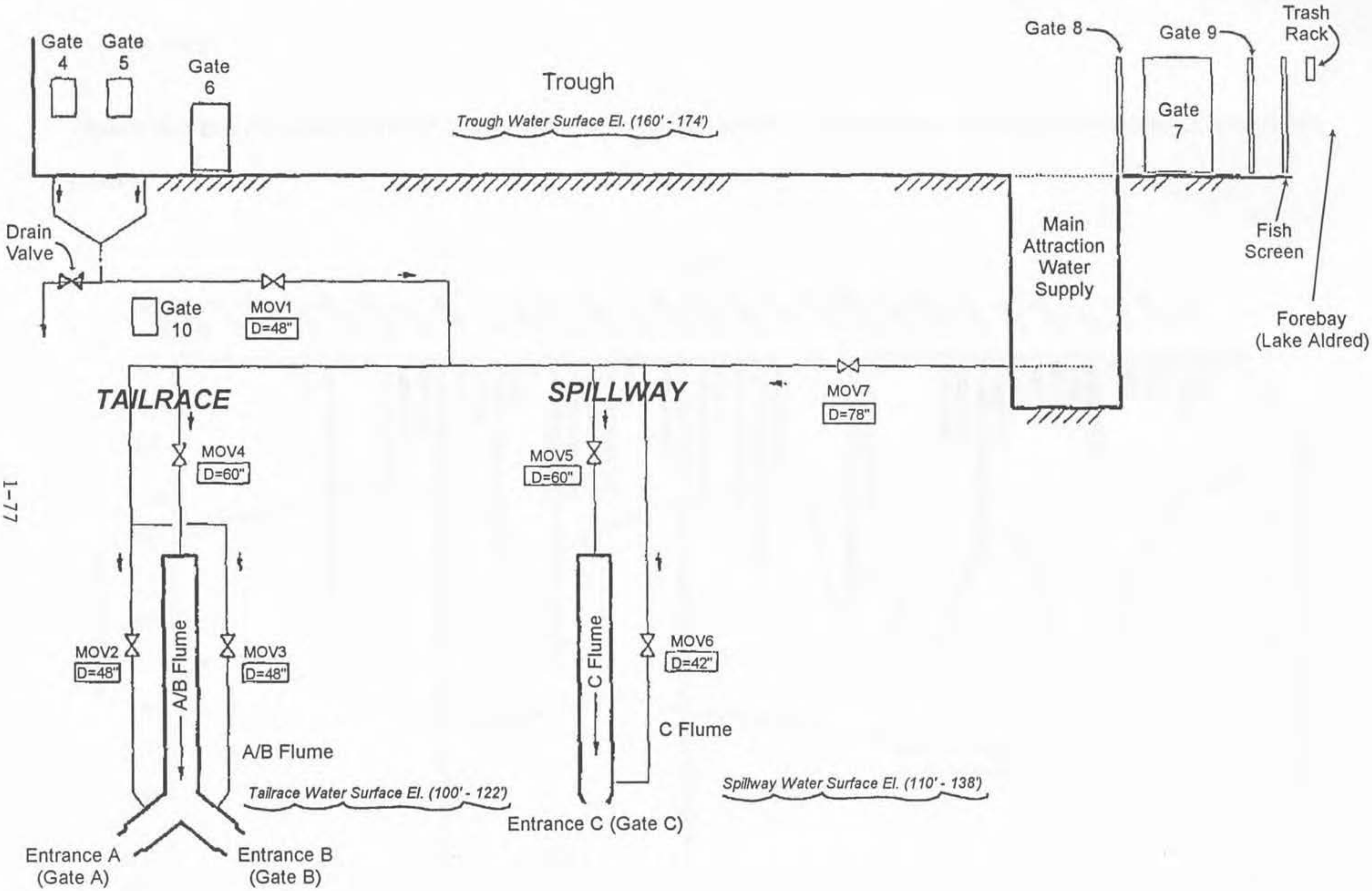

Figure 3

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

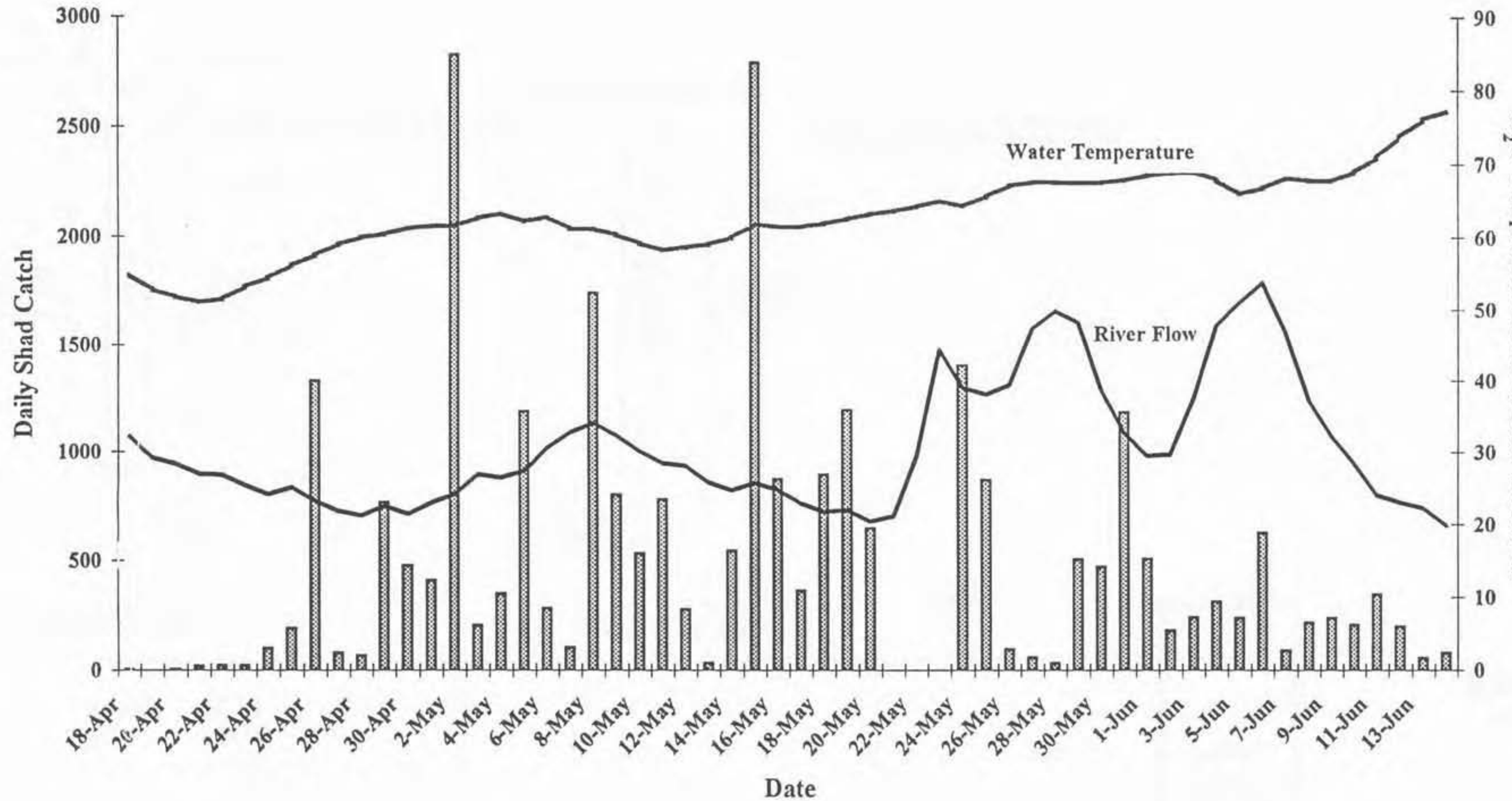

Figure 4

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Holtwood fish lift, spring 1997.

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JOB I - Part 4

SUMMARY OF OPERATION AT THE SAFE HARBOR FISH PASSAGE FACILITY IN 1997

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INTRODUCTION

On June 1, 1993 representatives of Safe Harbor Water Power Corporation (SHWPC), two upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. The agreement committed Safe Harbor, Holtwood, and York Haven Hydroelectric projects to provide migratory fish passage at the three locations by spring 2000. A major element of this agreement was for SHWPC, the operator of the Safe Harbor Hydroelectric Project (Safe Harbor), to construct and place in operation a fishway by April 1, 1997. This agreement was reached based on numerous factors including, but not limited to, an increasing Susquehanna River American shad (*Alosa sapidissima*) population and completion of a permanent fish passage facility at Conowingo Dam in 1991.

The Safe Harbor fish passage facility is a lift that provides fish access into Lake Clarke. It was designed according to United States Fish and Wildlife Service (USFWS) guidelines and specifications which resulted from extensive study, design review, hydraulic modeling, and discussions with resource agencies. Although a 100-year flood that began on January 20, 1996 caused extensive damage to the skimmer wall at the Safe Harbor project, it did not delay completion of fishway construction activities. Fishway operation started at the beginning of the 1997 spring spawning migration. Objectives of 1997 operation were: (1) monitor passage of migratory and resident fishes through the newly installed fishway; and (2) to assess fishway efficiency and effectiveness.

SAFE HARBOR OPERATIONS

Project Operation

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

Safe Harbor is the third upstream dam on the Susquehanna River. The station was built in 1931 and consisted of seven generating units. Five units were added and were operational in 1986 which increased the hydraulic capacity to 110,000 cfs. Each unit is capable of passing approximately 8,500 cfs. Natural river flows in excess of 110,000 cfs are spilled over three regulating and 28 crest gates. The five new mixed-flow turbines have seven fixed runner blades, a diameter of 240 in, and runner speed of 76.6 rpm (Figure 1-2). The runner blades are somewhat spiraled and do not have bands at the top or bottom. Two of these new turbines are equipped with aeration systems that permit a unit to draw air into the unit (vented mode) or operate conventionally (unvented mode). The seven old units are five-blade Kaplan type turbines. These units have horizontal, adjustable, propeller-shaped blades.

Fishway Design and Operation

Fishway design incorporated numerous criteria established by the USFWS and the resource agencies. Physical design parameters for the lift included: (1) a tailrace lift with a cycle time of 10 minutes; (2) operation of the lift at tailwater elevations between 164 ft and 177.9 ft; (3) three adjustable entrances from which water velocity was adjustable to 5 or 6 ft/sec; (4) a total of 1,000 cfs attraction flow; (5) a river flow operating limit of 150,000 cfs; and (6) operation at forebay water elevations between 224 ft and 228 ft. In addition, the fishway was sized to pass a design population of 2.5 million American shad and 5 million river herring.

The Safe Harbor lift has three entrances (gates A, B, and C; Figure 2). The lift has a fish handling system which includes a mechanically operated crowder, picket screen, hopper, and hopper trough gate. Fishes captured in the lift are sluiced into the trough through which fish swim into Lake Clarke. Attraction flow, in, through, and from the lift is supplied through a piping system controlled by motor operated valves, attraction water gates, attraction water pools, and two diffusers that are gravity fed from two intakes. Generally, water conveyance and attraction flow is controlled by regulating two motor operated valves and three attraction water gates which control flow from and into the attraction water pools and regulating the three entrance gates. Fish that enter the entrances are attracted by water flow into the mechanically operated crowder chamber by regulating gate F. Once inside, fish are crowded over the hopper (4,725 gal capacity). Fish are then lifted in the hopper and sluiced into the trough. Fish swim upstream through a counting facility, which includes a separate public viewing window, and into the forebay approximately 150 ft upstream of the dam.

Conceptual design guidelines for fishway operation included three entrance combinations. They were: (1) entrance A, B, and C; (2) entrance B and C; and (3) entrance A, B, and C individually. The majority of 1997 fishway operation utilized a combination of entrance A and C.

Fishway operation began on April 21 and it was operated daily through April 28. Fishway operation was terminated on April 28 due to a failure of the transition structure (square to round) adjacent to attraction water isolation gate G. Repairs were completed quickly and operation resumed on May 10 and continued daily through May 31. An electrical failure involving the hopper occurred late in the day on May 31. The problem was identified and repaired and lift operation resumed on June 3 and continued daily through June 15.

Operation of the fishway's two main systems, the attraction water and fish handling systems, are controlled by a Programmable Logic Controller (PLC). The attraction water system (two motor operated valves, three entrance gates, and three attraction water gates) can be operated in either automatic, manual, or remote mode. The fish handling system, including the hopper, crowder, separation screen, and a telescoping trough gate which is normally maintained 1 ft above forebay elevation to facilitate sluicing of fish into the trough, can be operated in the automatic or manual mode. The fish handling system mode of operation is based on equipment availability and fish abundance. Generally, the attraction water system was operated in the manual mode for the entire season. Additionally, fish handling equipment was operated in the automatic mode if the equipment was available.

Hydraulics in the lift were generally a function of forebay and tailwater elevation, position of valves, position of attraction water gates, and depth of entrance gates. A schematic diagram of the Safe Harbor fishway attraction water system is provided in Figure 3. Two motor operated valves control the distribution and volume of water in the fishway. Flow control in and from the fishway is accomplished by adjusting the position of the valves, three attraction water gates, and three entrance gates. Valves 1 and 2 control the total volume of water in the fishway's main attraction water pool. Valve 2 controls the velocity of water in the trough. Control of hydraulics in the crowder channel is based on the operation/position of attraction water gate F. Gate E controls flow of water from the main attraction water pool into attraction pool 1 and floor diffuser 1 and flow from entrance gate A. Gate D controlled flow of water from the main attraction water pool into attraction pool 2 and floor diffuser 2 and flow to entrance gates B and C. Velocity from each entrance is controlled by the position of the entrance gates A, B, and C.

Initially, the volume of attraction flow utilized in the fishway varied from 200 to 500 cfs. Following the failure of the water conveyance system the volume of attraction flow utilized in fishway operation was restricted to 550 cfs. Flow was limited by the fixed position (65% open) of valve 1. The volume of attraction water resulted in a mode of fishway operation that utilized entrance gates A and C.

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

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

Fish Counts

Fish that were lifted and sluiced into the trough were identified to species and enumerated as they passed the counting window by a biologist and/or technician. The counting area is located in the trough (Figure 2). As fish swim upstream and approach the counting area they are directed by a series of fixed screens to swim up and through a 3 ft wide channel on the east side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are enumerated prior to passage from the fishway. Passage from the fishway was controlled by one gate located downstream of the window. Generally during the day fish passage was controlled by the technician who opened/closed a set of gates downstream of the viewing window from a controller located in the counting room. To facilitate fish identification during periods of low ambient light a 1500 watt halogen lamp was mounted above the viewing window on 10 May. At night fish were denied passage from the fishway by closing these gates downstream of the window.

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

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

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

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

The recorded tapes were reviewed using a video cassette recorder/player equipped with a jog/shuttle control. This feature allowed a day's tape to be reviewed at different speeds during playback, including slow motion and frame by frame. Selected segments of tape were reviewed by a biologist/technician who counted the number of shad passing the window during the selected time period. Fish were counted as they appeared in the field of view while moving upstream past the window. The reviewer had to be able to distinguish the American shad from gizzard shad as they passed the window. This was especially difficult during times when viewing conditions were poor (*i.e.*, low light and high turbidity). During these periods the tapes had to be played back in slow motion (frame by frame) which greatly increased the time required to complete the review.

RESULTS

The relative abundance of fishes collected and passed by the Safe Harbor fishway is presented in Table 1. A total of 211,084 fish of 36 taxa passed upstream into Lake Clarke. Gizzard shad (116,158) was the dominant fish species passed and comprised over 55% of the catch. Some 20,828 American shad were collected and passed upstream through the fishway. Other predominant fishes passed included quillback (36,958), walleye (14,699), shorthead redhorse (12,781), carp (2,200), and smallmouth bass (2,200). Peak passage occurred on 6 May when some 13,851 fish were passed.

American Shad Passage

The Safe Harbor fishway captured and passed 20,828 American shad in the first season of operation (Table 1). The lift captured and passed shad on its first day of operation which was 21 April. Collection and passage of shad varied daily with over 76% (15,881) of the shad captured and passed between 10 May and 31 May. The fishway captured and passed over 750 American shad per day on ten occasions and on three of these days more than 1,375 shad were passed. Peak shad passage occurred on 10 May when 2,026 shad were captured and passed in approximately 12.5 hours of operation. Some 4.9%, 76.2%, and 18.9% of the shad passage occurred during operation in April, May, and June, respectively.

American shad were collected and passed at water temperatures of 49.7°F to 75.0°F and river flows of 19,900 to 52,900 cfs (Table 2 and Figure 4). Over 81% of the shad (16,894) were passed prior to 1 June at water temperatures <66.5°F. The hourly passage of American shad in the Safe Harbor fishway is given in Table 3. Most shad (17,950) passed through the fishway between 0800 hrs and 1900 hrs. Peak hourly passage of shad (2,200) occurred between 1400 hrs and 1459 hrs. Although the number of shad passed each day varied greatly it appeared that a trend in daily passage was evident. Generally, shad passage increased hourly each day, peaked by 1500 hrs, and declined until operation was ended each evening.

Other Alosids

A total of 534 blueback herring was collected (Table 1). Blueback herring were collected from 11 May to 14 June. Most (51.6%) blueback herring were passed between 21 and 24 May when 276 herring were passed. The Safe Harbor fishway passed over 51% of the 1,042 herring that were passed into Lake Aldred by the Holtwood fishway. No alewife or hickory shad were observed.

Video Record

A limited review of the video record showed that fish passage was not adequately captured on the tape record. Data in Table 4 lists by date and time the shad count, the number of shad visually estimated, and the difference between the two counts. The tape count derived from the review of the five periods was always less than that derived from the visual estimate. The differences between visual counts and tape counts varied from 37 to 165 shad. Poor tape quality caused by changing light conditions and high turbidity often made it difficult to distinguish fish species. Generally, the poor visibility conditions resulted in tape derived counts that consistently underestimated the numbers of shad passing through the fishway.

SUMMARY

The spring 1997 Safe Harbor fishway operating season was very successful even though breakdowns reduced the operation season by 13 days. Relatively large numbers of American shad utilized the lift. Some 20,828 American shad were passed into Lake Clarke, or almost 75% of the American shad that were passed into Lake Aldred this year. Few blueback herring were captured and passed. However, the Safe Harbor fishway passed over half of the herring that were passed by the Holtwood fishway. Debugging of the fishway occurred daily throughout the season and operation was modified based on equipment availability and visual observations of fish movement. Throughout the season operating personnel made modifications to lift operation based on visual observations of fish movement into and through the fishway to enhance capture and passage. Generally, fish survival in the fishway was excellent as few mortalities were observed.

Numerous insights into efficient fishway operation were gained during the 1997 season. Many of these will be utilized in future fishway operation. Although fishway operation was successful it is anticipated that completion of repairs to the fishway water conveyance system will result in significant improvements to fish passage in the future.

RECOMMENDATIONS

- Operate the fishway at Safe Harbor Dam per an annual guideline developed and approved by the Safe Harbor Fish Passage Committee. Fishway operation should adhere to the guideline, however, flexibility must remain with operating personnel to maximize fishway operation and performance.

- Improve visibility conditions at the fish counting window by installation of a screen capable of reducing exit channel width from 36 inches down to a minimum of 18 inches at the counting window. Screen design should also allow several intermediate positions between 18 and 36 inches. Channel width should be set daily based on visibility and/or the secchi reading.

- Investigate installation of adjustable underwater lighting at the counting window to improve fish counts and the video record of fish passage in the lower third of the water column during periods of low ambient light. Low levels of light, particularly from 1700 hrs to 1900 hrs each evening, made fish identification/counting difficult.

Table 1

Number and disposition of fish passed by the Safe Harbor fishway in 1997.

Date:	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*
Hours Of Operation:	*8.1*	*8.3*	*9.0*	*8.0*	*8.5*	*7.1*	*8.0*	*1.3*
Start Time:	*10:35*	*10:31*	*10:00*	*10:25*	*10:00*	*11:15*	*10:39*	*11:43*
End Time:	*18:30*	*18:45*	*18:58*	*18:33*	*18:32*	*18:25*	*18:35*	*13:05*
Numbers Of Lifts:	*13*	*13*	*13*	*13*	*16*	*14*	*23*	*5*
Water Temperature (F):	*49.7*	*52.0*	*53.6*	*53.6*	*55.4*	*55.4*	*58.0*	*57.1*
American Shad	6	6	4	21	73	142	739	22
Gizzard Shad	699	401	88	865	733	644	673	21
Blueback Herring	-	-	-	-	-	-	-	-
Alewife	-	-	-	-	-	-	-	-
Brown Trout	-	1	-	-	-	-	-	-
Rainbow Trout	-	2	-	-	-	-	-	-
Palomino (Rainbow Trout)	-	1	-	-	-	-	-	-
Northern Pike	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	1	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	-	-	-	-	4	16	82	11
Quillback	14	154	242	838	1,353	665	1,070	21
Spottail Shiner	3	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	1	-	-	-	-	1	-
Northern Hog Sucker	-	-	-	-	5	4	-	-
Shorthead Redhorse	12	65	429	987	2,183	1,123	850	22
White Catfish	-	-	-	-	-	-	-	-
Yellow Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	-	-	-	-	-	-	-
White Perch	-	-	-	-	-	-	-	-
Rock Bass	-	-	1	7	12	41	20	1
Redbreast Sunfish	-	-	-	-	-	1	1	-
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	-	-	-	-
Bluegill	-	-	-	-	-	-	1	-
Smallmouth Bass	16	23	106	121	305	253	137	5
Largemouth Bass	-	-	1	-	2	2	-	-
White Crappie	-	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	-
Yellow Perch	-	-	-	-	-	1	1	1
Walleye	3	14	19	80	109	159	154	-
Etheostoma Sp.	-	-	-	-	-	-	-	-
Sea Lamprey	-	-	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	1	-	-	-
Total	**753**	**668**	**890**	**2,919**	**4,781**	**3,051**	**3,729**	**104**

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Table 1

Continued.

Date:	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*
Hours Of Operation:	*12.6*	*11.5*	*13.6*	*12.8*	*11.8*	*12.0*	*10.8*	*11.9*
Start Time:	*7:30*	*8:40*	*7:58*	*8:02*	*7:45*	*8:05*	*9:30*	*7:50*
End Time:	*20:07*	*20:07*	*21:32*	*19:50*	*19:30*	*20:00*	*20:15*	*19:40*
Numbers Of Lifts:	*50*	*38*	*35*	*32*	*30*	*35*	*28*	*29*
Water Temperature (F):	*59.0*	*58.1*	*56.0*	*58.3*	*58.9*	*59.8*	*57.6*	*59.6*
American Shad	2,026	517	1,536	753	863	562	1,394	928
Gizzard Shad	8,121	7,055	3,482	1,125	932	1,329	1,057	1,994
Blueback Herring	-	5	7	-	21	16	43	42
Alewife	-	1	-	-	-	-	-	-
Brown Trout	1	-	-	1	-	2	-	-
Rainbow Trout	-	-	-	-	-	-	-	-
Palomino (Rainbow Trout)	-	-	-	-	-	-	-	-
Northern Pike	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	1	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	-	5	175	27	14	81	60	151
Quillback	59	61	2,297	2,333	2,555	4,642	1,816	2,140
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	-	-	-	-	-	-	-	-
White Sucker	-	-	2	3	1	-	1	3
Northern Hog Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	3	49	1,522	795	684	558	581	227
White Catfish	-	-	-	-	-	-	-	-
Yellow Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	-	1	-	22	-	-	2	4
White Perch	-	-	-	-	-	-	1	-
Rock Bass	4	1	32	19	37	47	90	21
Redbreast Sunfish	-	-	-	2	1	5	3	7
Green Sunfish	-	-	-	-	-	-	-	-
Pumpkinseed	-	-	-	-	1	1	1	2
Bluegill	1	-	1	1	2	3	6	1
Smallmouth Bass	32	33	115	81	37	33	91	33
Largemouth Bass	2	-	2	-	-	2	1	1
White Crappie	-	-	-	-	-	2	-	1
Black Crappie	-	-	1	-	-	1	2	-
Yellow Perch	-	-	-	1	1	-	-	1
Walleye	67	33	297	1,410	1,463	707	2,090	555
Etheostoma Sp.	-	-	-	-	-	-	-	-
Sea Lamprey	-	-	-	-	-	-	1	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
Total	**10,316**	**7,761**	**9,469**	**6,573**	**6,612**	**7,992**	**7,240**	**6,111**

Table 1

Continued.

Date:	18 May	19 May	20 May	21 May	22 May	23 May	24 May	25 May
Hours Of Operation:	12.9	11.9	6.8	11.3	13.3	10.5	11.3	11.3
Start Time:	7:24	8:37	13:00	8:39	7:38	7:30	7:31	7:19
End Time:	20:18	20:31	19:50	19:58	21:00	18:00	18:45	18:45
Numbers Of Lifts:	34	31	18	38	36	25	24	28
Water Temperature (F):	59.2	59.0	62.3	60.5	63.0	63.4	65.7	64.4
American Shad	389	750	634	771	602	560	205	759
Gizzard Shad	889	442	513	984	1,799	1,475	3,286	8,929
Blueback Herring	1	13	5	64	62	76	74	8
Alewife	-	-	-	-	-	-	-	-
Brown Trout	-	-	-	1	-	-	3	3
Rainbow Trout	1	-	-	-	-	-	3	1
Palomino (Rainbow Trout)	-	-	-	-	-	-	-	-
Northern Pike	-	-	-	-	-	-	-	1
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	1	-
Carp	74	92	34	117	63	48	295	83
Quillback	1,170	4,286	3,001	2,718	1,423	361	1,060	47
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	1
Notropis Sp.	-	-	-	-	-	3	-	-
White Sucker	-	1	2	-	-	1	-	-
Northern Hog Sucker	-	-	-	1	-	-	-	-
Shorthead Redhorse	340	345	150	394	608	85	118	53
White Catfish	-	-	-	3	6	-	-	-
Yellow Bullhead	-	-	1	-	-	-	-	-
Channel Catfish	-	1	1	6	40	68	20	9
White Perch	-	-	-	-	-	-	-	-
Rock Bass	13	24	25	61	90	16	43	52
Redbreast Sunfish	6	12	1	23	35	13	20	31
Green Sunfish	-	-	-	-	-	5	-	4
Pumpkinseed	8	2	3	18	4	6	5	5
Bluegill	5	-	3	12	12	-	2	5
Smallmouth Bass	48	52	12	50	74	21	40	53
Largemouth Bass	-	3	1	-	1	-	1	2
White Crappie	1	4	4	6	3	-	-	2
Black Crappie	-	-	1	1	3	1	5	1
Yellow Perch	-	1	-	2	1	-	3	-
Walleye	491	495	286	1,046	2,126	205	118	284
Etheostoma Sp.	-	-	-	-	-	-	-	-
Sea Lamprey	-	-	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
Total	**3,436**	**6,523**	**4,677**	**6,278**	**6,952**	**2,944**	**5,302**	**10,333**

Table 1

Continued.

Date:	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*	*3 Jun*	*4 Jun*
Hours Of Operation:	*10.5*	*4.1*	*11.1*	*9.8*	*10.8*	*10.2*	*8.1*	*11.0*
Start Time:	*8:40*	*15:12*	*8:00*	*9:44*	*8:15*	*8:00*	*10:15*	*7:30*
End Time:	*19:08*	*19:05*	*19:05*	*19:30*	*19:06*	*18:10*	*19:00*	*18:30*
Numbers Of Lifts:	*30*	*12*	*22*	*28*	*26*	*40*	*29*	*18*
Water Temperature (F):	*64.1*	*61.7*	*61.7*	*65.0*	*66.4*	*66.2*	*68.0*	*65.3*
American Shad	837	149	314	417	398	517	976	401
Gizzard Shad	12,202	4,780	9,259	5,189	6,750	10,385	6,485	2,207
Blueback Herring	2	7	8	6	6	1	6	-
Alewife	-	-	-	-	-	-	-	-
Brown Trout	3	-	1	9	6	3	-	2
Rainbow Trout	2	-	-	-	-	-	1	-
Palomino (Rainbow Trout)	-	-	-	-	-	-	-	-
Northern Pike	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	1	-	-	-	-	-	-	-
Carp	232	14	26	14	78	377	92	15
Quillback	40	-	22	33	69	489	40	98
Spottail Shiner	-	-	-	70	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	4	600	-	-	-	-	-	-
White Sucker	6	3	-	-	-	3	1	-
Northern Hog Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	23	8	24	45	66	44	4	9
White Catfish	1	-	2	-	-	-	-	-
Yellow Bullhead	-	-	2	-	-	-	-	-
Channel Catfish	99	79	280	65	43	14	30	73
White Perch	13	1	1	3	3	17	10	1
Rock Bass	88	21	24	38	27	10	3	4
Redbreast Sunfish	37	-	12	42	25	41	15	9
Green Sunfish	8	2	2	1	9	3	1	3
Pumpkinseed	12	1	-	12	3	6	4	-
Bluegill	4	3	1	8	-	9	2	-
Smallmouth Bass	44	9	23	27	30	77	43	32
Largemouth Bass	1	-	-	-	2	2	-	-
White Crappie	-	-	4	1	-	-	-	1
Black Crappie	3	3	-	1	2	4	2	1
Yellow Perch	4	1	-	1	2	-	-	-
Walleye	185	95	128	152	123	207	168	80
Etheostoma Sp.	-	-	-	-	-	-	-	-
Sea Lamprey	-	-	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
Total	**13,851**	**5,776**	**10,133**	**6,134**	**7,642**	**12,209**	**7,883**	**2,936**

Table 1

Continued.

Date:	1 Jun	6 Jun	7 Jun	8 Jun	9 Jun	10 Jun	11 Jun	12 Jun
Hours Of Operation:	*11.8*	*12.3*	*13.0*	*11.3*	*9.0*	*12.3*	*12.8*	*7.7*
Start Time:	*7:49*	*7:11*	*7:00*	*7:08*	*7:45*	*7:43*	*7:41*	*11:19*
End Time:	*19:35*	*19:30*	*20:00*	*18:30*	*16:46*	*20:05*	*19:02*	*19:00*
Numbers Of Lifts:	*18*	*22*	*18*	*17*	*24*	*24*	*20*	*16*
Water Temperature (F):	*63.0*	*63.5*	*64.4*	*67.0*	*65.0*	*67.0*	*71.1*	*73.1*
American Shad	279	431	254	152	226	353	180	194
Gizzard Shad	1,620	1,851	562	1,053	1,012	1,100	1,420	990
Blueback Herring	2	37	4	1	-	3	4	-
Alewife	-	-	-	-	-	-	-	-
Brown Trout	2	-	-	-	-	1	1	1
Rainbow Trout	-	7	2	2	-	3	1	-
Palomino (Rainbow Trout)	-	-	-	-	-	-	-	-
Northern Pike	-	-	-	-	-	-	-	-
Muskellunge	-	-	-	-	-	-	-	-
Esox Sp.	-	-	-	-	-	-	-	-
Carp	25	90	25	12	6	51	94	89
Quillback	146	500	385	72	6	40	296	150
Spottail Shiner	-	-	-	-	-	-	-	-
Spotfin Shiner	-	-	-	-	-	-	-	-
Notropis Sp.	2	-	-	-	-	-	56	-
White Sucker	-	-	-	-	-	2	-	-
Northern Hog Sucker	-	-	-	-	-	-	-	-
Shorthead Redhorse	1	70	210	30	5	6	23	7
White Catfish	-	2	3	3	-	-	-	-
Yellow Bullhead	-	-	-	-	-	-	-	-
Channel Catfish	32	135	157	110	1	20	38	58
White Perch	-	-	-	-	-	2	-	50
Rock Bass	2	5	3	2	1	1	2	1
Redbreast Sunfish	9	12	15	7	9	16	21	10
Green Sunfish	-	1	2	-	1	1	4	1
Pumpkinseed	-	1	2	-	2	2	2	2
Bluegill	1	5	-	5	-	1	3	4
Smallmouth Bass	18	6	25	13	5	16	24	14
Largemouth Bass	1	-	-	-	-	-	-	-
White Crappie	-	-	-	-	-	-	1	-
Black Crappie	-	-	-	1	-	-	1	1
Yellow Perch	-	-	-	-	-	-	-	1
Walleye	50	131	333	200	81	120	171	97
Etheostoma Sp.	-	-	-	-	-	-	1	-
Sea Lamprey	-	-	-	-	-	-	-	-
Hybrid Striped Bass	-	-	-	-	-	-	-	-
Total	**2,190**	**3,284**	**1,982**	**1,663**	**1,355**	**1,738**	**2,343**	**1,670**

Table 1

Continued.

Date:	*13 Jun*	*14 Jun*	*15 Jun*	*TOTAL*
Hours Of Operation:	*11.5*	*9.3*	*0.8*	
Start Time:	*7:25*	*7:15*	*7:21*	
End Time:	*19:07*	*16:54*	*8:05*	
Numbers Of Lifts:	*31*	*14*	*3*	
Water Temperature (F):	*74.0*	*75.0*	*75.0*	
American Shad	384	49	55	**20,828**
Gizzard Shad	950	760	47	**116,158**
Blueback Herring	-	10	-	**534**
Alewife	-	-	-	**1**
Brown Trout	-	-	-	**41**
Rainbow Trout	-	-	-	**25**
Palomino (Rainbow Trout)	-	-	-	**1**
Northern Pike	-	-	-	**1**
Muskellunge	1	-	-	**3**
Esox Sp.	-	-	-	**2**
Carp	40	24	1	**2,737**
Quillback	242	4	-	**36,958**
Spottail Shiner	-	-	-	**73**
Spotfin Shiner	-	-	-	**1**
Notropis Sp.	-	-	-	**665**
White Sucker	-	-	-	**31**
Northern Hog Sucker	-	-	-	**10**
Shorthead Redhorse	16	7	-	**12,781**
White Catfish	-	-	-	**20**
Yellow Bullhead	-	-	-	**3**
Channel Catfish	12	29	-	**1,449**
White Perch	-	-	-	**102**
Rock Bass	1	-	-	**890**
Redbreast Sunfish	16	9	-	**466**
Green Sunfish	5	3	3	**59**
Pumpkinseed	2	3	-	**110**
Bluegill	9	6	2	**118**
Smallmouth Bass	6	17	-	**2,200**
Largemouth Bass	-	-	-	**27**
White Crappie	-	-	-	**30**
Black Crappie	-	-	-	**35**
Yellow Perch	-	1	-	**23**
Walleye	103	61	3	**14,699**
Etheostoma Sp.	-	-	-	**1**
Sea Lamprey	-	-	-	**1**
Hybrid Striped Bass	-	-	-	**1**
Total	**1,787**	**983**	**111**	**211,084**

Table 2

Summary of daily average river flow, water temperature, turbidity (secchi), unit operation, entrance gates utilized, attraction flow, and project water elevations during operation of the Safe Harbor fish passage facility in 1997.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
21 Apr	26,200	49.7	-	6	2-7	B and C	-	226.1	169.8
22 Apr	26,000	52.0	-	5	3-7	B and C, A and C	337/220	225.9	169.8
23 Apr	24,600	53.6	-	4	3-6	B and C, A and C	-	226.0	170.0
24 Apr	23,400	53.6	-	7	3-9	A, B and C	550	225.3	172.7
25 Apr	24,400	55.4	-	8	2-9	A and C	550	226.5	171.3
26 Apr	22,600	55.4	-	7	3-9	A, A and C	550	226.5	171.1
27 Apr	21,200	59.0	-	6	2-7, 9	A and C	550	226.6	170.2
28 Apr	21,200	57.1	-	7	2-8	A	550	226.6	170.9
29 Apr	21,600	-	-	-	-	-	-	-	-
30 Apr	21,200	-	-	-	-	-	-	-	-
1 May	22,200	-	-	-	-	-	-	-	-
2 May	23,500	-	-	-	-	-	-	-	-
3 May	26,200	-	-	-	-	-	-	-	-
4 May	25,600	-	-	-	-	-	-	-	-
5 May	26,600	-	-	-	-	-	-	-	-
6 May	29,900	-	-	-	-	-	-	-	-
7 May	32,100	-	-	-	-	-	-	-	-
8 May	33,400	-	-	-	-	-	-	-	-
9 May	31,600	-	-	-	-	-	-	-	-
10 May	29,400	59.0	16	7	4-10	A and C	550	226.8	168.7
11 May	27,900	58.1	28	6	4-9	A and C	550	226.1	170.2
12 May	27,500	56.0	28	8	2, 4-8, 10, 11	A and C	550	226.3	172.1
13 May	25,200	58.3	28	6	2, 4-7, 11	A and C, B and C	561	226.5	170.2
14 May	24,100	58.9	28	7	2-8	A and C	550	226.8	169.3
15 May	25,200	59.8	28	10	2-11	A and C, BC, ABC	550	225.9	170.7
16 May	24,400	57.6	24	10	2-11	A and C	550	227.0	169.7
17 May	22,300	59.6	24	5	4-6, 8, 10	A and C	550	226.5	168.7
18 May	21,500	59.2	32	6	4-6, 8, 10, 11	A and C	550	226.8	169.6
19 May	21,100	59.0	24	7	2, 4-6, 8, 10, 11	A and C	550	226.8	168.9
20 May	19,900	62.3	24	7	4-6, 8, 10, 11, 12	A and C	550	225.3	169.3
21 May	20,700	60.5	24	6	2, 4-6, 8, 10	A and C	550	226.9	169.1

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Table 2

Continued.

Date	River Flow (cfs)	Water Temperature (°F)	Secchi (in)	Maximum Units in Operation	Units Generated	Entrance Gates Utilized	Attraction Flow (cfs)	Tailrace Elevation (ft)	Forebay Elevation (ft)
22 May	28,900	63.0	28	8	2, 4-6, 8, 10, 11, 12	A and C	550	227.0	169.7
23 May	43,900	63.4	28	11	2-12	A and C	550	227.0	173.2
24 May	38,800	65.7	32	6	4-6, 8, 9, 10	A and C	550	225.5	173.9
25 May	35,900	64.4	32	7	4-6, 8, 9, 10, 11	A and C	550	226.7	. 170.0
26 May	36,900	64.1	32	7	4-6, 8, 9, 10, 11	A and C	550	227.1	171.2
27 May	46,500	61.7	28	9	, 4-6, 8, 9, 10, 11, 1	A and C	550	225.3	173.9
28 May	49,100	61.7	28	9	, 4-6, 8, 9, 10, 11, 1	A and C	550	226.2	173.5
29 May	47,600	65.0	28	9	, 4-6, 8, 9, 10, 11, 1	A and C	550	225.9	173.6
30 May	38,100	66.4	24	9	, 4-6, 8, 9, 10, 11, 1	A and C	550	226.5	171.9
31 May	32,100	66.2	24	7	4-6, 8, 9, 10, 11	A and C	550	226.8	171.5
1 Jun	28,900	-	-	-	-	-	-	-	-
2 Jun	28,900	-	-	-	-	-	-	-	-
3 Jun	36,100	68.0	20	6	2, 4, 5, 7, 8, 9	A and C	550	227.2	171.2
4 Jun	46,600	65.3	20	9	2, 4, 5, 7-12	A and C	550	226.8	172.9
5 Jun	50,100	63.0	20	9	2, 4, 5, 7-12	A and C	550	226.8	172.9
6 Jun	52,900	63.5	26	9	2, 4, 5, 7-12	A and C	550	224.8	173.9
7 Jun	48,000	64.4	22	7	4, 5, 7, 9-12	A and C	550	226.0	173.4
8 Jun	36,600	67.0	20	6	4, 5, 9-12	A and C	550	227.1	170.6
9 Jun	31,600	65.0	22	6	2, 4, 5, 9-12	A and C	550	227.0	169.7
10 Jun	28,300	67.0	26	4	2, 4, 9, 10	A and C	550	226.7	169.5
11 Jun	24,000	71.1	20	5	2, 4, 5, 9, 10	A and C	550	227.0	170.2
12 Jun	22,500	73.1	20	5	4, 5, 7, 8, 9	A and C	550	226.6	170.6
13 Jun	21,700	74.0	20	5	2, 4, 5, 7, 8	A and C	550	227.0	170.3
14 Jun	19,400	74.0	20	5	2, 4, 5, 7, 8	A and C	550	227.0	170.3
15 Jun	19,100	75.0	20	-	-	-	-	-	-

Table 3

Hourly summary of American shad passage at the Safe Harbor fish passage facility in 1997.

Date:	*21 Apr*	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*10 May*	*11 May*
Observation Time (Start):	*1032*	*1034*	*1045*	*1030*	*1004*	*1120*	*1037*	*955*	*757*	*855*
Observation Time (End):	*1856*	*1846*	*1852*	*1825*	*1843*	*1834*	*1851*	*1259*	*2012*	*2017*
MILITARY TIME (HRS)										
0700 To 0759	-	-	-	-	-	-	-	-	2	-
0800 To 0859	-	-	-	-	-	-	-	-	144	8
0900 To 0959	-	-	-	-	-	-	-	0	237	91
1000 To 1059	0	0	0	1	6	-	5	0	279	66
1100 To 1159	0	2	0	4	1	7	158	6	104	43
1200 To 1259	1	0	0	4	10	9	171	16	176	23
1300 To 1359	1	1	2	2	10	38	119	-	34	23
1400 To 1459	1	1	1	1	11	25	77	-	-	71
1500 To 1559	0	2	0	4	12	26	66	-	-	44
1600 To 1659	2	0	0	2	6	22	54	-	-	47
1700 To 1759	0	0	1	1	9	11	50	-	-	38
1800 To 1859	1	0	0	2	8	4	39	-	-	47
1900 To 1959	-	-	-	-	-	-	-	-	-	9
2000 To 2059	-	-	-	-	-	-	-	-	-	7
2100 To 2159	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	1050*	-
TOTAL CATCH	**6**	**6**	**4**	**21**	**73**	**142**	**739**	**22**	**2,026**	**517**

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Table 3

Continued.

Date:	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*	*20 May*	*21 May*
Observation Time (Start):	*744*	*726*	*810*	*732*	*933*	*758*	*818*	*725*	*1240*	*809*
Observation Time (End):	*2158*	*1953*	*1938*	*1954*	*2025*	*1940*	*2034*	*2049*	*1957*	*2051*
MILITARY TIME (HRS)										
0700 To 0759	2	0	-	-	-	-	-	0	-	-
0800 To 0859	62	74	237	21	-	-	23	4	-	59
0900 To 0959	60	78	109	26	3	-	34	22	-	131
1000 To 1059	56	33	57	61	26	-	48	57	-	85
1100 To 1159	28	54	40	12	311	-	22	55	-	70
1200 To 1259	49	40	52	19	185	-	26	97	1	65
1300 To 1359	101	42	84	32	210	-	40	97	130	80
1400 To 1459	190	32	73	101	147	-	55	106	188	90
1500 To 1559	363	39	49	101	175	-	45	45	161	65
1600 To 1659	157	102	65	86	95	-	26	52	58	25
1700 To 1759	161	120	51	34	106	-	30	71	29	25
1800 To 1859	99	106	34	38	50	-	20	75	34	55
1900 To 1959	70	33	12	31	70	-	10	37	33	10
2000 To 2059	43	-	-	-	16	-	10	32	-	11
2100 To 2159	95	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	928*	-	-	-	-
TOTAL CATCH	1,536	753	863	562	1,394	928	389	750	634	771

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Table 3

Continued.

Date:	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*	*30 May*	*31 May*
Observation Time (Start):	*818*	*803*	*811*	*800*	*900*	*1547*	*805*	*1003*	*830*	*819*
Observation Time (End):	*2118*	*2024*	*1910*	*1851*	*1901*	*1913*	*1954*	*1945*	*1932*	*1815*
MILITARY TIME (HRS)										
0700 To 0759	-	-	-	-	-	-	-	-	-	-
0800 To 0859	46	69	11	131	-	-	22	-	24	12
0900 To 0959	39	72	19	84	71	-	32	-	63	42
1000 To 1059	35	32	5	84	42	-	0	93	52	59
1100 To 1159	16	21	9	46	74	-	0	47	53	40
1200 To 1259	14	40	29	14	105	-	45	39	48	75
1300 To 1359	70	54	17	64	147	-	50	49	25	93
1400 To 1459	77	66	27	78	119	-	50	51	29	76
1500 To 1559	58	108	29	94	92	13	51	56	60	70
1600 To 1659	55	34	25	45	29	55	1	25	22	21
1700 To 1759	57	21	17	70	71	38	15	14	8	24
1800 To 1859	45	19	17	49	42	37	34	19	11	5
1900 To 1959	35	10	-	-	45	6	14	24	3	-
2000 To 2059	40	14	-	-	-	-	-	-	-	-
2100 To 2159	15	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
TOTAL CATCH	**602**	**560**	**205**	**759**	**837**	**149**	**314**	**417**	**398**	**517**

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Table 3

Continued.

Date:	3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	8 Jun	9 Jun	10 Jun	11 Jun	12 Jun
Observation Time (Start):	813	739	820	721	742	738	757	750	805	1256
Observation Time (End):	1859	1829	1928	1840	1901	1807	1908	1958	1917	1921
MILITARY TIME (HRS)										
0700 To 0759	-	16	-	56	27	3	7	34	-	-
0800 To 0859	2	81	21	71	43	15	39	99	43	-
0900 To 0959	0	34	29	27	43	5	9	37	29	-
1000 To 1059	38	34	24	46	25	4	9	22	26	-
1100 To 1159	332	21	15	30	18	9	26	20	8	-
1200 To 1259	154	37	22	16	22	7	-	22	-	12
1300 To 1359	143	50	36	42	13	22	-	17	-	52
1400 To 1459	101	46	59	42	17	17	-	12	5	58
1500 To 1559	68	47	0	14	-	36	-	-	18	3
1600 To 1659	57	18	0	34	-	6	-	-	-	-
1700 To 1759	23	12	0	34	-	27	-	-	40	-
1800 To 1859	58	5	16	19	46	1	125	74	9	66
1900 To 1959	-	-	7	-	-	-	11	16	2	3
2000 To 2059	-	-	-	-	-	-	-	-	-	-
2100 To 2159	-	-	-	-	-	-	-	-	-	-
	-	-	50**	-	-	-	-	-	-	-
TOTAL CATCH	**976**	**401**	**279**	**431**	**254**	**152**	**226**	**353**	**180**	**194**

Table 3

Continued.

Date:	*13 Jun*	*14 Jun*	*15 Jun*	*TOTAL*
Observation Time (Start):	*810*	*820*	*834*	
Observation Time (End):	*1912*	*1732*	*1444*	
MILITARY TIME (HRS)				
0700 To 0759	-	-	-	**147**
0800 To 0859	55	3	3	**1,422**
0900 To 0959	50	0	0	**1,476**
1000 To 1059	80	1	0	**1,491**
1100 To 1159	30	8	0	**1,740**
1200 To 1259	20	0	12	**1,677**
1300 To 1359	50	6	1	**2,047**
1400 To 1459	40	7	39	**2,186**
1500 To 1559	0	7	-	**2,021**
1600 To 1659	5	1	-	**1,232**
1700 To 1759	0	16	-	**1,224**
1800 To 1859	30	-	-	**1,339**
1900 To 1959	24	-	-	**515**
2000 To 2059	-	-	-	**173**
2100 To 2159	-	-	-	**110**
	-	-	-	**2,028**
TOTAL CATCH	384	49	55	20,828

* Time data lost; ScriptWriter failure.

** Fish removed for Turb'N Tag study.

Table 4

Comparison of American shad passage, visual counts versus video based counts, during several discrete time periods of the 1997 Safe Harbor fish passage season.

Date	Visibility (Secchi)	Time Period Reviewed	Visual Counts	Video Count	Difference
10 May	16	1100 to 1200	106	69	37 (35%)
12 May	28	1251 to 1351	111	67	44 (40%)
14 May	28	0820 to 0912	167	79	88 (53%)
26 May	32	1440 to 1441	108	*	* *
3 Jun	20	1051 to 1151	295	130	165 (56%)

* No count possible, video record extremely blurry and bright.

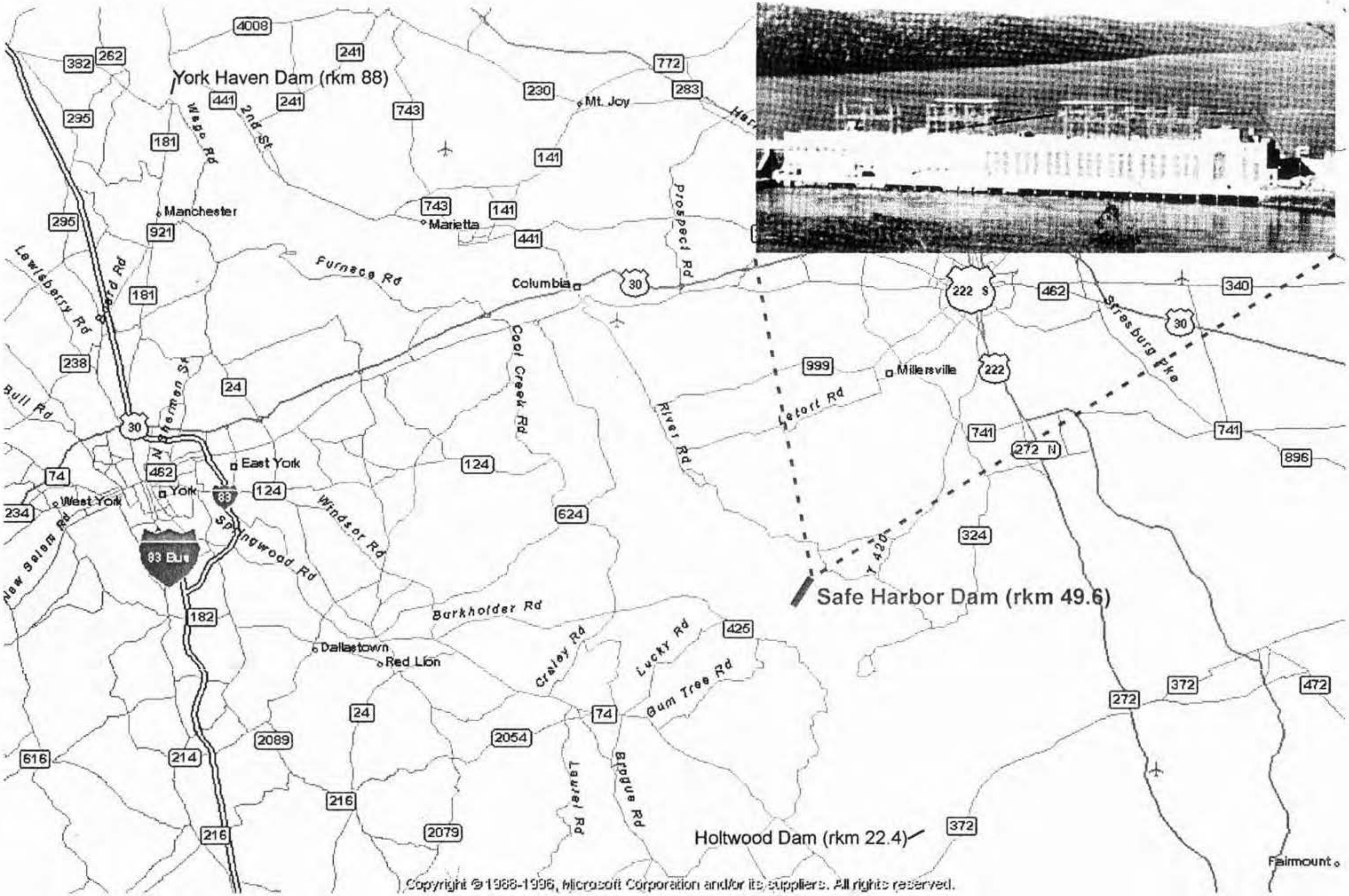
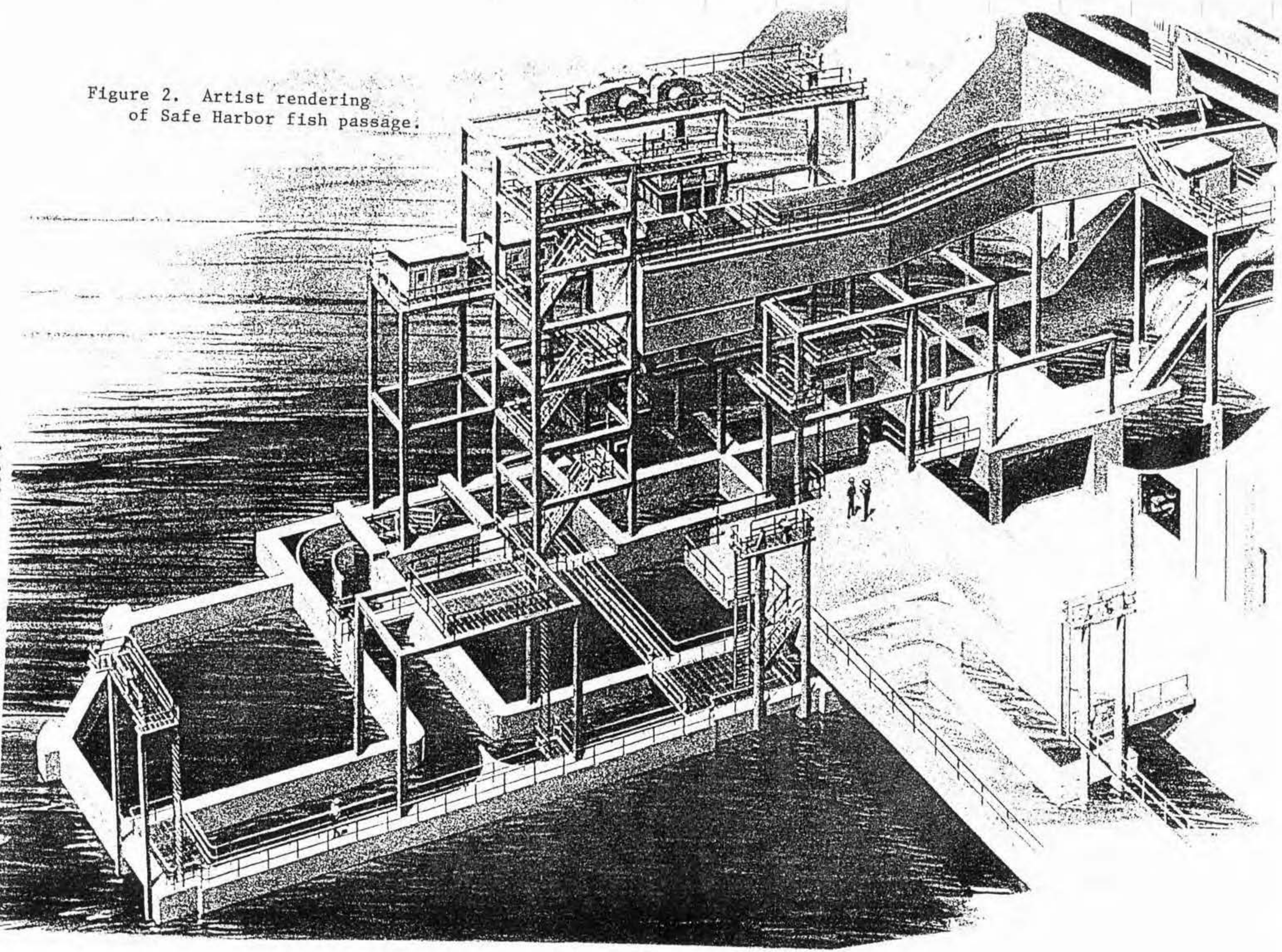


Figure 1

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

Figure 2. Artist rendering of Safe Harbor fish passage.



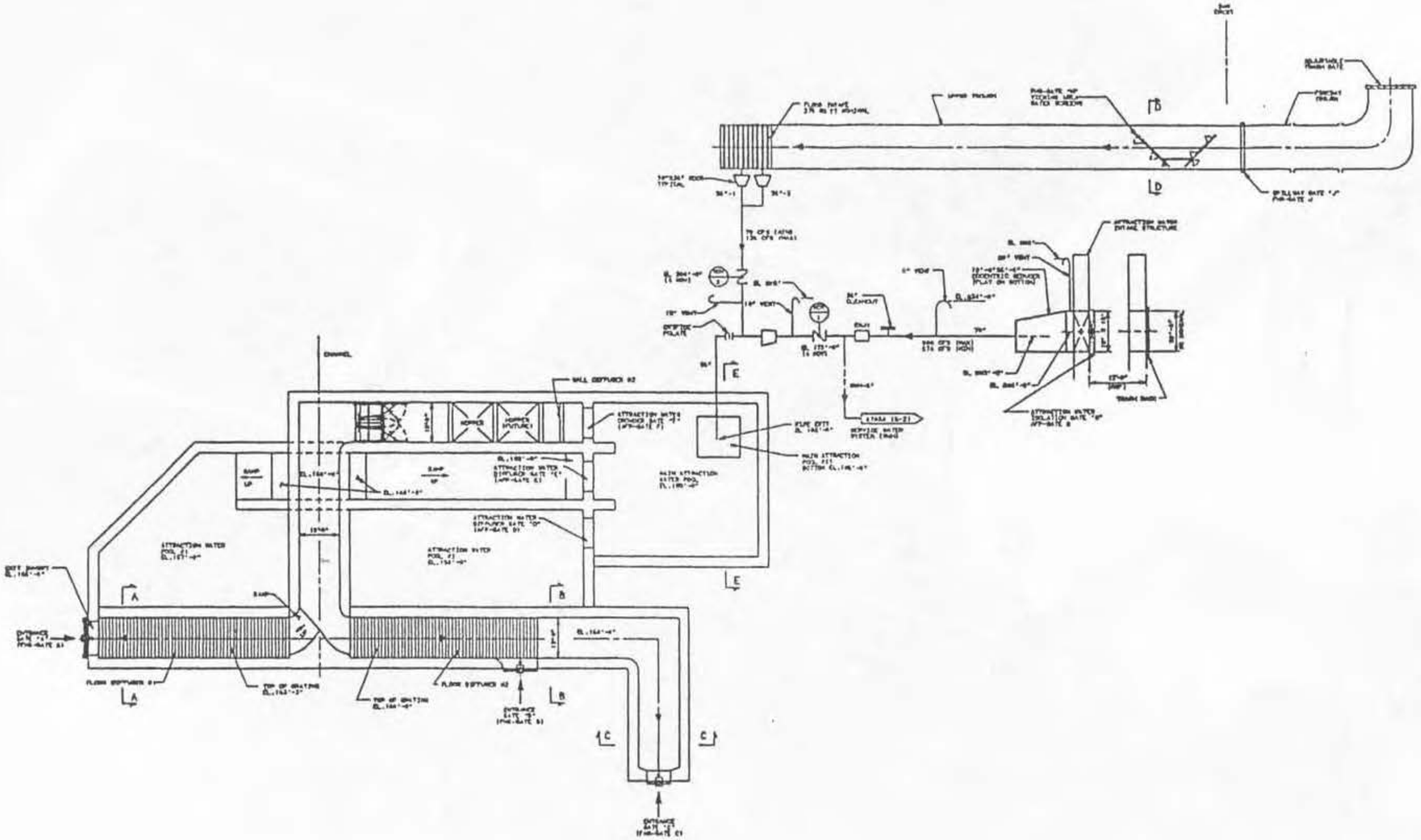


Figure 3

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

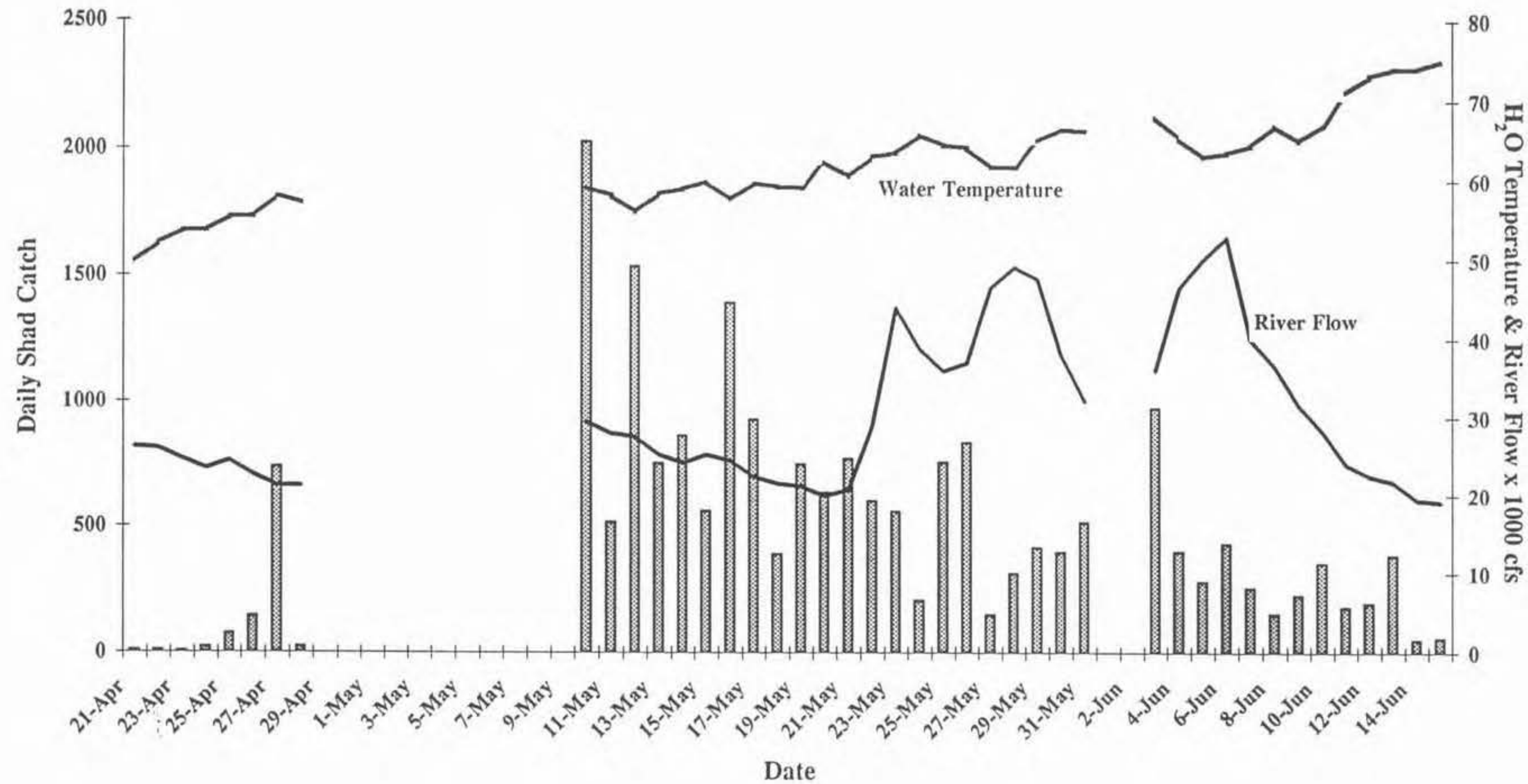


Figure 4

A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the daily American shad catch at the Safe Harbor fish lift, spring 1997.

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JOB II - Part 1

AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER IN 1997

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INTRODUCTION

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

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. was contracted to capture ripe adult shad on the spawning grounds during spawning activity, artificially fertilize the eggs, and deliver them to the hatchery. The objective in 1997 was to deliver up to 20 million fertilized American shad eggs, with a viability of 60-70 percent.

Since 1980 more than 460 million eggs have been obtained as part of the Susquehanna River anadromous fish restoration program. Annual production has ranged from 11 to 52 million eggs per year. The highest production was from the Columbia River, Oregon which was discontinued in 1989. All subsequent egg collection efforts have been made on the East Coast. Since 1995 the primary rivers used have been the Delaware and Hudson Rivers (Table 1).

PROJECT MANAGEMENT

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

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

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

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

Gill net and haul seine operations were conducted in areas of the river where it has been shown that ripe shad can be captured with consistency. Gill netting was not conducted from Friday at 6:00 PM to Saturday at 6:00 PM, in observance of a NYDEC designated lift day. Haul seining began when pre-spawned shad were available. The Wyatt Group checked the catch for ripe shad when water temperature was suitable for spawning. The project was terminated when eggs were no longer being taken regularly in a quantity (5 liters or more) which justified shipment to the Van Dyke Hatchery. This occurred when water temperature reached 64°F, in the first week of June.

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

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

COLLECTING METHODS AND SCHEDULES

Each collecting crew was assigned to a boat equipped with gill nets and the gear required for artificial fertilization and packing of shad eggs. When warranted, they fished simultaneously. The Wyatt Group project manager observed the haul seine operation to determine if conditions were appropriate for collection of ripe shad. Mr. Everett Nack, a commercial fisherman, provided two boats and six people for haul seining. A Wyatt Group collecting crew was available to help in the operation but was mainly responsible for the processing of ripe shad.

Shad were captured by gill net and haul seine. Monofilament gill nets were of 4.0 to 5.5 inch meshes, up to 1,000 feet long and 8 feet deep. Nets with larger mesh size were used primarily to capture female shad while the smaller mesh nets were used to capture male shad. Some 1,800 to 2,400 feet of net was set by each crew. Gill nets were mainly anchored at a site and tended regularly after being set, or occasionally drifted and tended after an approximately 30-45 minute drift.

The Nack haul seine fishery was conducted in the second week of May, when tidal conditions were appropriate. The haul seine was 500 feet long, 12 feet deep and had 2 inch meshes. Seine operations were conducted on an ebb tide between late afternoon and dusk. With this tidal condition, a landing site was available where the catch could be beached and processed. Ripe shad were not taken and therefore a Wyatt Group crew was not assigned to obtain eggs.

Gill netting and haul seining were planned to alternate with the changing tidal conditions with the haul seine to be used during periods of low water and gill nets at all other times. The haul seine is appropriate at the Rogers Island site because a shallow beach provides a net landing area at the low slack tide. The effectiveness of gill netting is influenced by water depth with nets typically fished in waters 4-8 feet deep.

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

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

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

Fishing commenced just before dusk and continued until ripe shad were no longer caught. Generally, this was from about 7:00 PM to 1:00 AM. Haul seining was conducted when tidal conditions provided a suitable net landing site at Rodgers Island. Usually this occurred for a 7-10 day period at a time when the water temperature was suitable for spawning. The hours for haul seining were from 4:00 - 9:00 PM.

PROCESSING AND DELIVERY OF SHAD EGGS

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

Sperm and eggs were dry mixed for about one minute followed by addition of a small amount of water to activate the sperm and ensure fertilization. Eggs were allowed to settle for 2-4 minutes after which the water was repeatedly decanted and replaced until all dead sperm, unfertilized and broken eggs and debris was removed. Eggs were then slowly poured into large plastic buckets containing at least ten gallons of clean river water where they were allowed to water harden, with periodic water replacement, for a minimum of two hours.

After the eggs water hardened they were filtered and placed into doubled plastic bags, five liters of eggs with five liters of clean river water. Pure oxygen was injected into the bag which were then secured with a rubber O-ring. Ready for shipment the bags were placed into a cooler and labeled with river location, date, volume (liters) of eggs, and water temperature.

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

RESULTS AND DISCUSSION

The first crew began sampling on 6 May. The second crew started gill netting on 13 May following the collection of more than 0.5 million eggs at Cheviot the prior day. Once the second boat began operations, it was used regularly until egg collection efforts ceased. Egg collection was ended on 3 June when water temperature reached 64°F. Sampling occurred on 25 dates during this period including 43 boat-days of gill netting. Haul seining was unsuccessful in producing ripe shad.

A total of 11.1 million eggs was shipped to the Van Dyke Hatchery (Table 2). The Van Dyke Hatchery received all eggs for culture with none being provided to Maryland's Manning Hatchery. Egg production in 1997 almost doubled that of 1996 when 5.7 million eggs were collected. Most eggs (10.4 million or 93.6%) came from two sites; 5.2 million were taken at Cheviot and 5.2 million were collected at Coxsackie. The Castleton site was about as productive in 1997 as in 1996. It accounted for 0.71 million eggs in 1997 and 0.77 million eggs in 1996.

Egg viability averaged 54.5% (Table 2) and ranged from 0.0 to 95.9% in individual shipments. The relatively low viability (as compared with previous years) is attributed to two shipments of 0.9 and 1.4 million eggs which had viabilities of 3.4 and 0.0%, respectively. In the former, water temperature in the shipping containers decreased from 54°F to 50°F during transport. In the latter, few ripe males were available for fertilization. In the future, water changes will be made before packing to ensure that temperature in the shipping containers remains within 2 degrees of the ambient river temperature. To improve fertilization, smaller mesh net will be used to in an attempt to obtain more males. The total viability for the remainder of the shipments averaged 68.4%. For these shipments the goal set for viability (60-70%) was achieved.

Eggs were collected over a period of 29 days from 6 May to 3 June. Examination of daily results (Table 5) shows that eggs were available over a short period (several days to a week) at a site. This pattern has been noticed in past years on the Hudson River. Both crews contributed about equally to the results obtained in 1997. Boat 1 first collected eggs on 12 May and by end of season took 5.675 million eggs. Boat 2 collected eggs on its first night of operation, 13 May, and completed the season with 5.405 million eggs. Each obtained eggs on a regular basis through May and only Boat 1 took eggs in June. The value of two crews operating is not restricted to egg production. Because spawning activity varies over the section of river sampled, the second crew is used to find new locations where eggs can be collected.

Weather conditions did not hamper egg collection in 1997. Sampling was suspended for only a period of 3 days (9-11 May) when efforts on 6-8 May did not result in any egg collection. Water temperature increased gradually contributing in part to consistent collection of eggs.

SUMMARY

A total of 11.1 million American shad eggs was collected from the Hudson River and delivered to the PFBC's Van Dyke Hatchery in 1997. The number of eggs was approximately double that collected in 1996. This can be attributed in great part to favorable weather and water temperature conditions. Egg viability averaged 68.5% when two aberrant collections are deleted from the calculation. The use of two boat crews provided flexibility needed on the Hudson River for obtaining maximum numbers of eggs available.

TABLE 1. Total number (millions) of American shad eggs collected from the Delaware and Hudson Rivers and delivered to the Van Dyke Hatchery, 1983-1997.

Year	Delaware	Hudson	Totals
1983	2.40	1.17	3.57
1984	2.64	-	2.64
1985	6.16	-	6.16
1986	5.86	-	5.86
1987	5.01	-	5.01
1988	2.91	-	2.91
1989	5.96	11.18	17.14
1990	13.15	14.53	27.68
1991	10.74	17.66	28.40
1992	9.60	3.00	12.60
1993	9.30	2.97	12.27
1994	10.27	6.29	16.56
1995	10.75	11.85	22.60
1996	8.31	5.69	14.00
1997	11.76	11.08	22.84
Totals	103.06	74.34	177.40

TABLE 2. Collection data for American shad eggs, Hudson River, New York, 1997.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temperature (F)	Percent Viability	Gear
12-May	16.0	629,829	1	55	78.1	Gill
13-May	28.7	895,378	3	54	3.4	Gill
14-May	28.5	898,945	5	55	71.7	Gill
15-May	26.6	767,650	6	56	72.8	Gill
17-May	27.9	889,690	8	52	61.5	Gill
18-May	23.5	709,244	10	54	68.7	Gill
19-May	14.9	444,713	11	54	67.8	Gill
20-May	20.2	563,450	14	54	55.4	Gill
21-May	7.7	232,391	16	56	65.3	Gill
24-May	7.0	251,092	17	58	63.5	Gill
25-May	6.1	229,397	18	58	38.4	Gill
26-May	7.7	270,447	20	59	58.4	Gill
27-May	10.5	372,701	22	59	76.1	Gill
27-May	15.2	550,967	23	59	48.9	Gill
28-May	5.8	288,693	25	61	91.5	Gill
28-May	25.8	1,370,595	26	61	0.0	Gill
29-May	10.5	338,496	28	62	77.9	Gill
29-May	24.3	773,297	29	62	69.3	Gill
31-May	3.1	124,528	30	62	69.1	Gill
1-Jun	6.6	244,272	32	63	83.7	Gill
3-Jun	7.2	234,643	34	64	85.3	Gill
Total	323.8	11,080,418	21	57	54.5	

TABLE 3. American shad egg totals by site, Hudson River, New York, 1997.

Site	Number of Shipments	Volume of Eggs (liters)	Number of Eggs Received	Number of Viable Eggs	Percent Viability
Kingston	0	0.0	0	0	0.0
Cheviot	9	157.6	5,205,910	3,164,914	60.8
Castleton	3	21.5	711,306	556,330	78.2
Rogers Island	0	0.0	0	0	0.0
Glasco	0	0.0	0	0	0.0
Coxsackie	9	144.7	5,163,202	2,311,825	44.8
Total	21	323.8	11,080,418	6,033,069	54.5

TABLE 4 . Summary of American shad egg collections, Hudson River, New York, 1997.

Site	Date	Water Temp (F)	Eggs Shipped Liters	Eggs Shipped Number	Eggs Shipped Viability(%)	Shad Collected Roe	Shad Collected Males	Shad Collected Ripe
Castleton	6-May	52	-	-	-	6	3	1
Castleton	7-May	50	-	-	-	0	3	0
Castleton	21-May	56	7.7	232,391	65.3	21	18	8
Castleton	1-Jun	63	6.6	244,272	83.7	17	4	6
Castleton	2-Jun	64	0.0	0	-	12	0	0
Castleton	3-Jun	64	7.2	234,643	85.3	26	10	13
Cheviot	8-May	52	-	-	-	20	29	0
Cheviot	10-May	54	-	-	-	20	13	4
Cheviot	12-May	55	16.0	629,829	78.1	56	35	40
Cheviot	13-May	54	28.7	895,378	3.4	55	44	62
Cheviot	14-May	55	28.5	898,945	71.1	85	44	40
Cheviot	15-May	56	26.6	767,650	72.8	73	35	36
Cheviot	17-May	52	27.9	889,690	61.5	31	61	47
Cheviot	24-May	58	-	-	-	12	11	5
Cheviot	25-May	59	-	-	-	39	9	13
Cheviot	27-May	59	10.5	372,701	76.1	31	9	13
Cheviot	28-May	61	5.8	288,693	91.5	-	-	-
Cheviot	29-May	62	10.5	338,496	77.9	31	10	19
Cheviot	31-May	62	3.1	124,528	69.1	36	13	11
Cheviot	1-Jun	62	-	-	-	0	8	4
			-	-	-			
Coxsackie	17-May	50	-	-	-	3	2	2
Coxsackie	18-May	54	23.5	709,244	68.7	42	16	19
Coxsackie	19-May	54	14.9	444,713	67.8	78	56	28
Coxsackie	20-May	54	20.2	563,450	55.4	42	23	23
Coxsackie	21-May	55	-	-	-	15	13	7

TABLE 4. (Continued).

Site	Date	Water Temp (F)	Eggs Shipped Liters	Number	Viability(%)	Shad Collected Roe	Males	Ripe
Coxsackie	22-May	60	-	-	-	19	6	8
Coxsackie	24-May	56	7.0	251,092	63.5	32	10	17
Coxsackie	25-May	57	6.1	229,397	38.4	21	2	18
Coxsackie	26-May	57	7.7	270,447	58.4	13	16	11
Coxsackie	27-May	58	15.2	550,967	48.9	37	7	27
Coxsackie	28-May	60	25.8	1,370,595	-	57	20	46
Coxsackie	29-May	62	24.3	773,297	69.3	60	13	37
Coxsackie	31-May	62	-	-	-	15	1	4
Glasco	18-May	54	-	-	-	33	3	10
Glasco	2-Jun	61	-	-	-	4	0	1
Shad Island	3-Jun	65	-	-	-	0	1	0
Rogers Island	10-May	54	-	-	-	100	75	0
Totals		57	323.8	11,080,418	54.5	1,142	623	580

TABLE 5. Numbers of eggs collected by date and location, Hudson River, New York, 1997.

Date	Castleton RM 137	Coxsackie RM 123	Cheviot RM 106	Glasco RM 102
6-May	0	-	-	-
7-May	0	-	-	-
8-May	-	-	0	-
9-May		LIFT DAY		
10-May		Cancelled		
11-May		Cancelled		
12-May	-	-	629,829	-
13-May	-	-	895,378	-
14-May	-	-	898,945	-
15-May	-	-	767,650	-
16-May		LIFT DAY		
17-May	-	-	889,690	-
18-May	-	709,244	-	0
19-May	-	444,713	-	-
20-May	-	563,450	-	-
21-May	232,391	0	-	-
22-May	-	0	0	-
23-May		LIFT DAY		-
24-May	-	251,092	0	-
25-May	-	229,397	0	-
26-May	-	270,447	0	-
27-May	-	550,967	372,701	
28-May	-	1,370,595	288,693	-
29-May	-	773,297	338,496	-
30-May	-	LIFT DAY	-	-
31-May	-	0	124,528	-
1-Jun	244,272	-	0	-
2-Jun	0	-	-	0
3-Jun	234,643	-	0	-
Totals	711,306	5,163,202	5,205,910	0

JOB II - Part 2
COLLECTION OF AMERICAN SHAD EGGS
FROM THE DELAWARE RIVER, 1997

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PA Fish & Boat Commission
Area 5 Fisheries Manager
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Introduction

As in past years the goal of this activity in 1997 was to collect and ship up to 15 million eggs taken from American shad captured in gill nets set in Delaware River spawning waters in the vicinity of Smithfield Beach within the Delaware Water Gap National Recreation Area near Bushkill, PA. Immediately after netting ripe shad, eggs were stripped and fertilized and allowed to harden in river water. Water-hardened eggs were sealed in plastic bags containing river water and pure oxygen, and driven 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke Hatchery near Thompsontown, PA.

Methods

Ecology III provided a boat, equipment and labor support to assist the PFBC Area Fisheries manager and his staff stationed at Bushkill, PA. Each evening during the fishing season two crews gathered at the emergency boat ramp at Smithfield Beach. As many as nineteen 200-foot gill nets with mesh sizes ranging from 4.5 to 5.75 inches were anchored on the upstream end and allowed to fish parallel to shore in a concentrated array. Netting began at dusk and on a typical evening, shad were picked from the nets two or three times before retrieving the nets at about midnight.

Both male and female shad were placed into water-filled tubs and returned to shore. Eggs were stripped from ripe female shad and fertilized in dry pans with sperm from ripe males. Once gametes were mixed, a small amount of fresh water was added and they were allowed to stand for five minutes, followed by several washings. Cleaned fertilized eggs were then placed into floating boxes with fine mesh sides which promoted a continuous flushing with fresh river water. Eggs were water hardened for about one hour.

Water-hardened shad eggs were removed from the floating boxes and placed into buckets where excess water was decanted. Eggs were then gently scooped into large double-lined plastic bags - about 5 liters of eggs and 5 liters of fresh water. Medical grade oxygen was bubbled into the bags to supersaturation and they were sealed with rubber castration rings. Bags were then placed into coolers and delivered nightly to the hatchery.

After spawning the shad, representative samples of each night's catch of both sexes were measured and weighed and scale and otolith samples were removed for later analysis. Ovaries from green females were also removed and weighed. Most adult shad did not survive the rigors of netting and artificial spawning and it was necessary to properly dispose of the carcasses. The National Park Service provided a disposal pit on park property and shad carcasses were delivered there each night and covered with hydrated lime.

Results and Discussion

Despite unusually cool weather gill netting for shad began on 13 May when the river temperature was only 12.5°C, and continued until 9 June. All Delaware River shad egg collection results for 1997 are shown in Table 1.

The shad catch during the first week ranged from 27 to 63 fish for the three nights fished resulting in shipments of 10 to 14 liters of eggs (0.25 to 0.32 million eggs). Egg viability for the first night's catch was only 55%, but it increased to 81% on the third night as the water temperature warmed to 14°C.

Gill netting occurred for five nights during the second week from 18 to 22 May. The number of shad caught and the number of eggs collected were both dependent upon river temperature. Over four-fold more eggs were collected on nights when the river temperature increased compared to nights when it decreased. About 1.5 million eggs were shipped this week.

The third week of netting resumed on 26 May following the Memorial Day weekend. River temperature steadily increased during this four-day period, and shad catch averaged over 100 fish each night. Personnel from the U.S. Fish and Wildlife Service Fish Health Lab at Lamar, PA prepared tissue cultures of internal organs from 60 of the 124 shad caught on 27 May. Over 4.7 million eggs were shipped in four nights with an average viability of 55%.

The fourth week of five nights of gill netting began on 1 June. At the beginning of this week, river temperature had reached a season high of 19°C. Shad catch decreased on the first three nights as the river temperature dropped and increased on the last two nights when the temperature increased. A total of 87 liters of eggs (3.4 million eggs) were shipped this week. Egg viability had begun to decrease compared to earlier weeks.

During the fifth and final week fishing only occurred on 8 - 9 June. Although numbers of shad captured and egg shipments were relatively high on both nights, egg viability decreased to such low percentages that continued egg collection was not justified.

Summary

Shad were collected on all 19 nights fished from 13 May through 9 June, 1997. A total of 1,298 adult shad was captured and 269.5 liters of eggs (11.76 million) were shipped to Van Dyke with a season average viability of 39.2%. More eggs were collected this year than in 1996, but viability was considerably lower. Shad catches were relatively high on most nights when the river temperature increased during the previous day and they were markedly lower on all five nights when it decreased.

TABLE 1

Delaware River Shad Egg Collection Data
13 May - 09 Jun 1997

Date	Water Temp (C)	No. of Nets Set	No. of Shad Captured	Eggs Shipped (liters)		Eggs (million)	Percent Viability
				Field Count	Van Dyke Count		
13 May	12.5	14	63	12	7.8	0.254	55.5
14 May	13.5	16	27	14	10.0	0.316	77.6
15 May	14.0	18	52	10	9.3	0.259	81.0
18 May	13.0	18	39	6	6.1	0.186	44.9
19 May	14.0	18	75	20	18.8	0.647	31.6
20 May	15.5	18	78	24	15.8	0.603	34.6
21 May	14.8	18	16	5	3.7	0.103	69.8
22 May	13.0	18	17	NO SHIPMENT			
26 May	15.5	18	89	15	10.5	0.357	69.7
27 May	16.2	19	124	45	38.8	1.807	58.5
28 May	16.5	19	103	36	25.6	0.977	60.7
29 May	17.0	18	113	51	40.0	1.575	33.0
01 Jun	19.0	19	107	27	19.3	0.865	26.1
02 Jun	17.8	18	38	12	8.5	0.308	26.4
03 Jun	16.3	18	10	NO SHIPMENT			
04 Jun	17.0	18	48	16	9.7	0.351	31.3
05 Jun	18.0	18	137	32	21.4	0.868	49.4
08 Jun	19.0	18	43	10	6.3	0.451	22.2
09 Jun	20.0	19	119	27	17.9	1.837	4.4
TOTALS		340	1,298	362	269.5	11.764	39.2*

*Mean percent viability.

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1997

M. L. Hendricks

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Benner Spring Fish Research Station

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INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous Fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River Basin. The objectives of the Van Dyke Station were to research culture techniques for American shad and to rear juveniles for release into the Juniata and Susquehanna Rivers. The program goal was to develop a stock of shad imprinted to the Susquehanna drainage, which will subsequently return to the river as spawning adults. This year's effort was supported by funds from the settlement agreement between upstream hydroelectric project owners and intervenors in the FERC re-licensing proceedings related to shad restoration in the Susquehanna River.

Production goals for 1997 were to stock 10-20 million American shad fry. All Van Dyke hatchery-reared American shad fry were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by natural spawning of transplanted adults. All eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources.

EGG SHIPMENTS

A total of 22.8 million eggs (593 L) were received in 38 shipments in 1997 (Table 1). This represented the most eggs received since 1991 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 46.6%.

Seventeen shipments of eggs were received at Van Dyke from the Delaware River (11.7 million eggs) with a viability of 39.2%. Three different sites were fished on the Hudson River, producing a total of 21 shipments (11.1 million eggs) with an overall viability of 54.4%. Two Hudson River shipments exhibited extremely low viability: shipment 3, 3.4%, and shipment 26, 0.0%. Shipment 3 was collected at a river temperature of 54F, but cooled to 50F by 9:45AM when the shipment arrived at Van Dyke. The eggs were slow tempered for 2 hr and 18 min and put in egg jars at 60F. Based on the poor viability, future shipments were not allowed to cool before shipment and tempered even slower, at one degree F per hour. Shipment 26 exhibited viability of 0.0%, possibly due to lack of sufficient sperm for fertilization. The eggs were extremely small, averaging 53,000 per liter, indicating that they had not been fertilized and did not water harden.

SURVIVAL

Overall survival of fry was 87%, compared to 94% in 1996, 91% in 1995, 78% in 1994, 66% in 1993, 41% in 1992 and a range of 70% to 90% for the period 1984 through 1991. The high survival was due to extreme vigilance in preventing mortality due to fry laying on top of each other and smothering each other in the first few days after hatch. Maintaining water temperatures at 65 or 66F instead of the usual 64F appeared to help in this regard.

Survival of individual tanks followed four patterns (Figure 1). Twenty tanks exhibited 17d survival averaging 87.3%. Six tanks, reared to 13 or more days of age, exhibited survival of 94.5%. Twenty-one tanks, reared to at least 8 days of age, exhibited survival of 98.4%. Only two tanks (D42, H31) suffered high mortality due to smothering of fry when they lay on the bottom of the tank the day after hatch. This has been an ongoing problem (Hendricks, 1996). All the mortality problems noted in 1995 and 1996 were also associated with fry laying on the bottom of the tank, beginning the morning after hatch. In the past, this was thought to be related to decreases in water temperature or force-hatching the larvae too early, when the yolk-sac is too large. In 1996, we attempted to feed the larvae earlier, beginning at 3 days of age. We continued this practice in 1997, and attempted to maintain water temperatures at 65 or 66F. Fry laying on the bottom were fed immediately, regardless of age and forced off the bottom using water jets, a squeegee, or by positioning pieces of black rubber on the bottom in the areas where the fry tended to lay. These strategies appeared to all but eliminate the problems experienced in the past. Once forced off the bottom, the fry tended to remain swimming in the water column. The presence of food appeared to help in keeping the fry swimming. In addition, we continued to plumb tanks with temporary "double down" influent pipes which direct a flow of water into the center "well" to prevent larvae from laying there and smothering each other. This procedure is absolutely essential to preventing severe mortalities.

FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 9.3 million. A total of 3.0 million was released in the Juniata River and 2.8 million in the Susquehanna River at Montgomery Ferry. American shad fry were also stocked in other main stem areas and in tributaries: 174 thousand in Conodoguinet Creek, 231 thousand in the Conestoga River, 622 thousand in the West Branch Susquehanna River, and 1.2 million in the North Branch Susquehanna River. In addition, 1.2 million fry were stocked in the Lehigh River to support restoration efforts there.

Some thirty-two thousand were transferred to raceways at Benner Spring for mark retention analysis. Five thousand were given to Chesapeake Bay Foundation for experimental classroom culture as part of a public education initiative.

TETRACYCLINE MARKING

All American shad fry produced at Van Dyke received marks produced by immersion in tetracycline (Table 5). Immersion marks were administered by bath treatments in 256 ppm oxytetracycline hydrochloride for 4h duration. All fry were marked according to stocking site. Fry stocked in the Juniata River and in the Susquehanna River at Montgomery Ferry were assigned marks as part of a study to determine if it is better to stock fry at one site or spread them out at various sites (see Appendix 1). Fry stocked at various sites in the Juniata River were marked at 3, 13 and 17 days of age. Fry stocked at Millerstown (Greenwood Access, one stocking) or in the Susquehanna River at Montgomery Ferry (nine stockings) were marked at 5 days of age. Fry stocked in the Conodoguinet Creek were given a triple mark at 11, 14, and 17 days of age. Fry stocked in the Conestoga River were given a quadruple mark at 3, 13, 17, and 21 days of age. Fry stocked in the Juniata River at Huntingdon were given a triple mark at 3, 6, and 9 days of age and stocked at 10 days of age in coordination with a public education event. Fry stocked in the North Branch Susquehanna River were given a quadruple mark at 4, 8, 12, and 16 or 5, 9, 13, and 17 days of age. Fry stocked in the West Branch Susquehanna River were given a quadruple mark at 5, 9, 13 and 21 days of age. Fry stocked in the Lehigh River were given a triple mark at 5, 9, and 13 days of age.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways and examining otolith samples collected later. Retention of tetracycline marks for American shad was 100% for all groups analyzed.

FINGERLING CULTURE

American shad marked as larvae and reared in raceways for mark retention studies were sampled for mark retention, then combined into two raceways and given a 3 day feed mark using 40g OTC per pound of food. A sample of fish from each raceway was marked with Bismark Brown dye and a mark-recapture population estimate was conducted resulting in an estimate of 25,000 fingerlings. These were stocked in Swatara Creek on Sept. 12, 1997. This group included numbers of fish with each of the eight unique immersion mark combinations, however, the single feed mark distinguishes them from all other groups released in 1997.

SUMMARY

A total of 38 shipments (22.8 million eggs) was received at Van Dyke in 1997. Total egg viability was 46.6% and survival to stocking was 87.2%, resulting in production of 9.3 million fry. The majority of the fry were stocked in the Juniata River (2.9 million) and Susquehanna River at Montgomery Ferry (2.8 million). Fry were also released in Conodoguinet Cr. (174 thousand), Conestoga River (231 thousand), the West Branch Susquehanna River (622 thousand), the North Branch Susquehanna River (1.2 million), and the Lehigh River (1.2 million). Some 25,000 fingerlings were released in Swatara Creek.

Overall survival of fry was 87.2%. The high survival was largely due to preventing smothering of fry when they lay on the bottom in the first few days after hatch.

All American shad fry cultured at Van Dyke were marked by 4 hour immersion in 256 ppm oxytetracycline. Marks were assigned based on release site, regardless of egg source. Retention of tetracycline marks was 100% for all production marks.

RECOMMENDATIONS FOR 1998

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55F.
3. Routinely feed all fry beginning at 2 days of age.
4. Rear American shad larvae at 65 to 66F instead of 64F.
5. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
6. Continue to siphon egg shells from the rearing tank within hours of egg hatch.
7. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
8. Construct new foam bottom screens for Van Dyke jars each year.
9. Do not disinfect foam bottom screens prior to use.
10. Continue to hold Delaware River eggs until 8:00AM before processing.

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Figure 1. Survival of American shad fry, Van Dyke, 1997.

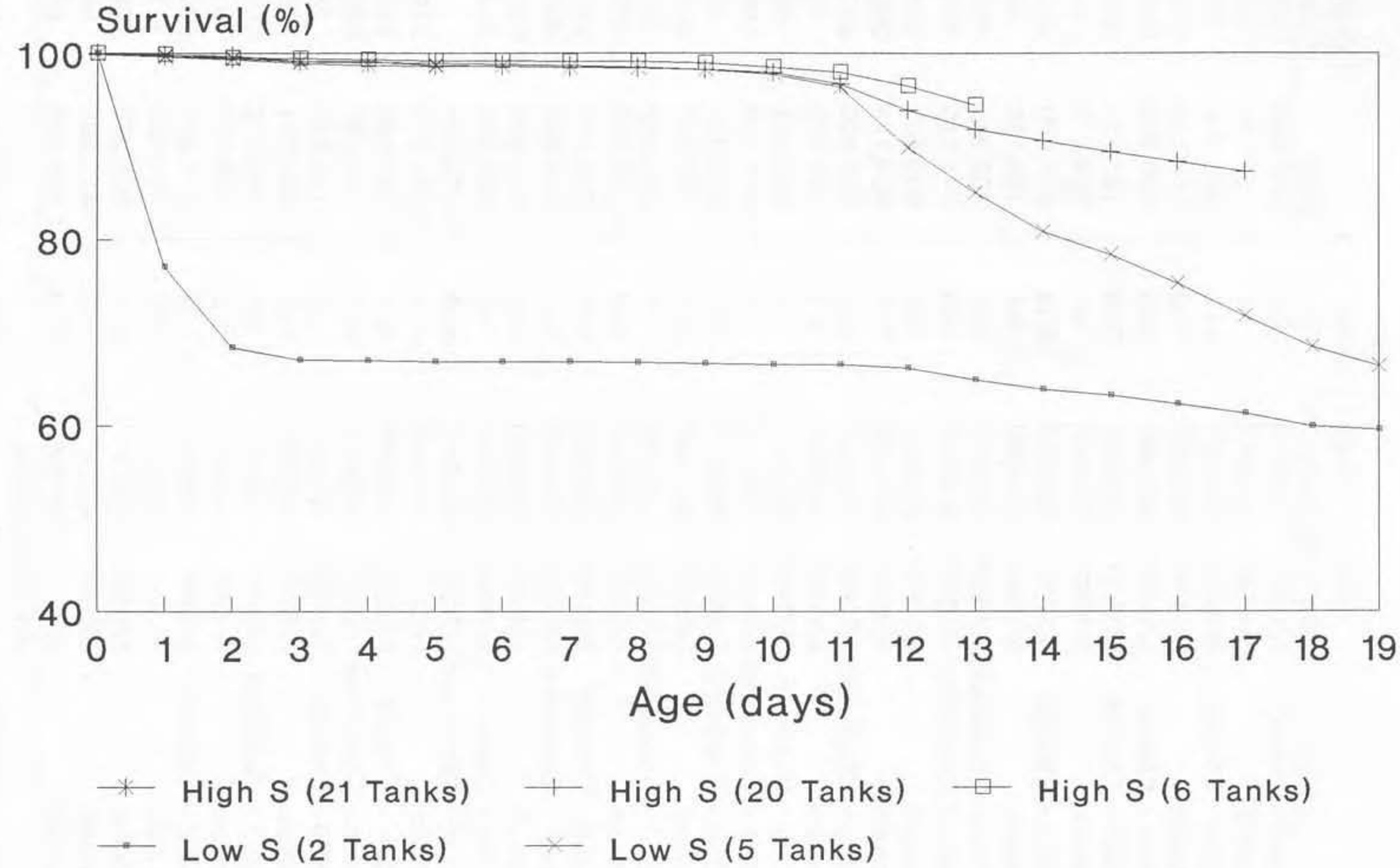

Table 1. American shad egg shipments recieved at Van Dyke, 1997.

Shipment No.	River	Date Spawned	Date Recieved	Vol. Recieved (L)	Eggs	Viable Eggs	Percent Viable
1	Hudson– Cheviot	5/12/97	5/13/97	16.0	629,829	492,115	78.1%
2	Delaware	5/13/97	5/14/97	7.8	254,197	140,961	55.5%
3	Hudson– Cheviot	5/13/97	5/14/97	28.7	895,378	30,000	3.4%
4	Delaware	5/14/97	5/15/97	10.0	315,419	244,748	77.6%
5	Hudson– Cheviot	5/14/97	5/15/97	28.5	898,945	639,515	71.1%
6	Hudson– Cheviot	5/15/97	5/16/97	26.6	767,650	558,503	72.8%
7	Delaware	5/15/97	5/16/97	9.3	259,410	210,139	81.0%
8	Hudson– Cheviot	5/17/97	5/18/97	27.9	889,690	547,046	61.5%
9	Delaware	5/18/97	5/19/97	6.1	186,155	83,527	44.9%
10	Hudson– Coxsackie	5/18/97	5/19/97	23.5	709,244	487,117	68.7%
11	Hudson– Coxsackie	5/19/97	5/20/97	14.9	444,713	301,321	67.8%
12	Delaware	5/19/97	5/20/97	18.8	646,460	204,568	31.6%
13	Delaware	5/20/97	5/21/97	15.8	603,174	208,568	34.6%
14	Hudson– Coxsackie	5/20/97	5/21/97	20.2	563,450	312,306	55.4%
15	Delaware	5/21/97	5/22/97	3.7	103,206	72,083	69.8%
16	Hudson– Castelton	5/21/97	5/22/97	7.7	232,391	151,669	65.3%
17	Hudson– Coxsackie	5/24/97	5/25/97	7.0	251,092	159,546	63.5%
18	Hudson– Coxsackie	5/25/97	5/26/97	6.1	229,397	88,179	38.4%
19	Delaware	5/26/97	5/27/97	10.5	357,227	249,042	69.7%
20	Hudson– Coxsackie	5/26/97	5/27/97	7.7	270,447	157,840	58.4%
21	Delaware	5/27/97	5/28/97	38.8	1,806,892	1,057,653	58.5%
22	Hudson– Cheviot	5/27/97	5/28/97	10.5	372,701	283,780	76.1%
23	Hudson– Coxsackie	5/27/97	5/28/97	15.2	550,967	269,424	48.9%
24	Delaware	5/28/97	5/29/97	25.6	977,294	593,265	60.7%
25	Hudson– Cheviot	5/28/97	5/29/97	5.8	288,693	264,084	91.5%
26	Hudson– Coxsackie	5/28/97	5/29/97	25.8	1,370,595	0	0.0%
27	Delaware	5/29/97	5/30/97	40.0	1,574,573	519,133	33.0%
28	Hudson– Cheviot	5/29/97	5/30/97	10.5	338,496	263,847	77.9%
29	Hudson– Coxsackie	5/29/97	5/30/97	24.3	773,297	536,092	69.3%
30	Hudson– Cheviot	5/31/97	6/1/97	3.1	124,528	86,023	69.1%
31	Delaware	6/1/97	6/2/97	19.3	864,661	225,700	26.1%
32	Hudson– Castelton	6/1/97	6/2/97	6.6	244,272	204,400	83.7%
33	Delaware	6/2/97	6/3/97	8.5	308,107	81,358	26.4%
34	Hudson– Castelton	6/3/97	6/4/97	7.2	234,643	200,261	85.3%
35	Delaware	6/4/97	6/5/97	9.7	351,604	110,006	31.3%
36	Delaware	6/5/97	6/6/97	21.4	868,359	428,671	49.4%
37	Delaware	6/8/97	6/9/97	6.3	450,697	99,919	22.2%
38	Delaware	6/9/10	6/10/97	17.9	1,836,825	81,617	4.4%
Totals		No. of shipments					
	Hudson– Cheviot	9		157.6	5,205,911	3,164,914	60.8%
	Hudson– Coxsackie	9		144.7	5,163,203	2,311,825	44.8%
	Hudson– Castelton	3		21.5	711,306	556,330	78.2%
	Delaware	17		269.5	11,764,260	4,610,957	39.2%
	Susquehanna	0		0	0	0	
	Grand Total	38		593.3	22,844,680	10,644,026	46.6%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1996.

					No. of shad stocked (all rivers)				
Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via–bility (%)	No. of Viable Eggs (exp.6)	Fry (exp.3)	Fing–erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.194	0.373
1977	146	6.4	46.7	2.9	969	35	1,003	0.159	0.342
1978	381	14.5	44.0	6.4	2,124	6	2,130	0.104	0.330
1979	165	6.4	41.4	2.6	629	34	664	0.104	0.251
1980	348	12.6	65.6	8.2	3,526	5	3,531	0.283	0.431
1981	286	11.6	44.9	5.2	2,030	24	2,053	0.177	0.393
1982	624	25.9	35.7	9.2	5,019	41	5,060	0.196	0.548
1983	939	34.5	55.6	19.2	4,048	98	4,146	0.120	0.216
1984	1,157	41.1	45.2	18.6	11,996	30	12,026	–	0.728
1985	814	25.6	40.9	10.1	6,960	115	7,075	0.279	0.682
1986	1,536	52.7	40.7	21.4	15,876	61	15,928	0.302	0.744
1987	974	33.0	47.9	15.8	10,274	81	10,355	0.314	0.655
1988	885	31.8	38.7	12.3	10,441	74	10,515	0.331	0.855
1989	1,221	42.7	60.1	25.7	22,267	60	22,327	0.523	0.869
1990	897	28.6	56.7	16.2	12,034	253	12,287	0.430	0.758
1991	903	29.8	60.7	18.1	12,963	233	13,196	0.443	0.729
1992	532	18.5	68.3	12.6	4,645	34	4,679	0.253	0.371
1993	558	21.5	58.3	12.8	7,870	79.4	7,949	0.370	0.621
1994	551	21.2	45.9	9.7	7,720 *	139.5	7,860	0.309	0.676
1995	768	22.6	53.9	12.2	10,930 *	–	10,930	0.426	0.789
1996	460	14.4	62.7	9.0	8,466 *	–	8,466	0.588	0.941
1997	593	22.8	46.6	10.6	8,019	25	8,044	0.353	0.759
						Total	171,007		
						Total since 1985 (OTC marked)	139,610		

*Includes fry reared at Manning.

Table 3. American shad stocking and transfer activities, 1996.

Date	Tank	Number	OTC mark (days)	Location	Origin	Age	Size
5/31/97	A11	245,000	3,6,9	Huntingdon	Hudson	10	Fry
5/31/97	A21	241,000	3,6,9	Huntingdon	Hudson	10	Fry
5/31/97	A21	4,000	3,6,9	Benner Spring Raceway F4	Hudson	10	Fry
6/2/97	B11	236,000	5	Millerstown (Greenwood)	Delaware	10	Fry
6/3/97	B21	213,000	5	Montgomery Ferry	Hudson	11	Fry
6/3/97	B31	173,000	5	Montgomery Ferry	Hudson	11	Fry
6/4/97	C11	177,000	5	Montgomery Ferry	Hudson	11	Fry
6/4/97	C21	171,000	5	Montgomery Ferry	Hudson	11	Fry
6/5/97	D21	180,000	5	Montgomery Ferry	Hudson	11	Fry
6/5/97	D31	82,000	5	Montgomery Ferry	Delaware	10	Fry
6/6/97	E21	156,000	5	Montgomery Ferry	Hudson	10	Fry
6/7/97	E31	147,000	5	Montgomery Ferry	Hudson	9	Fry
6/7/97	E41	150,000	5	Montgomery Ferry	Hudson	9	Fry
6/9/97	A31	152,000	3,13,17	Thompsontown	Delaware	18	Fry
6/9/97	A31	4,000	3,13,17	Benner Spring Raceway F3	Delaware	18	Fry
6/10/97	F21	99,000	5	Montgomery Ferry	Delaware	12	Fry
6/10/97	F31	93,000	5	Montgomery Ferry	Delaware	12	Fry
6/10/97	F31	4,000	5	Benner Spring Raceway F2	Delaware	12	Fry
6/11/97	A41	173,000	3,13,17	Millerstown (Rt. 17 bridge)	Hudson	19	Fry
6/11/97	B41	160,000	3,13,17	Millerstown (Rt. 17 bridge)	Hudson	18	Fry
6/11/97	C31	181,000	3,13,17	Millerstown (Rt. 17 bridge)	Delaware	18	Fry
6/12/97	G11	97,000	5	Montgomery Ferry	Hudson	14	Fry
6/12/97	G31	131,000	5	Montgomery Ferry	Hudson	13	Fry
6/12/97	H21	155,000	5	Montgomery Ferry	Hudson	8	Fry
6/13/97	C41	155,000	3,13,17	Miller's Canoe Rental	Hudson	19	Fry
6/13/97	D11	183,000	3,13,17	Miller's Canoe Rental	Hudson	19	Fry
6/16/97	D41	93,000	3,13,17	Muskrat Springs	Hudson	20	Fry
6/16/97	E11	112,000	3,13,17	Muskrat Springs	Hudson	20	Fry
6/17/97	F11	141,000	3,13,17	Mexico	Delaware	20	Fry
6/17/97	F41	98,000	3,13,17	Mexico	Hudson	19	Fry
6/18/97	G21	46,000	3,13,17	Mifflin	Delaware	19	Fry
6/19/97	H11	214,000	5,9,13	Lehigh River	Delaware	15	Fry
6/19/97	H41	385,000	5,9,13	Lehigh River	Delaware	15	Fry
6/19/97	I11	334,000	5,9,13	Lehigh River	Delaware	15	Fry
6/19/97	I21	314,000	5,9,13	Lehigh River	Delaware	15	Fry
6/19/97	I21	4,000	5,9,13	Benner Spring Raceway F1	Delaware	15	Fry
6/20/97	B32	116,000	5	Montgomery Ferry	Delaware	11	Fry
6/20/97	C22	191,000	5	Montgomery Ferry	Hudson	11	Fry
6/20/97	D22	79,000	5	Montgomery Ferry	Delaware	10	Fry
6/21/97	G41	186,000	3,13,17	Arch Rock	Hudson	20	Fry
6/22/97	E32	214,000	5	Montgomery Ferry	Delaware	9	Fry
6/22/97	F22	97,000	5	Montgomery Ferry	Delaware	6	Fry
6/23/97	H31	170,000	5,9,13,17	N. Branch Susq. R.	Hudson	19	Fry
6/23/97	I31	194,000	5,9,13,17	N. Branch Susq. R.	Hudson	19	Fry
6/23/97	I41	410,000	4,8,12,16	N. Branch Susq. R.	Delaware	17	Fry
6/23/97	J11	425,000	4,8,12,16	N. Branch Susq. R.	Delaware	17	Fry
6/23/97	J11	4,000	4,8,12,16	Benner Spring Raceway E1	Delaware	17	Fry
6/24/97	J21	174,000	11,14,17	Conodoguinet Cr.	Delaware	18	Fry
6/24/97	J21	4,000	11,14,17	Benner Spring Raceway E2	Delaware	18	Fry
6/25/97	F32	80,000	5	Montgomery Ferry	Delaware	8	Fry
6/27/97	B22	71,000	3,13,17	Treaster's Exxon	Hudson	19	Fry
6/27/97	C12	95,000	3,13,17	Treaster's Exxon	Delaware	18	Fry
6/30/97	J41	213,000	5,9,13,21	W. Branch Susq. R.	Hudson	23	Fry
6/30/97	A12	141,000	5,9,13,21	W. Branch Susq. R.	Hudson	23	Fry
6/30/97	A22	132,000	5,9,13,21	W. Branch Susq. R.	Hudson	23	Fry
6/30/97	B12	136,000	5,9,13,21	W. Branch Susq. R.	Hudson	23	Fry
6/30/97	A12	4,000	5,9,13,21	Benner Spring Raceway E3	Hudson	23	Fry
7/1/97	J31	231,000	3,13,17,21	Conestoga R.	Hudson	25	Fry
7/1/97	J31	4,000	3,13,17,21	Benner Spring Raceway E4	Hudson	25	Fry
7/1/97	D32	173,000	3,13,17	Lewistown	Hudson	20	Fry
7/1/97	E22	74,000	3,13,17	Lewistown	Delaware	19	Fry
7/1/97	E42	177,000	3,13,17	Lewistown	Delaware	18	Fry
9/12/97	Raceways	25,000	various/ single feed	Swatara Cr.	Various	?	Fing.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1997.

	Site	Fry
Releases	Millerstown (Greenwood)	236,000
	Millerstown (Rt. 17 bridge)	514,000
	Miller's Canoe Rental	338,000
	Thompsontown	152,000
	Muskrat Springs	205,000
	Mexico	239,000
	Mifflin	46,000
	Arch Rock	186,000
	Treaster's Exxon	166,000
	Lewistown	424,000
	Huntingdon	486,000
	Juniata River Sub-total	**2,992,000**
	Montgomery Ferry	2,801,000
	Conodoguinet Cr.	174,000
	Conestoga R.	231,000
	N. Branch Susq. R.	1,199,000
	W. Branch Susq. R.	622,000
	Susquehanna River Basin Sub-total	**8,019,000**
	Lehigh River	1,247,000
	Total	**9,266,000**
Transfers	Benner Spring Raceways	32,000
Fingerling Releases	Swatara Creek	25,000
	Total Fry Production	9,298,000
	Viable eggs	10,644,026
	Survival of fry (%)	**87.4%**

Table 5. Tetracycline marking regime for American shad stocked in the Chesapeake Bay watershed, 1997.

Year	Number	Size	Mark Immersion (days)	Mark Feed	Taggant Immersion	Taggant Feed	Mark Retention (%) Immers.	Mark Retention (%) Feed	Hatchery Fry Culture	Hatchery Fingerling Culture	Stocking Location	Egg Source
1997– American shad												
	236,000	Fry	5	–	256ppm OTC	–	–	–	Van Dyke	–	Juniata	Hud./Del.
	2,801,000	Fry	5	–	256ppm OTC	–	–	–	Van Dyke	–	Susq. (above Clarks Ferry)	Hud./Del.
	3,037,000	Fry	5	Subtotal			100					
	2,270,000	Fry	3,13,17	–	256ppm OTC	–	100	–	Van Dyke	–	Juniata	Hud./Del.
	486,000	Fry	3,6,9	–	256ppm OTC	–	100	–	Van Dyke	–	Jun. R. (Huntingdon)	Hudson
	622,000	Fry	5,9,13,21	–	256ppm OTC	–	100	–	Van Dyke	–	West Br. Susq. R.	Hudson
	1,199,000	Fry	5,9,13,17	–	256ppm OTC	–	100	–	Van Dyke	–	North Br. Susq. R.	Hud./Del.
	174,000	Fry	11,14,17	–	256ppm OTC	–	100	–	Van Dyke	–	Conodoguinet Cr.	Delaware
	231,000	Fry	3,13,17,21	–	256ppm OTC	–	100	–	Van Dyke	–	Conestoga R.	Hudson
	4,982,000	Fry	Subtotal									
	501,515	Fry	9,12	–	200ppm OTC	–	?	–	Manning	–	Patuxent R.	Susq.
	843,839	Fry	egg,1	–	200ppm OTC	–	?	–	Manning	–	Patuxent R.	Susq.
	345,511	Fry	6,12	–	200ppm OTC	–	?	–	Manning	–	Choptank R.	Susq.
	899,424	Fry	egg	–	200ppm OTC	–	?	–	Manning	–	Choptank R.	Susq.
	151,656	Fry	egg,6	–	200ppm OTC	–	?	–	Manning	–	Patapsco R.	Susq.
	42,188	Fry	egg	–	200ppm OTC	–	?	–	Manning	–	Nanticoke	Susq.
	50,000	Fry	egg	–	200ppm OTC	–	?	–	Ches. Bay Found.	–	Various	Susq.
	1,534,701	Fry	15	–	200ppm OTC	–	100	–	Harrison L.	–	Potomac R.	Potomac R.
	63,850	Fry	3,6,12,15	–	200ppm OTC	–	100	–	Harrison L.	–	York R.	York R.
	1,217,116	Fry	3,6,12,15	–	200ppm OTC	–	100	–	King & Queen	–	York R.	York R.
	1,280,966	Fry	Subtotal									
	4,895,893	Fry	9	–	200ppm OTC	–	100	–	King & Queen	–	James R.	York R.
	973,003	Fry	9	–	200ppm OTC	–	100	–	Harrison L.	–	James R.	York R.
	5,868,896	Fry	Subtotal									
	19,537,696	Fry	Total (American shad)									
	25,000	Fing.	various	single	256ppm OTC	40g OTC/# food	100	100	Van Dyke	Benner Spring	Swatara Cr.	Hud./Del.
	63,823	Fing.	–	single*	–	40g OTC/# food	?	?	Manning	PEPCO Ponds	Patuxent	Susq.
	32,612	Fing.	–	single*	–	40g OTC/# food	?	?	Manning	PEPCO Ponds	Choptank R.	Susq.
	121,435	Fing.	Total (American shad)									
Hickory Shad												
	3,347,330	Fry	3	–	200ppm OTC	–	?	–	Manning	–	Patuxent R.	Susq.
	1,770,725	Fry	egg,3	–	200ppm OTC	–	?	–	Manning	–	Patuxent R.	Susq.
	3,800,282	Fry	3	–	200ppm OTC	–	?	–	Manning	–	Choptank R.	Susq.
	1,770,726	Fry	egg,3	–	200ppm OTC	–	?	–	Manning	–	Choptank R.	Susq.
	1,695,070	Fry	3	–	200ppm OTC	–	?	–	Manning	–	Patapsco	Susq.
	35,982	Fing.	3	single	–	–	?	?	Manning	PEPCO Ponds	Patuxent	Susq.

*Also recieved coded wire tags

Table 6. Tetracycline mark retention for American shad reared in 1997.

Tank/ Raceway	Attempted Mark (days)	Observed Mark (days)	Number Exhibiting Mark	Projected Number Stocked	Disposition
Race E1	4,8,12,16 or 5,9,13,17	4,8,12,16 or 5,9,13,17	20/20 (100%)	1,199,000	Stocked North Br. Susq. R.
Race E2	11,14,17	11,14,17	20/20 (100%)	174,000	Stocked Conodoguinet Cr.
Race E3	5,9,13,21	5,9,13,21	20/20 (100%)	622,000	Stocked West Br. Susq. R.
Race E4	3,13,17,21	3,13,17,21	19/19 (100%)	231,000	Stocked Conestoga R.
Race F1	5,9,13	5,9,13	19/19 (100%)	1,247,000	Stocked Lehigh River
Race F2	5	5	19/19 (100%)	3,037,000	Stocked Montgomery Ferry + Millerstown (Greenwood)
Race F3	3,13,17	3,13,17	18/18 (100%)	2,270,000	Stocked Juniata River (Various sites)
Race F4	3,6,9	3,6,9	39/39 (100%)	486,000	Stocked Huntingdon
All Raceways	3d feed	3d feed	40/40 (100%)	25,000	Stocked Swatara Cr.

APPENDIX A

Survival of American shad larvae released via multiple releases at a single site vs. single releases at multiple sites.

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Introduction

American shad larvae reared at the Van Dyke Research Station for Anadromous Fish were traditionally 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.

Development of tetracycline marking has permitted evaluation of the relative success of the hatchery component of the 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, 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).

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.

Recovery rates of uniquely marked larvae stocked in 1995 and 1996 suggest that larvae released at 7 days of age may not survive any better than those released later. In 1995 and 1996, 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. Marking and recovery data for these releases are tabulated in Tables A1-1, and A1-2. In 1995, larvae released at 7 days of age exhibited lower recovery rates than 3 of the 4 other groups released at older ages. In 1996, larvae released at 7 days of age exhibited lower recovery rates than 3 groups released at older ages. One explanation for this observation is that multiple releases at any one site may be attracting predators to that site, resulting in reduced survival. Spreading larvae out by stocking at a number of sites may result in improved survival.

The purpose of this research was to determine if releasing larval shad at various sites (spreading the fish out) results in higher survival than multiple releases at a single site.

Materials and Methods

Production fish, stocked in the Juniata River, were divided into two groups with each group receiving a unique tetracycline mark. One group, marked on days 3,13, and 17, were a multiple stocking site group, in which each larval stocking took place at a different site, beginning with the first stockings at downstream sites, and moving upstream. A second group, marked on day 5, were to be stocked at a single site. Initial plans were to stock this group at Millerstown, however, only the first stocking took place at Millerstown. Subsequent stockings took place in the Susquehanna River at Montgomery Ferry. Production tanks were assigned to a group on an alternate basis for both the Hudson and Delaware River egg sources. Initial plans were to stock all larvae involved in the experiment at 18 to 22 days of age, however, hatchery capacity necessitated stocking some larvae early (see Results and Discussion).

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

The experimental design for this study was to stock all larvae at 18 days of age to block against variation in age at release. Before stocking began it became apparent that better than average egg deliveries would fill the limited hatchery space and necessitate stocking some of the larvae early to free up tank space for additional hatching larvae. Since the multiple site larvae were assigned marks on days 3, 13, and 17, they could not be stocked until 18 days of age. The single site larvae, marked at 5 days of age, had to be stocked at 8 to 14 days of age, to make room in the hatchery. Because the single site larvae were stocked at an earlier age, they were also stocked at earlier dates (Figures A1-1, A1-2). This was particularly true for the Hudson River fish.

Initial plans were to stock all the larvae in the Juniata River to block against variation in receiving stream. The initial release of the single site group occurred at the designated site (Greenwood Access, Juniata River). Subsequent to that release, the Juniata River became turbid due to precipitation in the Southwestern portion of the drainage. Since the effect of turbidity on stocked larvae is unknown, we were unwilling to stock an entire year's production in the muddy Juniata River. As a result, we stocked the remaining single site larvae in the Susquehanna River at Montgomery Ferry, a site which was not affected by turbid water. These deviations from the experimental design made it impossible to separate effects due to spreading the fish out from effects due to age at release, date of stocking, or receiving stream differences.

The 1997 data is presented in Table A1-3. Survival was best for the single site releases (relative survival 1.00), released at 8 to 14 days of age. The multiple site releases (released at 18 to 20 days of age) exhibited relative survival of 0.89, slightly lower than the single site releases. Thus, any increase in survival due to spreading the larvae out was canceled by (1) reduced survival due to turbidity, (2) increased survival in the other group resulting from stocking at an earlier age, or (3) increased survival in the other group resulting from stocking at earlier dates, or (4) some combination of the first three. The next best survival (0.77) was from larvae stocked at Huntingdon on 5/31 at 10 days of age. Larvae stocked from 17 to 19 days of age, on 6/23, in the North Branch Susquehanna River exhibited a relative survival of 0.68. Larvae stocked in the West Branch Susquehanna River, Conestoga R. and Conodoguinet Cr. were all represented in the catch but had relative survivals less than 0.37.

For comparison, relative survival for the period 1995-1997 are tabulated in Table A1-4. Note that the highest relative survival occurred at a different site each year. This suggests that spreading the fish around the basin may help to avoid localized unfavorable stocking conditions.

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Figure A1-1. Dates of larval releases in the Juniata and Susquehanna Rivers, Delaware River egg source, 1997.

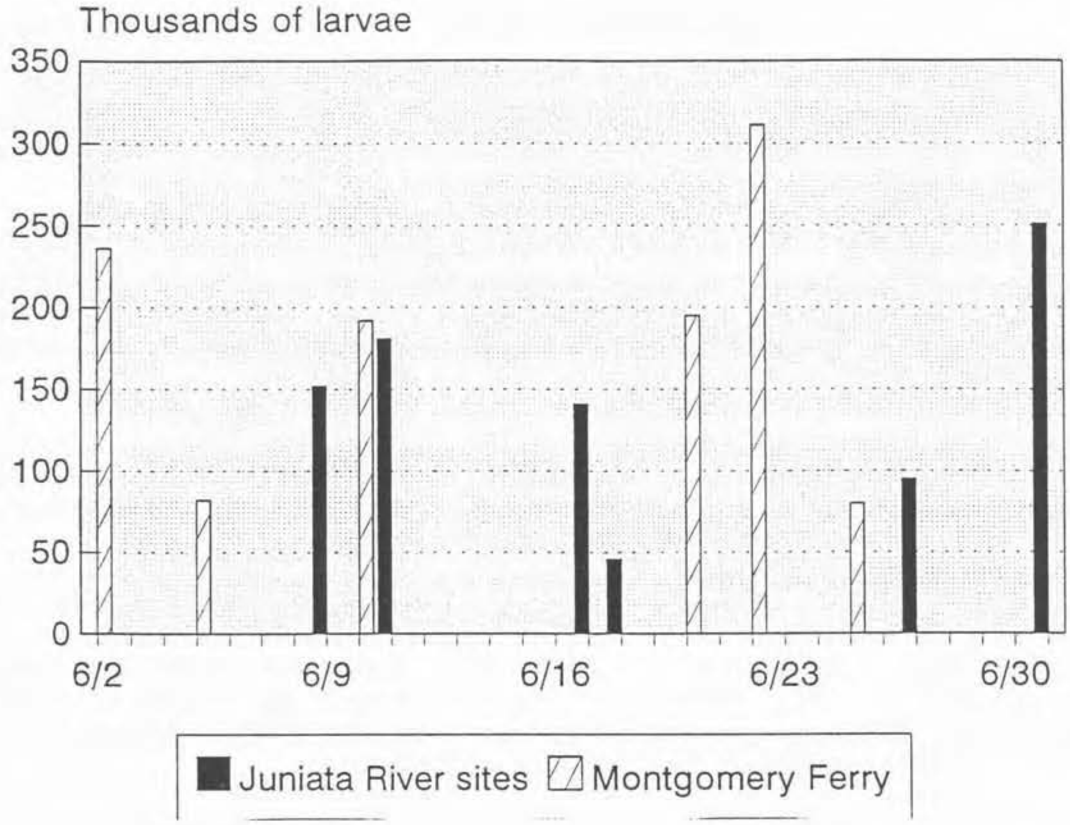

Figure A1-2. Dates of larval releases in the Juniata and Susquehanna Rivers, Hudson River egg source, 1997.

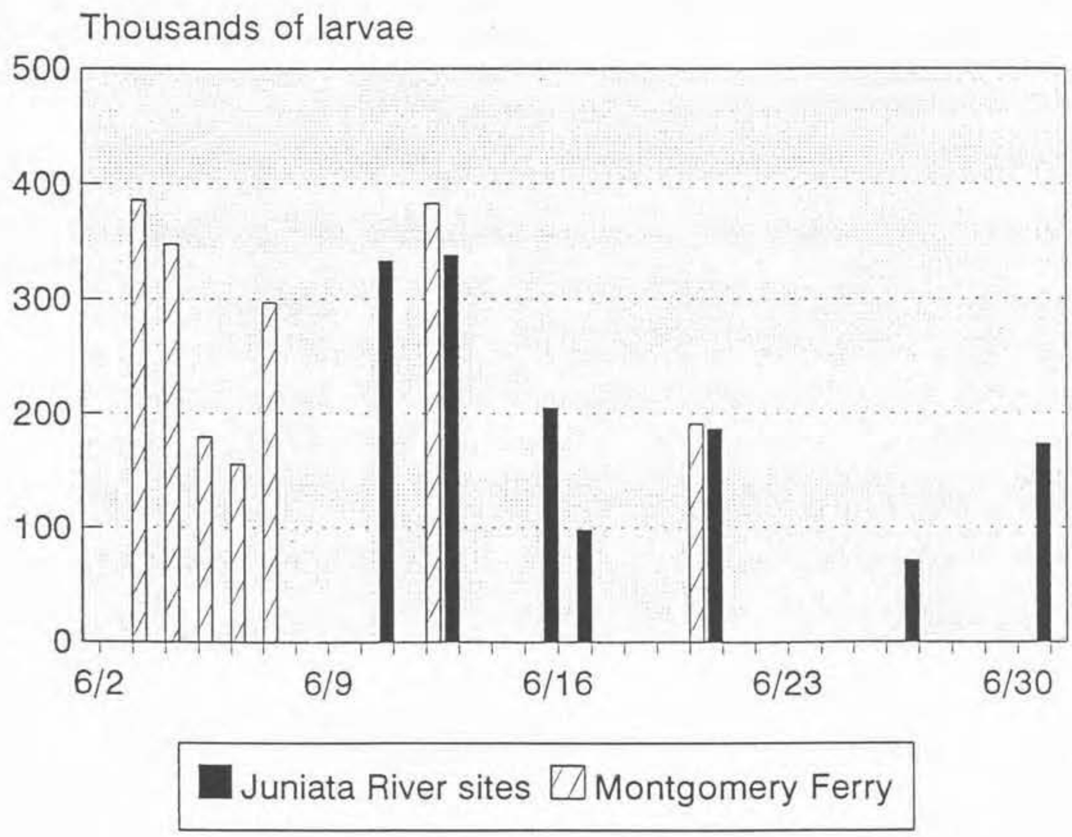

Table A1–1. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995.

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

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

Table A1–2. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1996.

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

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

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

Table A1–4. 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, 1995–1997.

Stocking Site	Recovery Rate 1995	1996	1997	Relative Survival 1995	1996	1997
Juniata R./Susq. R. @ Mont. Ferry	0.34	0.08	0.69	0.27	0.33	1.00
Juniata R.(various sites)			0.62			0.89
Huntingdon			0.53			0.77
Standing Stone Cr.		0.00			0.00	
Conodoguinet Cr.	0.23	0.12	0.17	0.18	0.50	0.25
mouth of Conodiguinet Cr.	0.39			0.31		
Conestoga R.	1.26	0.00	0.26	1.00	0.00	0.37
mouth of Conestoga Cr.	0.42			0.33		
Muddy Cr.	0.00			0.00		
W. Br. Susq. R.		0.09	0.24		0.38	0.35
N. Br. Susq. R.		0.23	0.48		1.00	0.68

JOB IV.

ABUNDANCE AND DISTRIBUTION OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER

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Introduction

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

In 1997, the Conowingo East Lift was operated in fish passage mode while the West Lift was used to transport shad and herring to spawning sites above dams. The east lift passed 103,945 American shad while new lifts at Holtwood and Safe Harbor passed 28,063 and 20,828, respectively. These fish had the opportunity to spawn naturally in the river reach below York Haven Dam. Of the 12,974 adult shad collected at Conowingo West Lift in 1997, 10,145 were hauled to stockings sites located at the Tri-County Marina and Safe Harbor Forebay during the period 24 April through 6 June. These fish had the opportunity to spawn naturally in the river reach from York Haven Dam to the Fabri Dam on the main stem and Warrior Ridge or Raystown on the Juniata. Observed transport and delayed mortalities amounted to 23 fish (0.2%). Overall sex ratio (SR) in these transfers was about 2:1 favoring males:females. This stocking level compares with about 37,500 live shad in 1996 (SR 1.1:1); 55,000 in 1995 (SR 1.1:1); 28,100 in 1994 (SR 1.8:1); 11,200 in 1993 (SR 1.3:1); 14,500 in 1992 (SR 1:1), and 22,000 in 1991 (SR 1.6:1). Approximately 28,600 blueback herring were stocked at the Tri-County Marina (18,600) and in three tributaries; Conestoga River (2,500), Little Conestoga River (2,500), and Conodoguinet Creek (5,000).

During the 1997 shad production season, the PFBC released 8.019 million shad larvae in the Susquehanna watershed. This stocking level compares with 3 to 10 million fry stocked each year in 1990 - 1996. All larvae were released between 31 May to 25 June in the following numbers, days(d) aged and locations (tetracycline marks by days of age in parentheses):

Juniata R. - Huntingdon	486,000 aged 10d (3,6,9)
Juniata R. - (various sites)	2,506,000 aged 18-20d (3,13,17)
Mifflintown/Susquehanna R.@ Montgomery Ferry	2,801,000 aged 8-14d (5)
West Branch-Montoursville	622,000 aged 23d (5,9,13,21)
North Branch-Berwick	1,199,000 aged 17-19d (5,9,13,17)
Conodoguinet Creek	174,000 aged 18d (13,17,21)
Conestoga River	231,000 aged 25d (5,13,17,21)
Swatara Creek	25,000 fingerlings (feed tag)

Juvenile American shad were collected at several locations in the

Susquehanna River basin during the summer and fall of 1997 in an effort to document relative abundance, distribution, growth, and timing of outmigration. Juvenile recoveries from all sources were provided to the Pennsylvania Fish and Boat Commission (PFBC) for analysis. Otoliths from sub-sampled shad were analyzed for tetracycline marks to determine hatchery contribution.

Methods

Juvenile American shad occurrence and outmigration in the river above Conowingo Dam was assessed at several locations during the summer and fall of 1997. Haul seining was conducted at Columbia by the Wyatt Group once each week on 15 dates during the period July through October. Sampling consisted of 6 to 10 hauls per date beginning at sunset and continuing into the evenings with a net measuring 400-ft x 6-ft with 3/8 in. stretch mesh.

Haul seining was conducted at six sites each on three tributaries using a net measuring 200-ft X 6-ft with 3/8 in. stretch mesh. Sampling began in July and continued through August at a rate of once per week at sites on the Conestoga and Little Conestoga Rivers and West Conewago Creek.

Pushnetting for juvenile alosids was conducted by the Wyatt Group at various sites on the lower Susquehanna River from 2 July until 3 September for a total of 10 sampling dates. The original pushnet design was 1.5 x 1.5 meter frame suspended from the bow of a 16-ft. jonboat on a 2.0 x 1.5 meter rectangular frame bolted to the gunwales. The net itself consisted of a 1/4-in. mesh with a mouth opening of 1.5 meters square. Net dimensions were modified in August by decreasing mouth size of the net to 1.5 x 0.75 meters and replacing the nylon mesh net with 1/2-in. monofilament netting. Each sampling date consisted of ten runs of five minutes duration with the net suspended at a depth of 1.75 meters. Pushnetting was conducted during the evening hours in deep pools or runs at Lake Frederic, Lake Aldred, Conowingo Pool and the haul seining site at Columbia.

Electrofishing was conducted by PFBC Fisheries Management staff in an effort to validate the use of this gear to effectively sample for juvenile shad in areas where seining is impractical. Three sites, two on the Susquehanna River and one on the Juniata River, were sampled using a jonboat and variable voltage pulsator electrofisher with anode mounted on a hand held pole. Sampling consisted of six 3 to 10 minute electrofishing runs per date at each site beginning at sunset and ending after dark. The Mifflintown site on the Juniata River was sampled on seven dates and Clemson Island site on the upper Susquehanna was sampled on eight dates from August into October. The Columbia site on the lower Susquehanna was sampled on six dates during approximately the same time period.

Sampling at Holtwood Dam Inner Forebay was conducted by RMC/Normandeau using a fixed 8-ft. square lift net beginning in mid-September and continuing every three days through mid-December.

Sampling began at sunset and consisted of 10 lifts with 10 minute intervals between lift cycles. A new lift net platform was constructed in 1997 to replace the one damaged during 1996 flooding. No lift netting was conducted during 1996.

At Conowingo Dam, RMC checked cooling water strainers for impinged shad bi-weekly from September through November. RMC biologists also inspected intake screen washes at Peach Bottom Atomic Power Station three times each week during October and November.

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

Results

Haul Seine Surveys

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. Haul seining was conducted at Columbia by the Wyatt Group once each week on 15 dates during the period July through October. Sampling was concentrated near the Columbia Borough boat launch since this location proved very effective in past years. A total of 879 American shad were captured in 90 hauls for an overall Catch-Per-Unit-Effort (CPUE) of 9.77. Over approximately the same time period in 1996, 1995 and 1994, CPUE in the Columbia vicinity averaged 2.70, 4.79 and 3.75, respectively. Highest daily CPUE was 28.5 per haul on 20 August, 1997. Table 1 shows juvenile shad catch and effort by date for in-river seine collections at Columbia in 1997.

The Conestoga River, Little Conestoga River and W. Conewago Creek were sampled by seine on a weekly basis from late July through late August. This is the first year this study was conducted. A total of 90 hauls were conducted at 18 stations (Table 2) on each of the three tributaries. Juvenile shad were captured on 6 and 13 August at a single site (station 5) on the Conestoga River, approximately 9.5 miles downstream of the stocking site at Conestoga Pines Park (Tables 3,4 & 5). CPUE for this site was 3.4 fish per haul.

Pushnetting Survey

Complications with net design and inexperience with gear rendered pushnetting ineffective in 1997. A total of nine migratory alosids were collected during 500 minutes of pushnetting. These include three juvenile blueback herring captured in Conowingo Pool on 29 July and six American shad captured in Lake Frederic just upstream of York Haven Dam on 22 July. Numerous gizzard shad were also collected at the various sampling sites. Pushnetting is used as an effective method of capturing juvenile alosids in many jurisdiction and it should be expected to produce similar results in

Pennsylvania. Changes in net configuration near the end of the sampling season appeared to address problems associated with original net design and insufficient tow speed. This was the first year this study was conducted.

Electrofishing Surveys

Three sites were sampled for a total of 1179 minutes of shock time producing 164 juvenile shad (Table 6). The Columbia site yielded 8.5 juveniles per hour of shock time. This compares to 11.5 fish per hour of shock time during approximately the same time period in 1996. Highest daily catch at Columbia was 26 juveniles in one hour of shock time observed on 21 October, 1997. The Clemson Island site on the Susquehanna was sampled on eight dates and yielded 5.2 juveniles per hour of shock time. This compares to 2,2 juveniles per hour of shock time during approximately the same time period in 1996. The highest daily catch at Clemson Island was 12 juveniles in one hour of shock time observed on 18 August, 1997. The Mifflintown site on the Juniata River above Thompsontown yielded 12.6 juveniles per hour of shock time. This compares to 0.3 juveniles per hour of shock time during approximately the same time period in 1996. Highest daily catch at Mifflintown was 21.2 juveniles per hour of shock time observed on 12 August, 1997. Shad stockings upstream of Mifflintown prior to sampling obviously attributed to higher catches in 1997. No shad were stocked upstream of Mifflintown in 1996.

Holtwood Dam, Peach Bottom APS, and Conowingo Dam

The lift net platform at Holtwood was damaged during 1996 flooding. It was replaced by a coffer cell and lift netting resumed in 1997 after a one year hiatus. Lift netting at Holtwood Dam Inner Forebay was conducted by RMC/Normandeau beginning in mid-September and continuing every three days through mid-December. A total of 1,372 juvenile shad were captured in 160 lifts from 18 October to 2 December for an overall CPUE of 8.6 fish per lift (Table 7). This compares 2100 juveniles in 230 lifts for a overall CPUE of 21.0 fish per lift in 1995. Highest daily catch occurred on 11 November resulting in a CPUE of 57.7 fish per lift. Twenty-six juvenile blueback herring were also captured by lift net in 1997.

With the cooperation of PECO Energy, RMC biologists examined intake screen washes for impinged American shad at the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pool. Screen sampling occurred three times a week during the period 7 November through 10 December. Collections for the season amounted to approximately 7500 fish, most of which were gizzard shad. Other anadromous fish collected were 64 American shad, 358 blueback herring, and numerous alewives.

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged fish twice per week from 3 November through 8 December. Collections for the season amounted to approximately 24,000 fish. Total number of American shad and blueback herring collected were 66 and 14, respectively.

Susquehanna River Mouth and Flats

As part of a fin fish survey, Maryland DNR researchers collected 29 juvenile American shad in the upper Chesapeake Bay during August through October.

Otolith Mark Analysis

Otoliths from 1096 juvenile American shad taken in the summer and fall collections by RMC, Wyatt Group, PFBC and Maryland DNR were analyzed for hatchery marks. A total of 600 juvenile shad otoliths from seine and electrofishing collections above Holtwood Dam was successfully processed (Table 8). Overall, 516 (86%) of the fish were marked and the remaining 84 (14%) fish were wild. All but one fish each from the Clemson Island and Mifflintown collections were hatchery produced. Seine collections from Columbia included 404 (83%) hatchery fish and 82 (17%) wild fish. Of the 17 juvenile shad captured with seines on the Conestoga River, all were hatchery produced and stocked in the Conestoga prior to sampling.

Otoliths from a total of 496 juvenile American shad collected at Holtwood Dam, Peach Bottom, and Conowingo strainers were successfully processed. Overall, 460 (93%) of the fish were marked and the remaining 36 fish (7%) were wild. Recapture of shad from various stocking sites is discussed in Job III, Appendix 1.

Only 2 fish (5%) of the 29 processed from DNR collections in the upper Bay were hatchery marked both of which were marked on day 5 and stocked at Montgomery Ferry. The remaining 27 fish (95%) were wild. Maryland DNR did not stock shad larvae in the Susquehanna River during 1997.

Discussion

<u>In-Stream Movements and Outmigration Timing</u>

The results of sampling for juvenile American shad by haul seine on the lower Susquehanna River are similar to those observed in previous years. The pattern of occurrence of juveniles, present in July and moving downstream in mid-October, remained essentially the same. The first marked fish collected at Columbia occurred on 17 July. These included a single shad of 486,000 stocked at Huntingdon on 31 May as well as those stocked at the Juniata River (various sites) and Mifflintown/Montgomery Ferry. Capture of a fish from the Huntingdon stocking suggests that a pre-migratory movement of approximately 140 miles within 47 days or less. A large proportion (48%) of the shad were captured in a two week period beginning on 20 August to 4 September. This coincided with an 2.5 fold increase in river flow from 13 August to 20 August (4,100 to 10,800 cfs). All stockings sites with the exception of the Conestoga, Conodoguinet, and Swatara were represented in the Columbia collections. Shad fry stocked in the North Branch at Berwick first appeared in the Columbia collections on 13 August, having moved downstream 120 miles in 51 days or less. Seventeen juvenile shad stocked in the Conestoga River on 7 July were collected by seines approximately 9.5 miles downstream on the Conestoga on 6 and 13 August.

The 1997 nursery season was characterized by higher than normal flows in early spring followed by lower than normal flows in summer and fall. The peak outmigration period, as determined by lift net catches at Holtwood Dam Inner Forebay, occurred from 5 November until 26 November with 99.4 percent of the juvenile shad being captured during that period. Lower than normal flows and clear water conditions delayed and condensed outmigration period until the first major freshet.

Abundance

Comparison of relative abundance of juvenile shad in the Susquehanna River from year to year remains difficult due to the opportunistic nature of net sampling and wide variation in river conditions which may influence catches. Monthly CPUE for 1997 seining at Columbia was highest in August (13.5) and lowest in July (5.2). Overall CPUE (all months combined) of 9.77 per haul is the highest recorded since standardized sampling at Columbia began in 1990. The previous record was 4.03 observed in 1990. Individual hauls produced up to 162 juvenile shad during the 1997 sampling season.

Efforts to use electrofishing to overcome inherent bias of net sampling were initiated in 1996 and have experienced only marginal success. Electrofishing CPUE (fish per hour) at Columbia was 8.5 during the 1997 sampling season. This is similar to the observed CPUE of 11.5 in 1996. However, extreme low flows in conjunction with clear water conditions apparently influenced juvenile distribution and catchability at Columbia. Areas where juveniles were abundant, and with high catches in 1996, apparently had fewer fish and low catches in 1997. Despite some drawbacks, electrofishing remains an effective method for collecting juveniles in areas where haul seining is impractical. 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. Increased electrofishing catches at upper river sites at Mifflintown (CPUE 11.9) and Clemson Island (CPUE 5.2) in 1997 may be attributed to increased survival of fry, location of upriver stocking sites, or more experienced crews. Total CPUE for electrofishing all sites combined was 8.3 fish per hour.

Juvenile shad CPUE at Peach Bottom Cool Water Intakes in 1997 (from dates of first and last occurrence in November) was 4.1 fish per sampling date. This compares to one fish captured during the entire month of November in 1996.

Resumption of lift netting at Holtwood Dam in 1997 marked the return of what is considered historically the best indicator of juvenile stock abundance. CPUE for lift netting in 1997 was 8.6 fish per lift. This is comparable to average CPUE of 7.1 from 1992 to 1995. CPUE of 8.6 fish per lift is the fourth highest since 1985. Higher than average CPUE for both lift netting and haul seining suggest good fry survival and juvenile production in 1997.

Growth

Wild juvenile shad collected with seines at Columbia averaged 57 mm total length (TL) from 17 July to 30 July (range 28-81 mm) and grew to an average 120 mm (range 110-136 mm) by 8 October to 22 October. Hatchery fish in these collections were about the same size as wild fish, growing from an average 59 mm TL (range 43-83 mm) to 123 mm (range 109-155 mm).

Stock Composition and Mark Analysis

Of the 1096 juvenile shad otoliths analyzed from collections above Conowingo Dam, 120 (11%) were unmarked. This compares to 42% wild fish in 1996 collections, and 21-58% in 1991-1995. The high percentage of hatchery juveniles observed in 1997 may be due, in part, to changes in stocking procedures. Fry were stocked at numerous sites throughout the Juniata drainage rather than consistently at 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 may have resulted reduced natural reproduction. Relative survival of larval shad from the various stocking locations, in terms of their recovery rates above and below Holtwood Dam, is discussed in Appendix 1 of Job III. In the past, Hudson River eggs had four times the survival rate as Delaware River eggs; however, it is doubtful that differences in relative survival between stocking sites could be attributed to differential survival among egg sources of stocked fry since few sites were exclusively stock from a single egg source.

Summary

Haul seining and lift netting were effective in collecting juvenile American shad during 1997. Haul seining CPUE of 9.77 was the highest ever recorded for that gear since sampling at Columbia was standardized in 1992. Tributary haul seining was less successful resulted in a CPUE of 3.4 shad per haul at a single station on the Conestoga River. No juveniles were captured by seines on the Little Conestoga River and West Conewago Creek. Lift netting at Holtwood resulted in a CPUE of 8.6 fish per lift, the fourth highest on record since 1985. Efforts continued to develop alternative methods of collecting juveniles. Pushnetting and electrofishing were conducted with only marginal success. Peak out-migration occurred during the month of November in response to fall freshets and subsequent drops in water temperatures. Relative survival of stocked fry by river system was comparable to those observed in previous years. Fry released in the Juniata and Susquehanna River and North Branch of the Susquehanna survived better than those released in the West Branch or smaller tributaries. Otolith analysis determined that only 11% of the juveniles collected were of wild origin. Despite this, observed CPUE for seining and lift netting suggest a strong year class which is directly attributed good survival in hatchery fish. The capture of juvenile blueback herring at Holtwood suggest at least limited successful reproduction of trucked and released adults.

Acknowledgements

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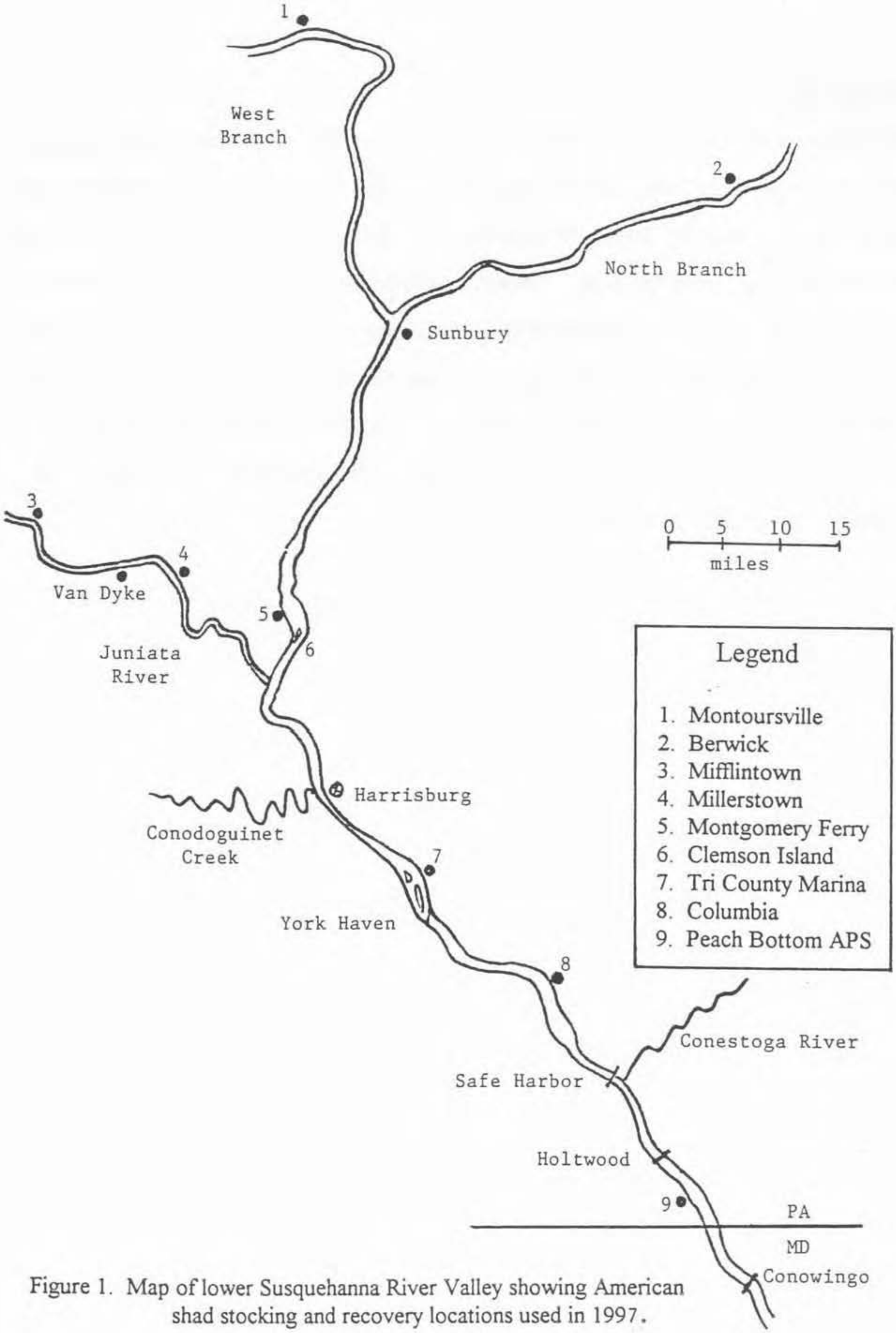

Figure 1. Map of lower Susquehanna River Valley showing American shad stocking and recovery locations used in 1997.

Table 1. Summary of Juvenile American Shad Collected with Seines in the Lower Susquehanna River near Columbia, PA, July–October, 1997.

Date	Water temp (C)	Flow (cfs)	Turbidity (NTU'S)	Number of shad	Number of hauls	Catch/ effort
7/17	28.0	7300	11.7	44	6	7.3
7/23	27.6	6500	7.8	28	6	4.7
7/30	24.7	6300	12.0	22	6	3.7
8/5	26.0	4900	6.4	14	6	2.3
8/13	25.7	4100	8.8	20	6	3.3
8/20	26.6	10800	6.1	171	6	28.5
8/26	23.3	9500	8.9	120	6	20.0
9/4	24.5	6500	8.8	129	6	21.5
9/10	22.4	5000	17.4	46	6	7.7
9/17	22.1	9000	10.0	89	6	14.8
9/25	20.9	5100	8.0	59	6	9.8
9/30	19.2	5100	8.9	32	6	5.3
10/8	17.9	12000	9.4	91	6	15.2
10/15	17.5	10400	9.7	0	6	0.0
10/22	11.0	9800	8.6	14	6	2.3
Totals				879	90	9.8

Table 2. Descriptions of Susquehanna River tributary stations sampled by haul seine in 1997.

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

Table 3. Summary of fishes collected by haul seine in the Conestoga River, 1997.

Station Number:	1	2	3	4	5	6	
Sampling Date:	29-Jul	29-Jul	29-Jul	29-Jul	29-Jul	29-Jul	
Sampling Time:	1040	1110	1140	1240	1345	1415	
Water Temperature (°F):	75	76	76	76	76	77	
Secchi:	>28	>28	>28	>36	>28	>28	
River Flow (cfs)*:	250	250	250	250	250	250	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	45	112	287	–	125	–	569
Spotfin Shiner	6	–	–	–	7	3	16
Spottail Shiner	–	4	2	53	13	4	76
Comely Shiner	15	–	–	–	–	–	15
Bluntnose Minnow	–	–	1	–	–	–	1
Carp	–	–	2	–	–	–	2
Quillback	1	21	1	3	–	–	26
Northern Hog Sucker	1	1	–	2	–	–	4
White Sucker	7	3	4	41	–	–	55
Rock Bass	–	–	–	–	–	1	1
Bluegill	–	3	–	1	–	–	4
Smallmouth Bass	2	1	2	2	–	–	7
Total	**77**	**145**	**299**	**102**	**145**	**8**	**776**
Station Number:	1	2	3	4	5	6	
Sampling Date:	06-Aug	06-Aug	06-Aug	06-Aug	06-Aug	06-Aug	
Sampling Time:	1000	1025	1050	1115	1140	1220	
Water Temperature (°F):	69	70	71	71	73	71	
Secchi:	>24	>26	>28	>24	>30	>22	
River Flow (cfs)*:	190	190	190	190	190	190	TOTAL
American Shad	–	–	–	–	15	–	15
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	122	1	363	–	–	–	486
Spotfin Shiner	5	8	20	–	21	3	57
Spottail Shiner	–	–	25	81	11	–	117
Comely Shiner	2	1	5	–	–	–	8
Bluntnose Minnow	–	–	–	26	–	–	26
Carp	–	–	1	–	–	–	1
Quillback	–	2	5	–	–	–	7
Northern Hogsucker	1	–	2	–	–	–	3
Shorthead Redhorse	–	–	1	–	–	–	1
White Sucker	2	–	30	14	–	–	46
Channel Catfish	1	–	–	–	–	–	1
Rock Bass	–	–	–	–	–	–	0
Bluegill	–	–	–	–	–	–	0
Smallmouth Bass	–	1	1	–	–	–	2
Tessellated Darter	1	–	18	–	–	–	19
Total	**134**	**13**	**471**	**121**	**47**	**3**	**789**

Table 3. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	13–Aug	13–Aug	13–Aug	13–Aug	13–Aug	13–Aug	
Sampling Time:	1030	1050	1105	1120	1130	1150	
Water Temperature (°F):	76	77	77	77	77	77	
Secchi:	>24	>36	>36	>42	>42	>24	
River Flow (cfs)*:	163	163	163	163	163	163	TOTAL
American Shad	–	–	–	–	2	–	2
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	300	46	–	–	–	–	346
Spotfin Shiner	4	18	24	–	–	6	52
Spottail Shiner	3	1	11	56	1	–	72
Comely Shiner	–	–	–	–	–	–	0
Bluntnose Minnow	–	–	–	–	–	–	0
Carp	–	–	2	–	–	–	2
Quillback	–	–	28	–	–	–	28
Northern Hogsucker	–	–	19	–	–	–	19
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	–	26	5	–	1	32
Channel Catfish	–	–	–	–	–	–	0
Rock Bass	–	–	–	–	–	–	0
Bluegill	–	–	–	–	–	–	0
Smallmouth Bass	–	1	–	–	–	–	1
Tessellated Darter	5	14	17	–	–	–	36
Total	312	80	127	61	3	7	590

Station Number:	1	2	3	4	5	6	
Sampling Date:	18–Aug	18–Aug	18–Aug	18–Aug	18–Aug	18–Aug	
Sampling Time:	1115	1135	1200	1220	1245	1310	
Water Temperature (°F):	76.5	76.5	76.5	75.5	75.5	75.5	
Secchi:	>24	>28	>28	>40	>40	>24	
River Flow (cfs)*:	225	225	225	225	225	225	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	3	11	27	9	4	12	66
Spotfin Shiner	3	2	5	1	1	–	12
Spottail Shiner	2	9	2	50	5	3	71
Comely Shiner	–	–	2	–	–	–	2
Mimic Shiner	–	–	1	–	–	–	1
Bluntnose Minnow	–	–	4	–	–	–	4
Carp	–	–	–	–	–	–	0
Quillback	–	4	2	–	–	–	6
Northern Hogsucker	–	1	2	–	–	–	3
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	2	28	3	–	–	33
Channel Catfish	–	–	–	–	–	–	0
Rock Bass	–	–	–	–	–	–	0
Pumpinseed	–	–	1	–	–	–	1
Bluegill	–	1	4	7	–	–	12
Smallmouth Bass	–	–	1	–	–	–	1
Tessellated Darter	–	–	–	–	1	–	1
Total	8	30	79	70	11	15	213

Table 3. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	28–Aug	28–Aug	28–Aug	28–Aug	28–Aug	28–Aug	
Sampling Time:	1025	1045	1105	1140	1150	1215	
Water Temperature (°F):	71	70.5	71.5	71.5	72	72	
Secchi:	>24	>24	>30	>30	>30	>30	
River Flow (cfs)*:	245	245	245	245	245	245	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	23	6	68	3	16	–	116
Spotfin Shiner	14	11	7	4	4	7	47
Spottail Shiner	–	2	4	67	3	–	76
Comely Shiner	36	2	27	–	–	–	65
Mimic Shiner	–	–	–	2	–	–	2
Bluntnose Minnow	–	–	–	27	–	–	27
Carp	–	–	–	–	–	–	0
Quillback	3	1	2	–	1	–	7
Northern Hogsucker	–	2	2	–	–	–	4
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	3	13	3	–	–	19
Yellow Bullhead	–	–	1	–	–	–	1
Channel Catfish	–	–	–	–	–	–	0
Rock Bass	–	–	–	–	–	–	0
Pumpinseed	2	1	2	3	–	1	9
Bluegill	7	2	3	13	–	1	26
Smallmouth Bass	–	–	–	–	–	–	0
Tessellated Darter	1	1	3	3	–	–	8
Total	**86**	**31**	**132**	**125**	**24**	**9**	**407**

* Provisional river flow data – USGS gauge; Conestoga River at Conestoga.

Table 4. Summary of fishes collected by haul seine in the Little Conestoga River, 1997.

Station Number:	1	2	3	4	5	6	
Sampling Date:	29–Jul	29–Jul	29–Jul	29–Jul	29–Jul	29–Jul	
Sampling Time:	810	840	855	915	930	940	
Water Temperature (°F):	73	73	72.5	70	70	70	
Secchi:	12	14	16	18	20	20	
River Flow (cfs):	No gauge	No gauge	No gauge	No gauge	No gauge	No gauge	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	–	18	286	3	307
Spotfin Shiner	–	2	–	11	3	3	19
Spottail Shiner	1	–	–	–	15	1	17
Northern Hogsucker	–	–	–	9	8	2	19
White Sucker	–	–	1	36	4	4	45
Bluegill	–	–	–	–	1	–	1
Smallmouth Bass	–	–	–	–	–	1	1
Total	1	2	1	74	317	14	409

Station Number:	1	2	3	4	5	6	
Sampling Date:	06–Aug	06–Aug	06–Aug	06–Aug	06–Aug	06–Aug	
Sampling Time:	805	830	845	901	925	940	
Water Temperature (°F):	67	64	64	64	63	63	
Secchi:	20	>24	>20	>18	>20	>18	
River Flow (cfs):	No gauge	No gauge	No gauge	No gauge	No gauge	No gauge	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	1	–	–	–	1
Spotfin Shiner	6	–	–	–	4	–	10
Creek Chub	–	–	–	1	–	–	1
Spottail Shiner	–	–	–	–	–	–	0
Northern Hogsucker	–	–	1	1	–	–	2
White Sucker	–	–	–	32	–	–	32
Rock Bass	1	–	–	–	–	–	1
Bluegill	–	–	–	–	1	–	1
Smallmouth Bass	–	–	–	–	3	–	3
Tessellated Darter	–	–	1	–	–	3	4
Total	7	0	3	34	8	3	55

Table 4. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	13–Aug	13–Aug	13–Aug	13–Aug	13–Aug	13–Aug	
Sampling Time:	730	800	815	840	920	1000	
Water Temperature (°F):	72	70.5	70.5	71	71	71	
Secchi:	>30	>12	>12	>12	>24	>12	
River Flow (cfs):	No gauge	No gauge	No gauge	No gauge	No gauge	No gauge	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	1	–	2	–	3
Spotfin Shiner	4	6	14	–	–	–	24
Comely Shiner	–	–	–	1	–	–	1
Spottail Shiner	–	–	1	–	–	–	1
Northern Hogsucker	–	–	7	–	1	–	8
White Sucker	–	–	10	–	–	–	10
Rock Bass	–	–	–	–	–	–	0
Bluegill	–	–	–	–	4	–	4
Smallmouth Bass	–	–	–	–	–	–	0
Tessellated Darter	–	–	4	2	1	1	8
Total	4	6	37	3	8	1	59

Station Number:	1	2	3	4	5	6	
Sampling Date:	18–Aug	18–Aug	18–Aug	18–Aug	18–Aug	18–Aug	
Sampling Time:	925	945	955	1015	1030	1045	
Water Temperature (°F):	73	72.5	72.5	72	71.5	71.5	
Secchi:	>30	>20	>20	>18	>30	>18	
River Flow (cfs):	No gauge	No gauge	No gauge	No gauge	No gauge	No gauge	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	–	63	23	13	99
Spotfin Shiner	–	–	1	2	–	3	6
Comely Shiner	–	–	–	–	–	–	0
Spottail Shiner	–	7	1	8	–	17	33
Quillback	–	–	–	–	–	3	3
Northern Hogsucker	–	1	1	–	–	1	3
White Sucker	13	1	–	–	–	3	17
Rock Bass	–	–	–	–	–	–	0
Bluegill	1	–	–	–	7	5	13
Smallmouth Bass	–	–	–	–	1	2	3
Tessellated Darter	–	–	–	–	1	2	3
Total	14	9	3	73	32	49	180

Table 4. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	28–Aug	28–Aug	28–Aug	28–Aug	28–Aug	28–Aug	
Sampling Time:	835	900	915	935	945	1000	
Water Temperature (°F):	68	67	67	67	65.5	66	
Secchi:	24	14	14	14	18	24	
River Flow (cfs):	No gauge	No gauge	No gauge	No gauge	No gauge	No gauge	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	2	–	1	23	17	2	45
Spotfin Shiner	9	2	3	9	2	2	27
Comely Shiner	–	–	1	2	–	–	3
Spottail Shiner	–	–	1	7	–	–	8
Bluntnose Minnow	–	1	–	2	–	–	3
Northern Hogsucker	–	–	1	–	2	1	4
White Sucker	–	–	2	6	7	3	18
Rock Bass	–	–	–	–	–	–	0
Redbreast Sunfish	1	–	–	–	–	–	1
Bluegill	–	–	–	–	–	–	0
Smallmouth Bass	–	–	–	3	–	2	5
Tessellated Darter	–	–	1	13	8	5	27
Shield Darter	–	1	–	6	–	–	7
Total	12	4	10	71	36	15	148

Table 5. Summary of fishes collected by haul seine in west Conewago Creek, 1997.

Station Number:	1	2	3	4	5	6	
Sampling Date:	30-Jul	30-Jul	30-Jul	30-Jul	30-Jul	30-Jul	
Sampling Time:	840	934	950	1030	1105	1150	
Water Temperature (°F):	74	74	73.5	73.5	74	74	
Secchi:	20	20	18	18	18	18	
River Flow (cfs)*:	81	81	81	81	81	81	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	–	21	38	13	72
Spotfin Shiner	7	3	7	6	5	2	30
Spottail Shiner	2	1	2	2	–	–	7
Bluntnose Minnow	2	1	–	–	1	–	4
Channel Catfish	–	1	–	1	–	–	2
Northern Hogsucker	–	2	–	1	–	–	3
White Sucker	2	7	–	2	–	–	11
Pumpkinseed	1	–	–	–	–	1	2
Bluegill	–	–	–	–	–	1	1
Smallmouth Bass	9	4	–	7	–	–	20
Tessellated Darter	–	–	–	–	1	–	1
Total	23	19	9	40	45	17	153

Station Number:	1	2	3	4	5	6	
Sampling Date:	07-Aug	07-Aug	07-Aug	07-Aug	07-Aug	07-Aug	
Sampling Time:	845	920	950	1005	1030	1100	
Water Temperature (°F):	68	72	71	70	71	72	
Secchi:	18	18	18	18	>20	>22	
River Flow (cfs)*:	55	55	55	55	55	55	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	4	–	–	–	4
Spotfin Shiner	–	–	6	9	14	41	70
Spottail Shiner	–	2	–	3	–	–	5
Bluntnose Minnow	–	–	–	–	–	–	0
Quillback	–	–	–	2	–	–	2
Brown Bullhead	–	–	–	1	–	–	1
Channel Catfish	–	–	–	–	–	–	0
Northern Hogsucker	–	–	–	–	–	–	0
Shorthead Redhorse	–	1	–	–	–	–	1
White Sucker	–	–	–	1	–	–	1
Pumpkinseed	–	–	–	–	–	–	0
Bluegill	–	2	–	–	–	–	2
Smallmouth Bass	1	1	1	3	1	–	7
Largemouth Bass	2	–	–	–	–	–	2
Shield Darter	–	–	–	1	–	–	1
Tessellated Darter	–	–	–	1	–	–	1
Total	3	6	11	21	15	41	97

Table 5. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	14–Aug	14–Aug	14–Aug	14–Aug	14–Aug	14–Aug	
Sampling Time:	845	915	935	950	1010	1027	
Water Temperature (°F):	75	77	77	76.5	76.5	76.5	
Secchi:	>24	>28	>24	>24	>12	38	
River Flow (cfs)*:	45	45	45	45	45	45	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	11	–	–	3	14
Spotfin Shiner	2	–	16	9	1	24	52
Spottail Shiner	–	–	9	–	–	–	9
Bluntnose Minnow	–	–	–	–	–	–	0
Creek Chub	–	–	–	–	1	–	1
Carp	–	1	–	–	–	–	1
Quillback	–	–	–	1	–	–	1
Brown Bullhead	–	–	–	–	–	–	0
Channel Catfish	–	–	–	–	–	–	0
Northern Hogsucker	–	–	–	–	–	1	1
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	4	–	–	–	–	4
Pumpkinseed	1	–	–	–	–	–	1
Bluegill	–	4	–	–	–	–	4
Smallmouth Bass	–	3	1	1	–	2	7
Largemouth Bass	2	3	–	–	–	–	5
Walleye	–	–	–	–	–	1	1
Shield Darter	–	–	–	–	–	–	0
Tessellated Darter	–	–	–	–	–	–	0
Total	5	15	37	11	2	31	101

Station Number:	1	2	3	4	5	6	
Sampling Date:	19–Aug	19–Aug	19–Aug	19–Aug	19–Aug	19–Aug	
Sampling Time:	820	845	940	1000	1015	1040	
Water Temperature (°F):	75	75.5	75.5	75	75.5	75.5	
Secchi:	>18	>20	>24	>24	>30	>28	
River Flow (cfs)*:	40	40	40	40	40	40	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	–	–	44	–	44
Spotfin Shiner	–	–	1	5	12	7	25
Spottail Shiner	3	9	7	4	9	1	33
Comely Shiner	–	–	–	–	1	–	1
Mimic Shiner	–	–	–	–	4	–	4
Common Shiner	–	–	–	1	–	–	1
Bluntnose Minnow	2	2	–	–	–	–	4
Fallfish	–	–	1	–	–	–	1
Creek Chub	–	–	–	–	–	–	0
Carp	–	–	–	–	–	–	0
Quillback	–	–	–	–	–	–	0
Brown Bullhead	–	–	–	–	–	–	0
Channel Catfish	–	–	–	–	–	–	0
Northern Hogsucker	–	–	–	–	3	–	3
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	–	14	–	–	1	15
Pumpkinseed	1	4	–	1	2	–	8
Bluegill	1	2	–	–	8	–	11
Smallmouth Bass	–	1	–	2	–	–	3
Largemouth Bass	1	–	–	–	–	–	1
Walleye	–	–	–	–	–	–	0
Shield Darter	–	–	–	1	–	–	1
Tessellated Darter	–	–	–	–	–	–	0
Total	8	18	23	14	83	9	155

Table 5. (Continued)

Station Number:	1	2	3	4	5	6	
Sampling Date:	27–Aug	27–Aug	27–Aug	27–Aug	27–Aug	27–Aug	
Sampling Time:	745	810	835	855	915	950	
Water Temperature (°F):	70	72	71	70	70	71	
Secchi:	>24	>30	>24	>24	>28	>32	
River Flow (cfs)*:	58	58	58	58	58	58	TOTAL
American Shad	–	–	–	–	–	–	0
Blueback Herring	–	–	–	–	–	–	0
Alewife	–	–	–	–	–	–	0
Gizzard Shad	–	–	–	17	–	–	17
Spotfin Shiner	7	2	27	3	16	7	62
Spottail Shiner	5	13	–	–	–	4	22
Comely Shiner	–	–	–	–	1	3	4
Mimic Shiner	6	–	–	–	–	–	6
Common Shiner	2	–	–	–	–	–	2
Bluntnose Minnow	3	9	2	–	2	–	16
Fallfish	–	–	1	–	–	–	1
Creek Chub	–	–	–	–	–	–	0
Carp	–	–	–	–	–	–	0
Quillback	–	–	–	1	–	–	1
Brown Bullhead	–	–	–	–	–	–	0
Channel Catfish	–	–	–	–	–	–	0
Northern Hogsucker	–	–	3	–	–	–	3
Shorthead Redhorse	–	–	–	–	–	–	0
White Sucker	–	–	2	–	–	–	2
Pumpkinseed	12	1	3	–	–	–	16
Bluegill	6	7	3	–	–	–	16
Smallmouth Bass	3	1	2	2	1	2	11
Largemouth Bass	2	–	–	–	–	–	2
Walleye	–	–	–	–	2	–	2
Shield Darter	1	–	–	–	–	–	1
Tessellated Darter	–	–	–	1	1	1	3
Total	47	33	43	24	23	17	187

* Provisional river flow data – USGS gauge; west Conewago Creek at Manchester.

Table 6. Summary of juvenile American shad collected by electrofishing in the Juniata and Susquehanna rivers during August – October, 1997.

Date	Site	Total Fishing time (min.)	Number of runs	Shad Caught	CPUE catch/hour
08/11	Clemson Island	60	6	4	4.0
08/12	Mifflintown	58	6	22	22.8
08/13	Columbia	60	6	0	0.0
08/18	Clemson island	59	6	12	12.2
08/19	Mifflintown	59	6	7	7.1
08/25	Clemson Island	55	6	8	8.7
08/26	Mifflintown	41	5	9	13.2
08/26	Columbia	60	6	20	20.0
09/02	Clemson Island	36	4	4	6.7
09/03	Mifflintown	60	6	10	10.0
09/08	Clemson island	58	6	1	1.0
09/09	Miffliintown	52	6	15	17.3
09/09	Columbia	60	6	0	0.0
09/17	Clemson Island	60	6	0	0.0
09/18	Mifflintown	46	6	10	13.0
09/22	Columbia	60	6	5	5.0
09/23	Clemson Island	59	6	4	4.1
09/24	Mifflintown	56	6	1	1.1
10/01	Clemson Island	60	6	6	6.0
10/07	Columbia	60	6	0	0.0
10/21	Columbia	60	6	26	26.0
Totals		1179	123	164	8.3

Table 7. Summary of Juvenile American Shad Collected with Lift Net in Holtwood Dam Inner Forebay, September–December, 1997.

Date	Water temp (C)	Flow (cfs)	Secchi (in)	Number of shad	Number of lifts	Catch/ effort
9/15	22.5	12000	40	0	10	0.0
9/18	23.0	8700	43	0	10	0.0
9/21	22.0	6800	38	0	10	0.0
9/24	24.5	5700	33	0	10	0.0
9/27	21.0	5500	45	0	10	0.0
9/30	21.0	5600	36	0	10	0.0
10/3	19.0	12200	39	0	10	0.0
10/6	19.5	9100	38	0	10	0.0
10/9	20.5	8600	40	0	10	0.0
10/12	20.5	6400	43	0	10	0.0
10/15	19.5	5300	46	0	10	0.0
10/18	20.5	5400	40	1	10	0.1
10/21	17.1	5200	40	0	10	0.0
10/24	15.5	5000	40	0	10	0.0
10/27	13.5	6000	48	3	10	0.3
10/30	13.5	5600	45	0	10	0.0
11/2	11.0	6500	50	1	10	0.1
11/5	11.0	22900	36	97	10	9.7
11/8	9.5	33600	35	79	10	7.9
11/14	9.0	87800	10	577	10	57.7
11/14	7.0	59100	25	428	10	42.8
11/17	5.0	39400	30	113	10	11.3
11/20	4.0	26900	38	41	10	4.1
11/23	5.0	25100	30	18	10	1.8
11/26	4.5	36900	40	12	10	1.2
11/29	4.5	32400	44	1	10	0.1
12/2	5.0	45500	39	1	10	0.1
12/5	4.0	45500	37	0	10	0.0
12/8	3.5	28500	48	0	10	0.0
12/11	3.0	29800	60	0	10	0.0
Totals				1372	300	4.6

Table 8. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1997.

Collection Site	Coll. Date	Immersion marks: Day 5	Days 3,6,9	Days 3,13,17	Days 5,9, 13,21	Days 5,9, 13,17	Days 13, 17,21	Days 5,13, 17,21	Days 3,6	Feed Marks: single	Hatchery Total	Wild Micro–structure Not Marked	Total
Mifflintown	8/12/97		6	14							20	1	21
	8/19/97			7							7		7
	8/26/97		5	4							9		9
	9/3/97		2	8							10		10
	9/9/97		3	12							15		15
	9/18/97			10							10		10
	9/24/97			1							1		1
Clemson I.	8/11/97	4									4		4
	8/18/97	12									12		12
	8/25/97	8									8		8
	9/2/97	4									4		4
	9/8/97	1									1		1
	9/15/97										0		0
	9/23/97	4									4		4
	10/1/97	5									5	1	6
Conestoga R.	8/6/97							15			15		15
	8/13/97							2			2		2
York Haven	8/22/97	6									6		6
Columbia	7/17/97	23	1	4							28	6	34
	7/23/97	17		6							23	4	27
	7/30/97	12		4							16	5	21
	8/5/97	5		2							7	3	10
	8/13/97	7		4		1					12	8	20
	8/20/97	29	1	6		2					38	5	43
	8/26/97	18		4							22		22

Table 8. (continued).

Collection Site	Coll. Date	Immersion marks: Day 5	Days 3,6,9	Days 3,13,17	Days 5,9, 13,21	Days 5,9, 13,17	Days 13, 17,21	Days 5,13, 17,21	Days 3,6	Feed Marks: single	Hatchery Total	Wild Wild Micro– structure Not Marked	Total
Columbia	8/28/97	24	1	7							32	12	44
(continued)	9/4/97	27	2	6							35	8	43
	9/10/97	25		4							29	1	30
	9/16/97	16	1	5							22	11	33
	9/22/97	1		3							4	1	5
	9/25/97	18	2	6		1					27	3	30
	9/30/97	12	4	7							23	6	29
	10/8/97	10	1	16							27	7	34
	10/21/97	7	1	13	2	1					24	2	26
	10/22/97	2		8		4					14		14
Above Holtwood		297	30	161	2	9	0	17	0	0	516	84	600
Percent		50%	5%	27%	0%	2%	0%	3%	0%	0%	86%	14%	
Holtwood	10/18/97							1			1		1
	10/27/97	1		1				1			3		3
	10/28/97	12		5				3			20	4	24
	10/28/97	25	2	5				1			33	1	34
	10/29/97	11	1	5							17		17
	11/2/97			1							1		1
	11/5/97	19	1	6	1						27	1	28
	11/8/97	7	1	13		5	1			1	28	2	30
	11/11/97	26	5	32	4	18					85	4	89
	11/14/97	21	2	17	2	11					53	7	60
	11/17/97	21	4	19	1	10				1	56	4	60
	11/20/97	11	1	6	3	3	1				25	5	30
	11/23/97	7	1	5	2	1	1				17	1	18

Table 8. (continued).

Collection Site	Coll. Date	Immersion marks Day 5	Days 3,6,9	Days 3,13,17	Days 5,9, 13,21	Days 5,9, 13,17	Days 13, 17,21	Days 5,13, 17,21	Days 3,6	Feed Marks single	Hatchery Total	Wild Wild Micro–structure Not Marked	Total
Holtwood	11/26/97	4		4	1	3					12		12
(continued)	11/29/97			1							1		1
	12/2/97										0	1	1
Peach	11/7/97	13	4	6		3					26	2	28
Bottom	11/10/97	3	1	1							5		5
	11/12/97	3		5		1					9		9
	11/14/97	1	1	1							3		3
	11/17/97	6									6		6
	11/19/97- 12/1/97	4		4	1	2					11	1	12
Conowingo Strainers	11/6/97– 11/17/97	16	2	3							21	3	24
Holt./P. Bot./Con.		211	26	140	15	57	3	6	0	2	460	36	496
Percent		43%	5%	28%	3%	11%	1%	1%	0%	0%	93%	7%	
Total (above Con.)		508	56	301	17	66	3	23	0	2	976	120	1096
Percent		46%	5%	27%	2%	6%	0%	2%	0%	0%	89%	11%	

Table 8. (continued).

Collection Site	Coll. Date	Immersion marks: Day 5	Days 3,6,9	Days 3,13,17	Days 5,9, 13,21	Days 5,9, 13,17	Days 13, 17,21	Days 5,13, 17,21	Days 3,6	Feed Marks: single	Hatchery Total	Wild Micro-structure Not Marked	Total
Below Conowingo:													
Hav. de Grace	not listed	2									2	1	3
Poplar Pt.	7/22/97										0	1	1
Plum Pt.	7/22/97										0	1	1
Plum Pt.	8/13/97										0	1	1
Tydings Park	8/13/97										0	3	3
Cell 2	8/20/97										0	1	1
Cell 16	8/27/97										0	2	2
Cell 17	8/27/97										0	2	2
Cell 19 & 20	8/27/97										0	6	6
Cell 21	8/27/97										0	4	4
Tydings Park	8/27/97										0	1	1
Spoil Island	9/10/97										0	1	1
Cell 1	9/16/97										0	1	1
Cell 2	9/16/97										0	1	1
Cell 21	10/30/97										0	1	1
Total (below Con.)		2	0	0	0	0	0	0	0	0	2	27	29
Percent		7%	0%	0%	0%	0%	0%	0%	0%	0%	7%	93%	

Stocking sites for immersion marks:

Day 5: Juniata R. at Millerstown or Susquehanna R. at Montgomery Ferry
Days 3,13,17: Various sites in the Juniata R.
Days 3,6,9: Juniata R. at Huntingdon
Days 13,17,21: Conodoguinet Cr.
Days 5,13,17,21: Conestoga R.
Days 5,9,13,21: W. Br. Susquehanna R.
Days 5,9,13,17: N. Br. Susquehanna R.
Days 3,6: Below Conowingo Dam
Single Feed Mark: Swatara Cr.

Job V. Analysis of adult American shad otoliths, 1997

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Abstract

A total of 254 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam fish lifts in 1997. Based on tetracycline marking and otolith microstructure, 60% of the 250 readable otoliths were identified as wild and 40% hatchery.

Wild fish represented a significantly higher proportion of the catch in samples collected in Upper Chesapeake Bay pound nets (78%) than that found in Conowingo Fish Lift collections (60%). Double marked fish (releases below Conowingo Dam) represented 5% of the marked fish in both the Conowingo Lift samples and the pound net samples.

Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1986-1993 year classes, stocking of approximately 373 hatchery larvae was required to return one adult to the lifts. For fingerlings, stocking of 168 fingerlings was required to return one adult to the lifts. For wild fish, transport of 1.51 adults to upstream areas was required to return one wild fish to the lifts. These numbers are maximum estimates, because the 1992 and 1993 year classes are not fully recruited. Actual survival is even higher since not all surviving adults enter the lifts.

Introduction

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). Funding for the project was provided by an agreement between the three upstream utilities and the appropriate state and federal agencies. The restoration approach consisted of two primary programs: 1) trapping of pre-spawn adults at Conowingo Dam and transfer to areas above dams; 2) planting of hatchery-reared fry and fingerlings.

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

The contribution to the overall adult population below Conowingo of hatchery-reared and wild fish resulting from restoration efforts was more complicated. The adult population of shad below Conowingo Dam includes: 1) wild upper bay spawning stocks which are a remnant of the formerly abundant Susquehanna River stock; 2) wild fish of upstream origin which are progeny of adults from out-of-basin or Conowingo trap and transfer efforts, 3) hatchery-reared fish originating from stockings in the Juniata River 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 1997.

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 pound nets in the upper

Chesapeake Bay as well as the Nanticoke Rivers were also sacrificed for otolith analysis. Net mortalities and moribund fish were used for the Upper Bay pound net sample.

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

For mark analysis, otoliths were ground on both sides to produce a thin sagittal section. Under white light, each otolith specimen was classified hatchery or wild based upon visual microstructural characteristics. After microstructure classification, the white light was turned off and the specimen examined under UV light for the presence of a tetracycline mark.

Whole otoliths were aged by viewing with a dissecting microscope and a fiber optic light. The best contrast was obtained by directing the light from the side, parallel to the sagittal plane of the otolith. Ageing was done by a single researcher. After initial ageing, length at age was analyzed and apparent outliers were re-examined. We have assembled a collection of approximately 15 otoliths whose age is known based on the presence of a unique tetracycline mark. These were used as reference material.

A Chi-square Test of Independence (Ott, 1973) was used to test the Upper Bay and Conowingo Lift samples to determine if the frequencies of wild and hatchery fish collected in those samples were the same. A T-test with unequal sample sizes (Ott, 1977) was used to test whether hatchery females were larger at age than wild females. Lengths were standardized by subtracting each length from the mean for that age. This allowed us to us pool data from three age classes and test the deviation from the mean length at age.

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 1997. Age composition data was gathered as follows: for 1996 and 1997, age composition data was collected from the otolith analysis above. For 1991-1995, age composition data was taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1989 and 1990, age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transport mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991).

Recruitment to the lifts by year class was determined for hatchery and wild origin fish by partitioning the lift catch for each year into its component year classes based upon age composition and otolith marking data. Total recruitment by year class was determined for hatchery and wild groups by summing the data for each year class over its recruitment history. Stock/recruitment ratios were determined for each year class by dividing total recruitment into the number of fry stocked above dams for hatchery fish, the number of fingerlings stocked above dams for fingerlings, or the number of adults transported above dams for wild fish.

Results and Discussion

A total of 254 shad was sacrificed for otolith analysis from the West lift catch at Conowingo Dam in 1997. No samples were collected from the East lift since it was operated in fish passage mode. For 4 of the sampled fish, otoliths were broken, not extracted, or had unreadable grinds, leaving 250 readable otoliths (Table 1). A total of 150 (60%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 40% of the specimens was identified as hatchery in origin. One-hundred otoliths exhibited tetracycline marks including single, double, and triple immersion marks. Four specimens (1%) exhibited feed marks, applied as pond-reared fingerlings. Two specimens (both otolith age 6) exhibited a triple immersion mark (days 3, 13, and 17) and a single feed mark, indicative of Upper Spring Creek Pond 3 culture in 1991. A third feed marked specimen (otolith age 3) exhibited a triple immersion mark (days 5, 9, and 13) and a single feed mark indicative of Canal Pond culture in 1994. The fourth feed marked specimen (otolith age 3) exhibited a double immersion mark (days 3, 17) and a single feed mark indicative of PEPCO pond culture in

1994. 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 1989-1997 ranged from 10 to 60% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish have been increasing steadily since 1993 (Figure 2).

Analysis of otoliths of adult American shad collected in Upper Chesapeake Bay pound nets suggests that the pound nets and fish lifts are sampling intermixed stocks. Wild fish contribution to the pound nets exceeded that in the lift catches in each year sampled (Table 3). Based on a Chi-square Test of Independence, we concluded that the proportion of wild and hatchery fish was dependent upon the collection site (Chi-square = 14.51, df =1, 1997 data) and therefore the samples at those two sites have different stock constituencies. Similar results were obtained in 1993 through 1996. One possible explanation for this is that Upper Bay stocks, whether wild or hatchery, do not have a strong urge to move upstream and do not enter the lifts with the same frequency as do fish which originated upstream.

Otoliths were extracted and analyzed from adult shad collected by MDNR in the Nanticoke River (Table 4). All 42 otoliths analyzed from the Nanticoke River were wild. This is comparable to a sample taken in 1996, in which all 36 otoliths were wild but contrasts with a sample taken there in 1995 in which 5 of 20 (25%) of the otoliths exhibited marks.

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 5). Overall mean age was 3.8 years for males and 4.8 years for females. For wild fish, mean ages were 3.8 for males and 4.6 for females, and sex ratios were 2.0 to 1, males to females (Table 6). For hatchery fish, mean age was 3.8 for males and 5.3 for females, and sex ratios were 2.1 to 1, males to females. The higher mean age for hatchery females (Table 6) may be related to a good returns from the 1991 hatchery year class (age 6), followed by poor returns from the 1992 and 1993 year classes (4 and 5 year olds). This is also apparent in the poor returns of age 4 hatchery males, in comparison to age 4 wild males.

Length frequencies and mean length at age are tabulated in Tables 7 to 10. As expected, females were larger than males. The apparent differences in length frequencies between wild and hatchery fish for females were related to differences in age composition resulting from the poor hatchery production in 1992 and 1993. Hatchery females were larger at age for ages 4, 5 and 6 than wild females (Table 10, t-test, t = 3.02, df= 74, a= .05). We have no explanation for this phenomenon.

Adult shad collected at the lifts were partitioned into their respective year classes using scale or otolith age data and corrected for hatchery contribution (Table 11). Analysis of otoliths to assess hatchery contribution was not conducted prior to 1989. As a result, data for year classes prior to 1986 could not be partitioned into hatchery and wild and are not presented (Table

11). Year classes after 1991 are not fully recruited, however, recruitment from the 1992 and 1993 year classes was above the long term average, and is included in the analysis. For the period 1986-1993, the number of hatchery larvae required to produce one returning adult ranged from 151 to 620, with a mean of 373. This is a maximum estimate since the 1992 and 1993 year classes are not fully recruited.

The number of hatchery larvae required to produce one returning adult was surprisingly low in comparison to wild fish. If fecundity of wild shad is assumed to be 200,000, then 2 of 200,000 eggs must survive to maturity to replace the spawning pair in a stable population. If we assume a fertilization rate of 60% (comparable to strip-spawning), 60,000 fertilized eggs would be required to produce one wild adult at replacement.

This analysis was repeated for fingerlings stocked above Conowingo Dam (Table 12). For the period 1986-1993, the number of hatchery fingerlings required to produce one returning adult ranged from 59 to 392, with a mean of 168. Again, this is a maximum estimate since the 1992 and 1993 year classes are not fully recruited. At first glance, it would appear that stocking fingerlings is advantageous over stocking larvae, however, on average, one must stock 100,000 larvae in a pond to harvest 10,000 to 20,000 fingerlings. Therefore, it would take 840 to 1,690 larvae, stocked in a pond, harvested and stocked in the river as fingerlings to produce one adult. Considering the cost of pond culture, it is clearly better to stock larvae directly.

A similar analysis was tabulated for wild fish (Table 13). For the period 1986 to 1993, transport of an average of 1.51 adults was required to produce one returning adult, below replacement. The actual stock/recruitment ratio of wild fish is unknown since some of the wild fish which entered the lifts would have been of Upper Bay origin and not all recruited fish entered the lifts. These factors may act to cancel each other out, but the magnitude of each is not known. Stress during trucking may account for reduced performance of transported spawners. The high fecundity of the species has the potential to overcome this, since just a few successful spawners can produce huge numbers of offspring. Another possible explanation is that there may be some threshold number of spawners required to ensure successful spawning. Whatever the cause, stock/recruitment ratios are improving for recent years and must do so to allow for successful restoration.

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Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1997.

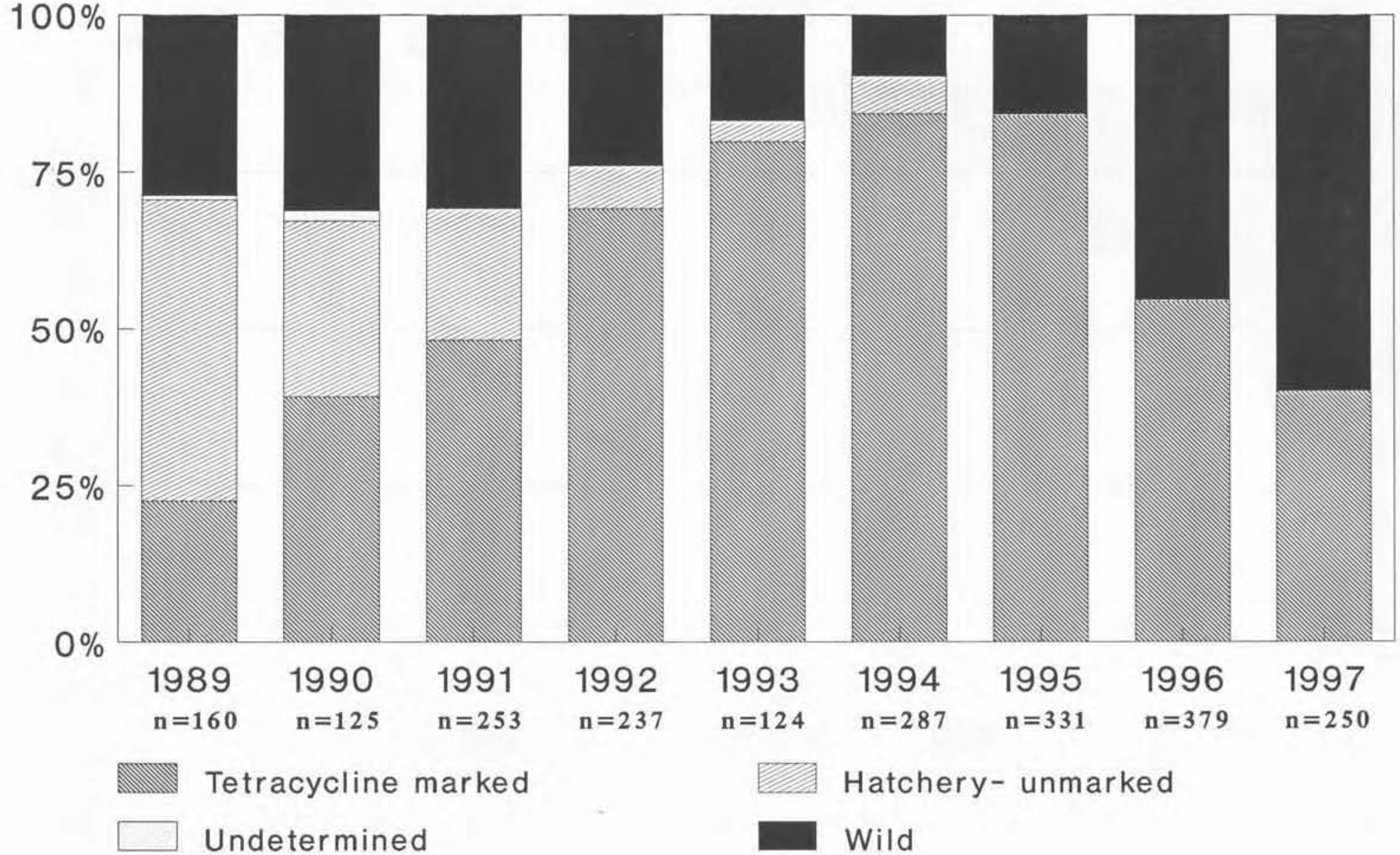

Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts, 1972-1997.

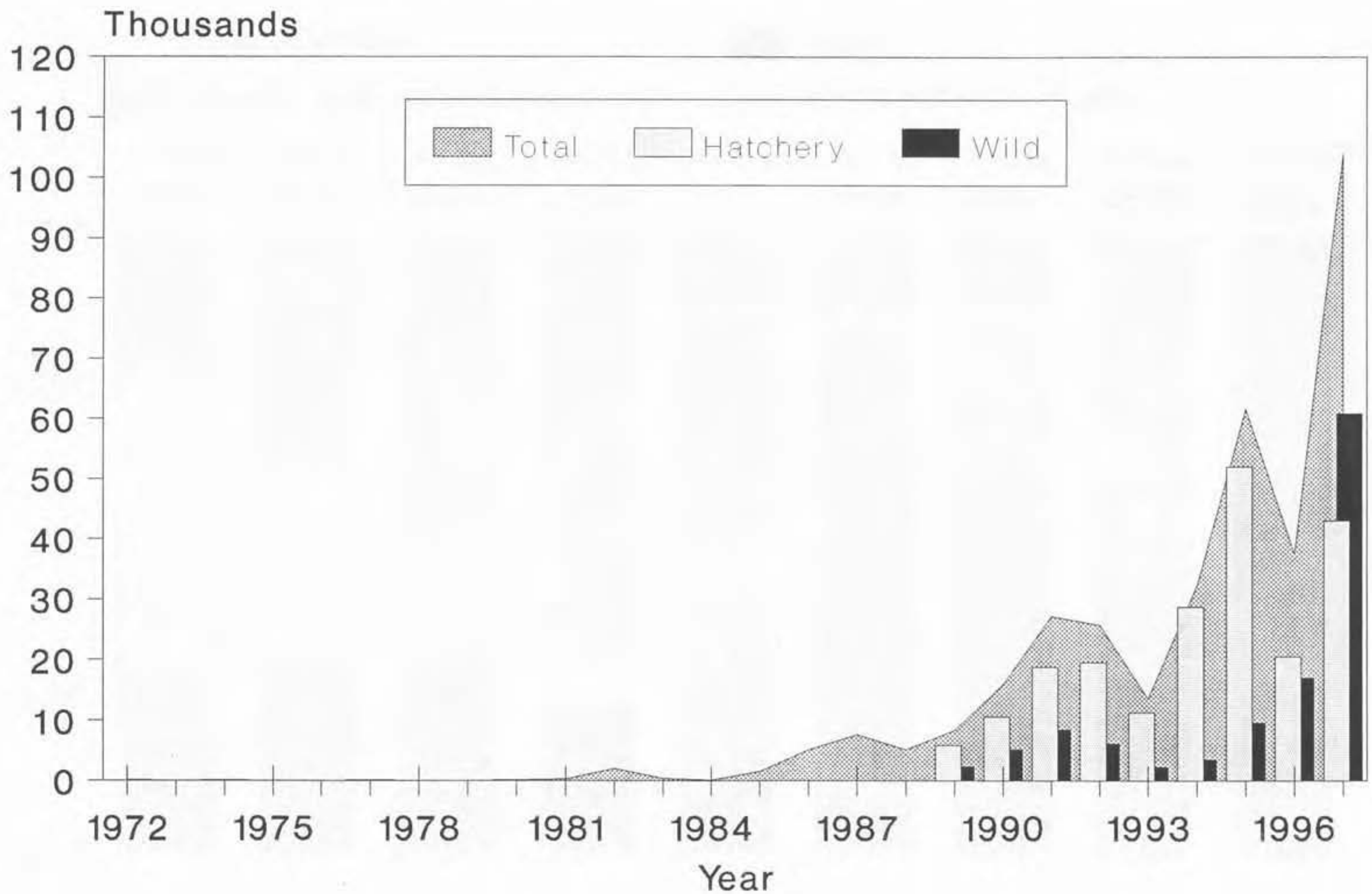

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam West Fish Lift and Susquehanna Flats pound nets, 1997. One of every 50 fish collected in the West Lift was sacrificed.

			Conowingo Dam		Susq. Flats	
			N	%	N	%
Wild Microstructure, No TC Mark			150	60%	125	78%
Hatchery Microstructure	No TC Mark*		–	0%	–	0%
	Single TC Mark	Day 5	20	8%	7	4%
		Day 18	1	0%	–	0%
	Double TC Mark	Days 5,9	10	4%	7	4%
		Days 3,17	2	1%	1	1%
	Triple TC Mark	Days 5,9,13	25	10%	6	4%
		Days 3,13,17	38	15%	12	8%
	Quintuple TC Mark	Days 5,9,13,17,21	–	0%	1	1%
	Feed Marks	Days 3,13,17 + single feed mark	2	1%	1	1%
		Days 3,17 + single feed mark	1	0%	–	0%
		Days 5,9,13 + single feed mark	1	0%	–	0%
		Total Hatchery	100	40%	35	22%
		Total readable otoliths	250		160	
		Unreadable Otoliths**	4		3	
		Total	254		163	

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

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

	Hatchery										
	Larvae										
	Susquehanna		below Conowingo Dam		Fingerling		Unmarked**	Naturally reproduced		Total sample size
Year	N	%*	N	%*	N	%*	N	N	%	
1989	36	82	–		–		94	29	18	159
1990	49	73	1	1	–		42	32	26	124
1991	111	67	8	5	3	2	63	68	27	253
1992	154	73	8	4	2	1	19	54	23	237
1993	76	64	21	18	2	2	4	21	17	124
1994	217	81	22	8	3	1	17	28	10	287
1995	255	77	19	6	4	1	1	52	16	331
1996	180	48	22	6	4	1	1	172	45	379
1997	84	34	12	5	4	2	0	150	60	250
Totals	1,078	68	101	6	18	1	241	456	24	1,894

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

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

	Pound net											
	Hatchery											
	Larvae											
	Susquehanna		below Conowingo Dam		Fingerling		Unmarked	Naturally reproduced		Naturally reproduced in lift catch	Total pound net sample size
Year	N	%	N	%	N	%	N	N	%	%	
1993	9	36	3	12		0	11	25	52	17	48
1994	12	26	14	30	–	0	7	26	44	10	59
1995	34	30	29	25	3	3	–	48	42	16	114
1996	20	17	12	10	2	2	–	81	70	45	115
1997	26	16	8	5	1	1	–	125	78	60	160
Totals	75	25	58	20	5	2	18	180	54	31	336

Table 4. Microstructure classification and tetracycline marking of adult American shad collected in the Nanticoke River, 1997.

			Nanticoke River N	Nanticoke River %
Wild Microstructure, No TC Mark			42	100%
Hatchery Microstructure	No TC Mark*		–	0%
	Single TC Mark	Day 5	–	0%
		Day 18	–	0%
	Double TC Mark	Days 5,9	–	0%
		Days 3,17	–	0%
	Triple TC Mark	Days 5,9,13	–	0%
		Days 3,13,17	–	0%
	Quadruple TC Mark	Days 5,9,13,17	–	0%
		Days 3,13,17,21	–	0%
		Days 3,7,11,21	–	0%
	Quintuple TC Mark	Days 5,9,13,17,21	–	0%
	Feed Marks	Days 3,13,17 + single feed mark	–	0%
		Days 3,17 + single feed mark	–	0%
		Days 3,13,17,21 + single feed mark	–	0%
		Days 5,9,13 + single feed mark	–	0%
		Total Hatchery	0	0%
		Total readable otoliths	42	
		Unreadable Otoliths**	0	
		Total	42	

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

Table 5. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1997.

Sex	2	3	4	5	6	7	8	??	Totals	Mean
Male		63	83	18	5			1	170	3.8
Female	1	2	28	27	21			1	80	4.8
Unknown									0	
Totals	1	65	111	45	26	0	0	2	250	4.1

Table 6. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1997.

Sex	2	3	4	5	6	7	8	??	Totals	Mean
Male– Wild		33	58	5	3				99	3.8
Male– Hatc.		28	24	12	2			2	68	3.8
Female– Wild		2	23	16	9				50	4.6
Female– Hatc.	1		5	11	12	2		1	32	5.3
Totals	1	63	110	44	26	2	0	3	249	4.2

Table 7. Length frequency by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 1997.

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		10	61	42	38	18	3						172
Female			3	3	13	26	17	15	3	2			82
Unknown													0
Totals	0	10	64	45	51	44	20	15	3	2	0	0	254

Table 8. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, 1997.

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		4	36	30	17	11	1						99
Male– Hatc.		5	24	11	20	6	2						68
Female– Wild			2	3	13	18	7	7					50
Female– Hatc.			1			8	10	8	3	2			32
Totals	0	9	63	44	50	43	20	15	3	2	0	0	249

Table 9. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1997.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)
Male			366	(63)	394	(84)	431	(18)	424	(5)		
Female	375	(1)	390	(2)	429	(28)	455	(27)	476	(21)	495	(2)

Table 10. Mean length at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo West Fish Lift, Susquehanna River, 1997.

Sex	2	(n)	3	(n)	4	(n)	5	(n)	6	(n)	7	(n)
Male– Wild			369	(33)	392	(58)	437	(5)	426	(3)		
Male– Hatc.			365	(28)	399	(24)	427	(12)	422	(2)		
Female– Wild			390	(2)	425	(23)	447	(16)	464	(9)		
Female– Hatc.	375	(1)			448	(5)	467	(11)	484	(12)	495	(2)

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

Year	Fish lift catch	% Age composition 8	7	6	5	4	3	2	Hatchery larvae %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		13 *							
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	82%	373	16						
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	73%	1,706	166	0					
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	67%	6,956	2,250	307	0				
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	73%	6,652	6,870	2,181	545	0			
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	64%	277	1,867	4,563	1,867	69	0		
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	81%	0	859	5,918	14,318	5,059	0	0	
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	77%		0	1,954	10,522	29,313	5,561	301	0
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	48%			0	152	2,881	7,430	6,015	1,365
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	34%				0	0	3,676	6,363	15,695
									Total recruits to lifts:	15,977	12,028	14,924	27,404	37,322	16,668	12,679	17,060
									Larval releases (millions):	9.90	5.18	6.45	13.46	5.62	7.22	3.04	6.54
									Number of larvae to return 1 adult:	620	431	432	491	151	433	240	383
									Mean number of larvae to return 1 adult (1986–1993):	373							

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

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

Year	Fish Lift Catch	% Age Composition 8	7	6	5	4	3	2	Fingerling Contribution %	Cohort 1986	1987	1988	1989	1990	1991	1992	1993
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2		0	0						
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0		0	0	0					
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	2%	188	61	8	0				
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	1%	83	85	27	7	0			
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	2%	7	50	122	50	2	0		
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	1%	0	12	80	195	69	0	0	
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	1%		0	30	163	455	86	5	0
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	1%			0	3	66	171	139	31
1997	103,945	0.0	0.0	10.5	18.1	44.8	26.2	0.4	1%				0	0	132	228	563
Total Recruits to Lifts:										278	208	268	418	592	390	372	594
Fingerlings stocked/10,000:										7.25	8.15	6.40	6.04	9.00	5.44	2.18	7.94
No. of fingerlings to return 1 adult:										261	392	239	144	152	140	59	134
Mean No. of fingerlings to return 1 adult (1986–1993):										168							

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

	Fish Lift	% Age Composition							Naturally Reproduced			Cohort					
Year	Catch	8	7	6	5	4	3	2	%	1986	1987	1988	1989	1990	1991	1992	1993
1988	5,146	0.0	4.0	31.7	38.1	21.2	4.7	0.4		4 *							
1989	8,218	0.0	4.3	18.1	41.5	30.2	5.6	0.2	18%	83	4						
1990	15,719	0.1	5.5	32.7	45.2	15.0	1.5	0.0	26%	612	59	0					
1991	27,227	0.0	10.7	36.7	38.4	12.4	1.7	0.0	27%	2814	910	124	0				
1992	25,721	0.6	12.3	35.7	36.8	11.7	2.9	0.0	23%	2092	2161	686	171	0			
1993	13,546	0.0	3.2	21.6	52.8	21.6	0.8	0.0	17%	73	494	1209	494	18	0		
1994	32,330	0.0	3.3	22.6	54.7	19.3	0.0	0.0	10%	0	104	717	1734	613	0	0	
1995	61,650	0.0	4.1	22.1	61.5	11.7	0.6	0.0	16%		0	397	2137	5954	1130	61	0
1996	37,513	0.0	0.8	16.1	41.5	33.6	7.6	0.3	45%			0	144	2742	7072	5725	1299
1997	103,945	0.0	0.0	10	18	45	26	0.4	60%				0	0	6538	11317	27914
Total Recruits to Lifts:										5,678	3,732	3,133	4,682	9,327	14,740	17,103	29,213
Adults transported/1000:										4.2	7.2	4.7	6.5	15.1	24.7	15.7	11.7
No. of adults transported to return 1 adult:										0.73	1.93	1.51	1.38	1.62	1.67	0.92	0.40

Mean No. of adults transported to return 1 adult (1986–1993): 1.51

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

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

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Introduction

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

Methods and Materials

Collection procedures for adult American shad in 1997 were nearly identical to those in 1996. Two commercial pound nets were sampled, one at Cherry Tree Point in Aberdeen Proving Ground and one at Rocky Point in the Susquehanna Flats (Figure 1). Hook and line sampling in the Conowingo tailrace continued unchanged from the previous year. Tagging procedures and data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Results

Pound net tagging for 1997 began on 24 March and continued until 18 May, while hook and line effort commenced on 23 April and ended 22 May. Of the 1,775 adult American shad captured, 1,035 (58.3%) were tagged and 144 (8.1%) subsequently recaptured (Table 1). The 144 total does not reflect 1 multiple recapture, 1 recapture outside the system from the Delaware River, and 17 fish marked in 1996. Recapture data for the 1997 season is summarized as follows:

144 fish recaptured or observed in the Conowingo Fish Lifts

1 fish recaptured by pound net

0 fish recaptured by hook and line from the tailrace

1 fish recaptured outside the system

1 multiple recapture

17 recaptured fish marked in 1996

The 1997 adult American shad Petersen population estimate for the upper Chesapeake Bay was 708,628 (Table 2, Figure 2), and has been increasing exponentially since 1980 (r^2=0.85, $P \leq 0.05$). Since one recapture occurred outside the upper Bay system, an emigration factor was calculated for the upper Bay estimate in order to adjust the number of fish marked from pound nets but lost and unavailable for later recapture. The Conowingo tailrace population estimate for 1997 was 423,324 (Table 3, Figure 3), and has also been increasing exponentially since 1984 (r^2=0.71, $P \leq 0.05$). A 3% adjustment for tag loss was included for both estimates.

Effort, catch, and catch-per-unit-effort (CPUE) by gear type for adult American shad in the upper Bay during 1997 and comparison with previous years is presented in Table 4. Estimates of pound net (1980-1997) and hook and line (1984-1997) CPUE have increased linearly during these time periods (r^2=0.41, $P \leq 0.02$; r^2=0.50, $P \leq 0.01$, respectively).

Prior to 1997, all American shad captured from both fish lifts were individually handled so that all fish, both marked and unmarked, could be totaled. Beginning in 1997, the East fish lift became fully automated. Consequently, both total counts and numbers of tagged shad were recorded by two trained observers stationed at the East lift viewing chamber. This change in operating procedure at the East lift increased the chances of missing both tagged and untagged American shad as well as double counting fish previously captured and released from the West lift, and including pre-1997 marked fish in with 1997 totals. These errors would, therefore, reduce the accuracy of the Petersen estimates.

Relative abundance of American shad can, however, be estimated and associated trends noted by examining the annual CPUE data of the various collecting gears. Measures of relative abundance from pound nets, hook and line, and the Conowingo fish lifts have been calculated as the geometric means (based on log e transformations) of fish caught per pound net day, fish caught per angling hour, and fish caught per lift hour, respectively. This data was log e transformed and geometric means used in order to normalize the data.

Analysis of these CPUE estimates indicates that the catch of adult American shad has been linearly increasing in all three gear types over time: pound net (1980-1997) $r^2 = 0.41$, $P = 0.02$; hook and line (1984-1997) $r^2 = 0.50$, $P = 0.50$;, fish lifts (1980-1997) $r^2 = 0.90$, $P < 0.0001$ (Figure 4). Comparisons of these CPUE estimates to both the upper Bay and tailrace Petersen estimates from 1980 to 1996 indicate that:

* pound net, hook and line, and fish lift CPUE's were correlated with log e transformed upper Bay estimates (Table 5, Figure 5);
* hook and line and fish lift CPUE's were correlated with log e transformed tailrace estimates (Table 5, Figure 6).

The increasing trends in CPUE over time for pound nets, hook and line, and the fish lifts through 1997 and the associated positive correlations between these CPUE's and Petersen estimates prior to 1997 provide strong evidence that the entire upper Bay American shad population, including the tailrace, continued to significantly increase in 1997. The magnitude of this increase, however, cannot be determined until the counting errors associated with the East lift operating procedures are further analyzed.

A total of 358 adult American shad (264 pound net, 94 hook and line) were examined for physical characteristics by DNR biologists in 1997 (Table 6). The 1993 year-class (age 4, sexes combined) was the most abundant year-class sampled in the upper Bay by pound net and hook and line, accounting for 52% of the total catch (Table 6). Age frequency modes occurred at age 4 for pound net males and at age 5 for hook and line males. Age frequency modes for females occurred at age 4 for both pound net and hook and line catches. Both sexes (gears combined) were present in age groups 3-7; there were 3 age 8 females collected. Males were more abundant at ages 3-5, and females were more abundant at ages 4-6. The overall incidence of repeat spawning in male American shad increased from 13.6% in 1996 to 25.4% in 1997. Similarly, female American shad repeat spawning increased from 19.0% in 1996 to 28.9% in 1997.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1997.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	658	246
	Rocky Point	510	218
	Subtotal	1168	464
Hook and Line	Conowingo Tailrace	607	571
Fish Lifts	Conowingo Tailrace	103945	
	TOTALS	105720	1035

Table 2. Upper Chesapeake Bay population estimate of adult American shad in 1997 using the Petersen statistic.

Chapman's Modification to the Petersen statistic -

$$N = \frac{(C + 1)(M + 1)}{R + 1}$$

where N = population estimate
M = # of fish tagged
C = # of fish examined for tags
R = # of tagged fish recaptured

For the 1997 survey -

C = 105,678
R = 145
M = 978

Therefore -

$$N = \frac{(105{,}678 + 1)(978 + 1)}{(145 + 1)}$$

= **708,628**

From Ricker (1975): Calculation of 95% confidence limits based on sampling error using the number of recaptures in conjunction with a Poisson distribution approximation.

Using Chapman (1951):

$$N^* = \frac{(C + 1)(M + 1)}{R^t + 1}$$

where R_t = tabular value (Ricker p 343)

$$\text{Upper } N^* = \frac{(105{,}678 + 1)(978 + 1)}{170.60 + 1} = 602{,}912$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(105{,}678 + 1)(978 + 1)}{123.24 = 1} = 832{,}741$$ @ .95 confidence limits

M adjusted for 3% tag loss and out-migration

Table 3. Conowingo Dam tailrace population estimate of adult American shad in 1997 using the Petersen statistic.

Chapman's Modification to the Petersen statistic -

$$N = \frac{(C+1)(M+1)}{R+1}$$

where N = population estimate
M = # of fish tagged
C = # of fish examined for tags
R = # of tagged fish recaptured

For the 1996 survey -

C = 99,156
R = 129
M = 554

Therefore -

$$N = \frac{(99{,}156 + 1)(554 + 1)}{(129 + 1)}$$

$$= 423{,}324$$

From Ricker (1975): Calculation of 95% confidence limits based on sampling error using the number of recaptures in conjunction with a Poisson distribution approximation.

Using Chapman (1951):

$$N^* = \frac{(C+1)(M+1)}{R_t + 1}$$ where R_t = tabular value (Ricker p 343)

Upper $N^* = \frac{(99{,}156 + 1)(554 + 1)}{153.27 + 1} = 356{,}726$ @ .95 confidence limits

Lower $N^* = \frac{(99{,}156 + 1)(554 + 1)}{108.57 + 1} = 502{,}256$ @ .95 confidence limits

M adjusted for 3% tag loss

Table 4. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad collected by pound net (a) and hook and line (b) during the 1980-1997 tagging program in the upper Chesapeake Bay.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH/POUND NET DAY	POPULATION ESTIMATE
A. Pound Net					
1980	Rocky Pt.	26	50	1.92	5,531
1981	Rocky Pt.	38	50	0.86	9,357
1982	Rocky Pt.	27	62	2.29	37,551
1985	Rocky Pt.	10	30	3.00	14,283
1988	Rocky Pt.	33	87	2.64	
	Cherry Tr.	41	75	1.83	
	Romney Cr.	41	8	0.20	
	Subtotal	115	170	1.48	38,386
1989	Rocky Pt.	32	91	2.84	
	Cherry Tr.	62	295	1.83	
	Beaver Dam	11	14	1.27	
	Subtotal	105	400	3.81	75,820
1990	Rocky Pt.	38	221	5.82	
	Cherry Tr.	71	178	2.50	
	Subtotal	109	399	3.66	123,830
1991	Rocky Pt.	38	251	6.61	
	Cherry Tr.	56	594	10.61	
	Bohemia R.	54	209	3.87	
	Subtotal	148	1054	7.12	139,862
1992	Cherry Tr.	56	147	2.63	
	Bohemia R.	47	43	0.87	
	Subtotal	103	190	1.80	105,255
1993	Cherry Tr.	48	255	5.31	
	Cara Cove	45	26	0.58	
	Subtotal	93	281	3.02	47,563

Table 4 - A. Pound Net (continued)

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH/POUND NET DAY	POPULATION ESTIMATE
1994	Cherry Tr.	48	320	6.67	
	Cara Cove	46	26	0.57	
	Subtotal	94	346	0.57	129,482
1995	Rocky Pt.	48	425	8.85	
	Cherry Tr	57	472	8.28	
	Beaver Dam	23	262	11.39	
	Subtotal	128	1159	9.05	333,891
1996	Rocky Pt.	60	315	5.25	
	Cherry Tr.	58	330	5.69	
	White Pt.	40	311	7.76	
	Subtotal	158	956	6.05	203,216
1997	Rocky Pt.	56	658	11.25	
	Cherry Tr.	55	510	9.27	
	Subtotal	111	1168	10.52	708,628

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

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

Table 5. Pearson Product Moment Correlation (r_p) for the annual upper Chesapeake Bay Petersen population estimate, annual geometric mean CPUE's for three gear types (1980-1996), annual Conowingo tailrace Petersen population estimates, and geometric mean CPUE's for two gear types (1984-1996) where N = number of years.

GEAR TYPE	PETERSEN POPULATION ESTIMATES UPPER BAY	TAILRACE
Pound Net		
r_p	0.86	-
N	13	-
P	0.0002	-
Hook & Line		
r_p	0.58	0.56
N	13	13
P	0.0378	0.0456
Fish Lifts		
r_p	0.81	0.77
N	16	13
P	0.0002	0.0022

Table 6. Catch (N), age composition, number and percent of repeat spawners (RPTS), and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1997 upper Chesapeake Bay spring tagging operation.

	MALE				FEMALE			
AGE	N	RPTS	MEAN	RANGE	N	RPTS	MEAN	RANGE
Pound Net								
III	19	0	345	315-365	2	0	363	350-360
IV	70	3	377	340-425	40	0	407	375-440
V	39	14	416	375-470	31	6	450	400-560
VI	11	8	455	435-475	32	16	479	430-515
VII	8	7	473	445-495	10	5	500	470-535
VIII	0	-	-	-	2	2	520	520-520
% RPTS		21.7				24.6		
Hook and Line								
III	13	0	336	330-345	2	0	360	348-372
IV	5	0	389	340-435	20	8	393	355-418
V	11	2	433	413-460	8	1	457	435-475
VI	12	10	460	430-500	12	4	485	460-510
VII	4	4	479	470-493	6	5	502	475-520
VIII	0				1	1	508	
% RPTS		35.6				38.8		
Gears Combined								
III	32	0	341	315-365	4	0	362	348-360
IV	75	3	376	340-435	60	8	402	355-440
V	50	16	420	375-470	39	7	451	400-560
VI	23	19	458	430-500	44	20	481	430-515
VII	12	11	476	445-495	16	10	501	470-535
VIII	0				3	3	516	
% RPTS		25.4				28.9		

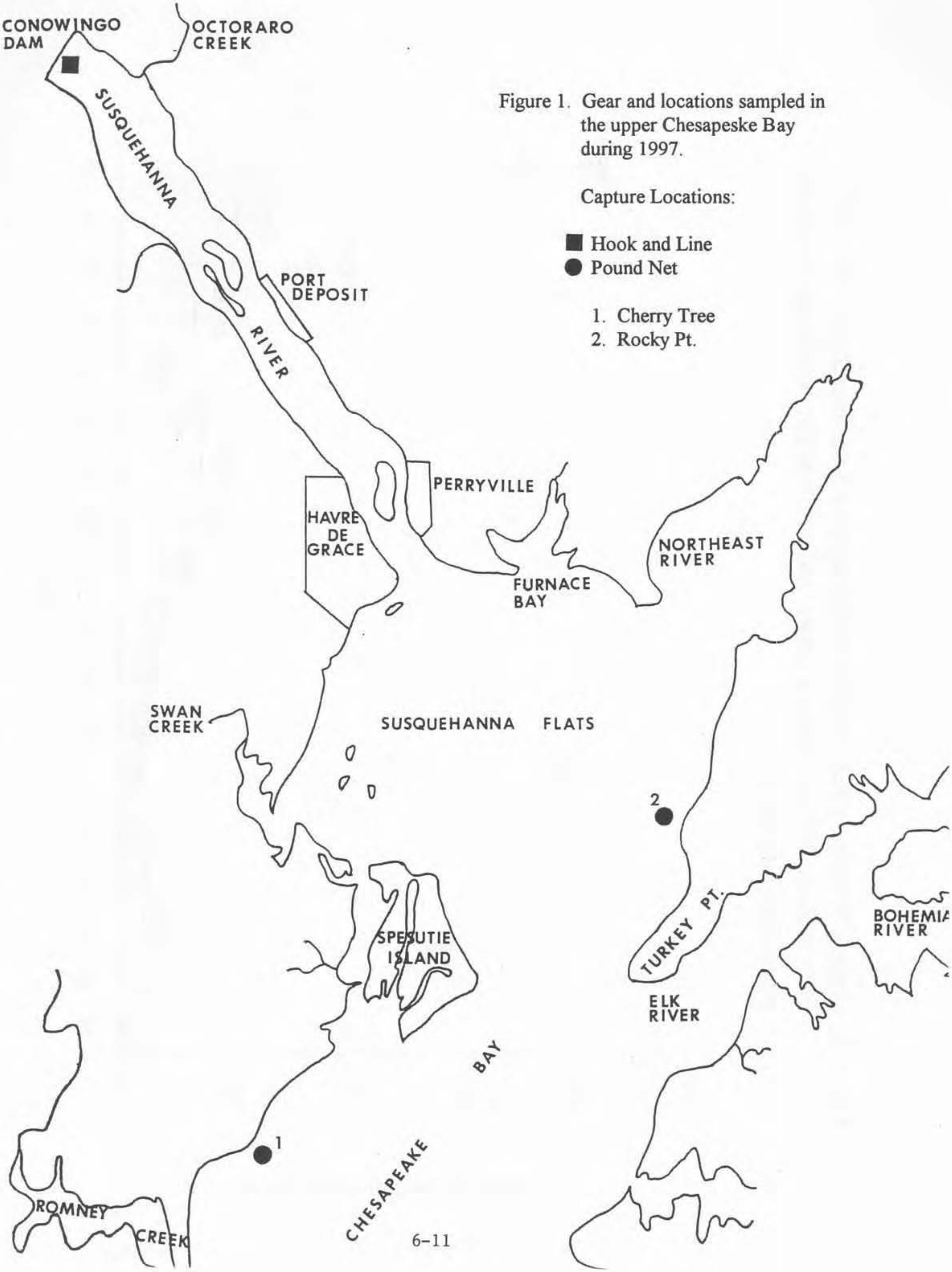


Figure 1. Gear and locations sampled in the upper Chesapeske Bay during 1997.

Capture Locations:

■ Hook and Line
● Pound Net

1. Cherry Tree
2. Rocky Pt.

Figure 2. Upper Chesapeake Bay population estimates of American shad, 1980-1997. Bars indicate 95% confidence ranges and numbers above indicate the yearly population estimate.

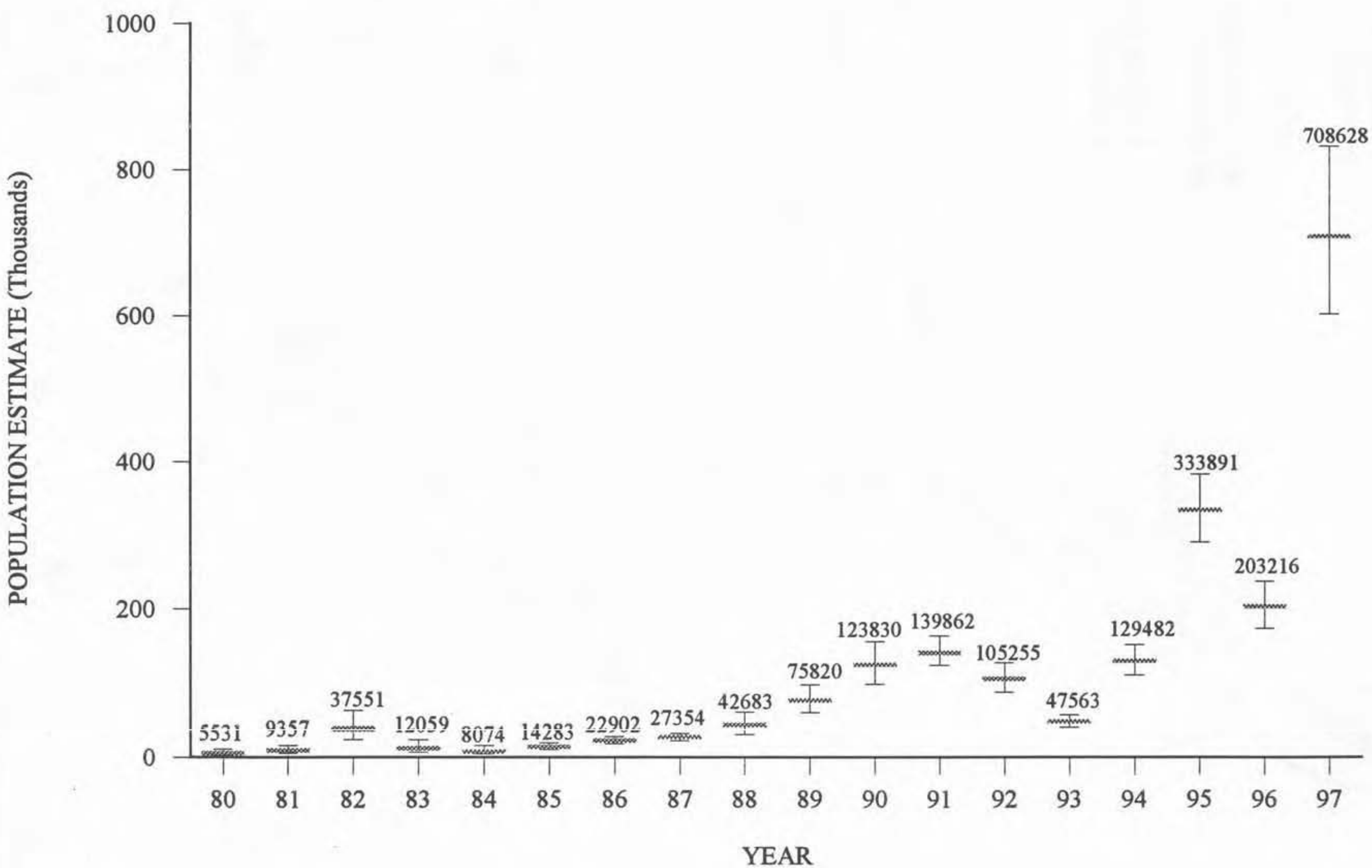


Figure 3. Conowingo Dam tailrace population estimates of American shad, 1984-1997. Bars indicate 95% confidence ranges and numbers above indicate the yearly population estimate.

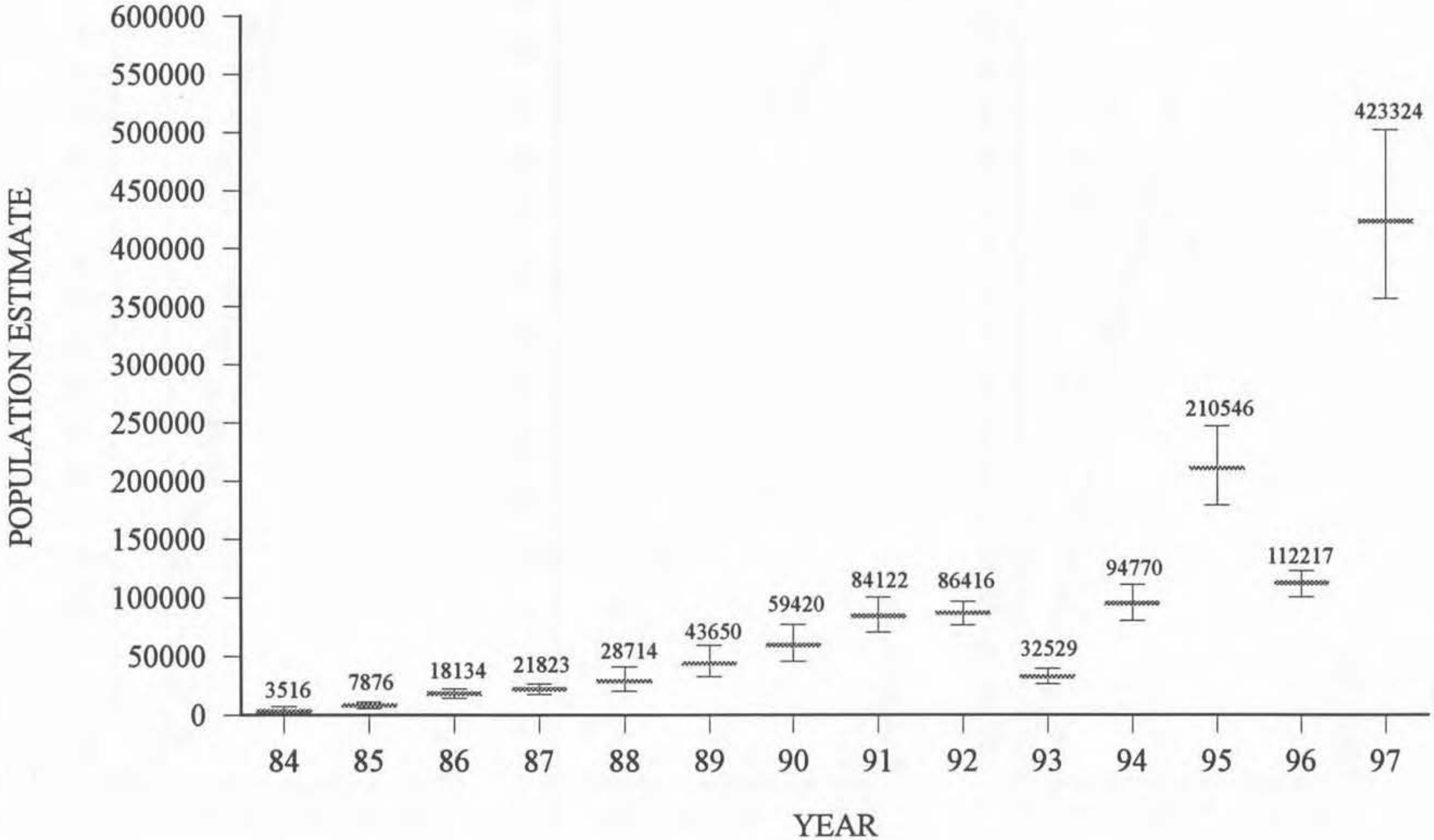
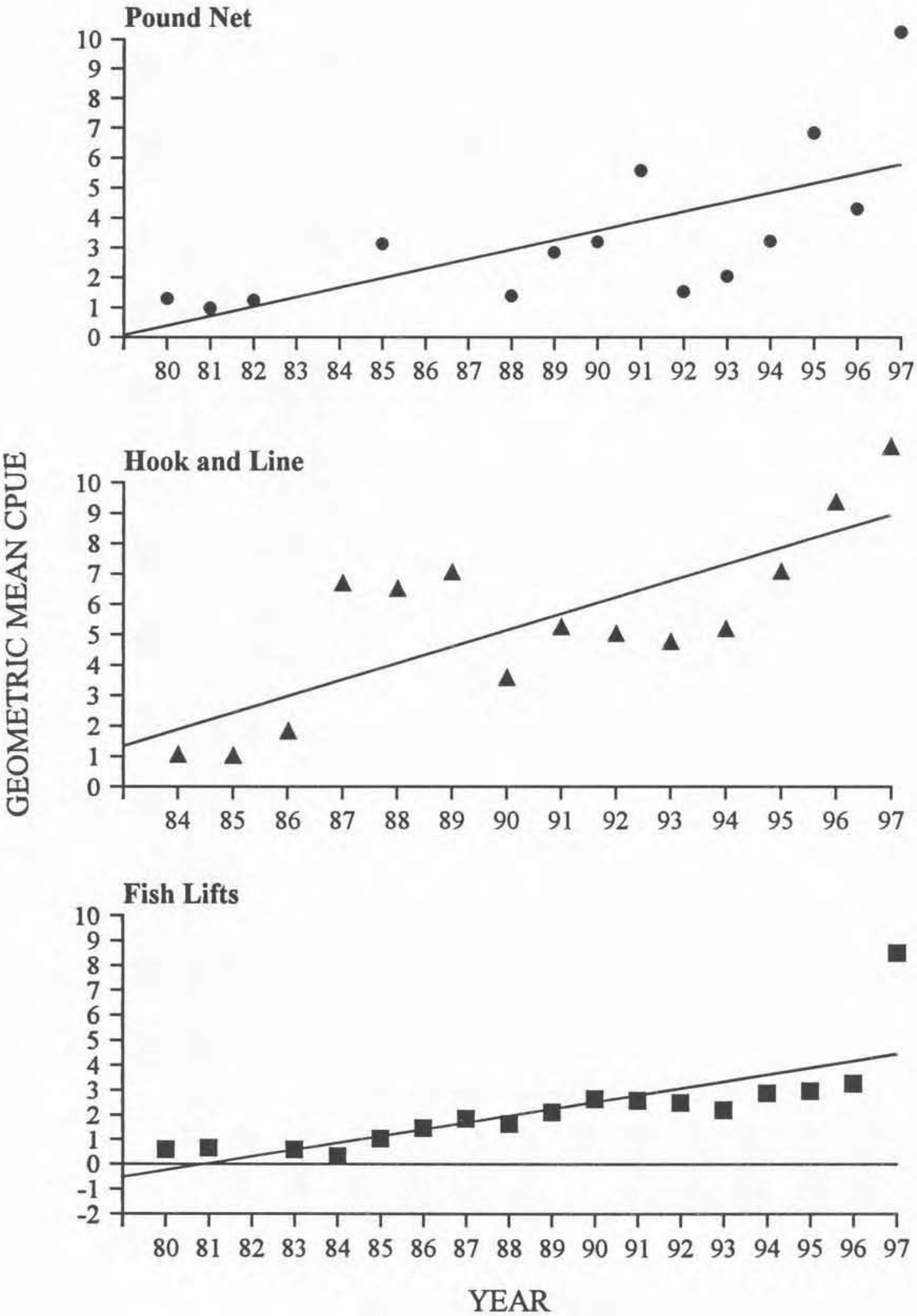


Figure 4. Regression analysis of geometric mean catch-per-unit-effort (CPUE) of American shad sampled by pound net, hook and line and Conowingo fish lifts in the upper Chesapeake Bay, 1980-1997.



Note Fish lift data is preliminary.

Figure 5. Pound net, hook and line and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus Upper Bay population estirnates of American, 1980-1996.

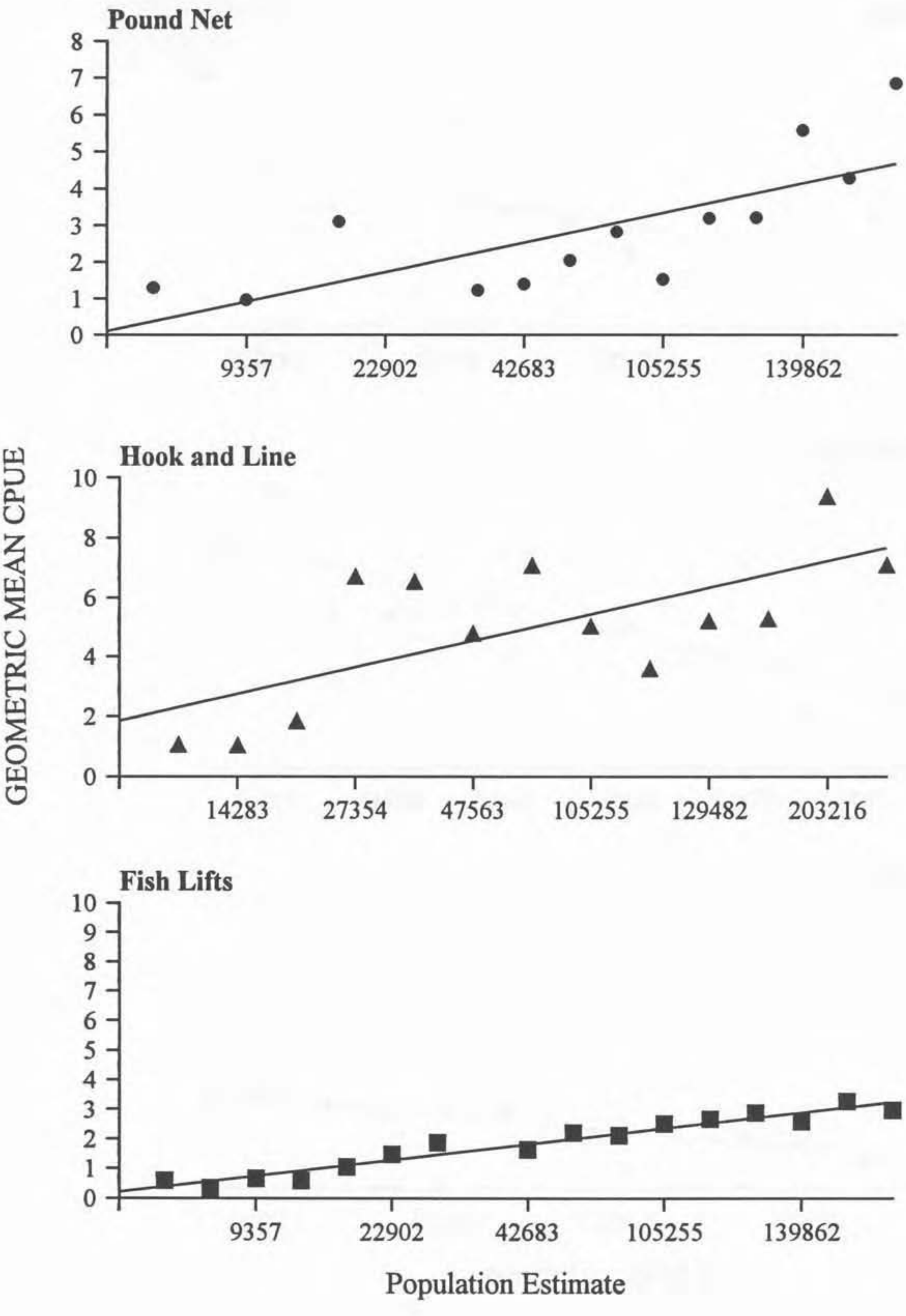
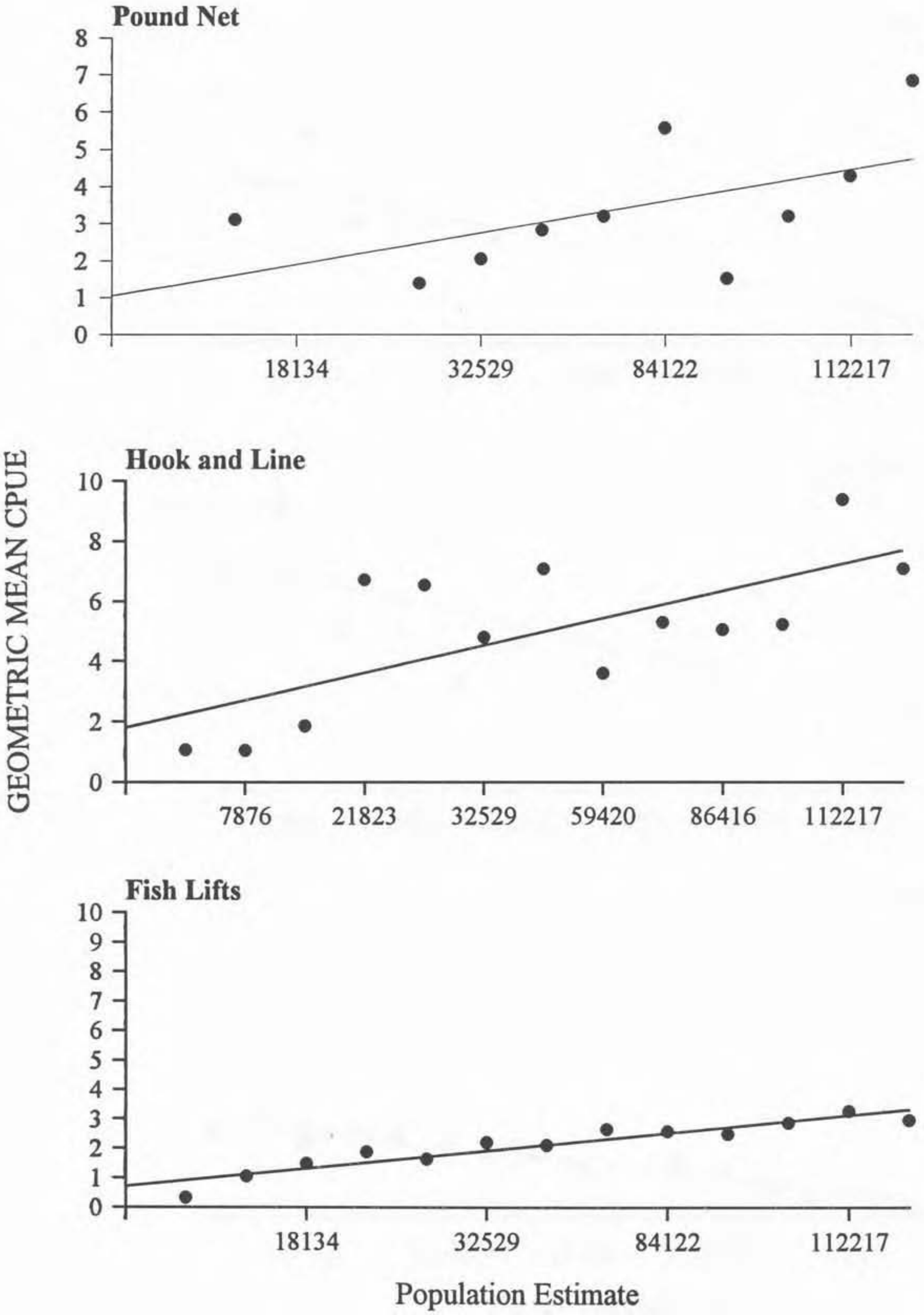


Figure 6. Pound net, hook and line and Conowingo fish lift geometric mean catch-per-unit-efforts (CPUEs) versus Conowingo Dam tailrace population estimates of American shad, 1980-1996.



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