Restoration of American Shad to the Susquehanna River

ANNUAL PROGRESS REPORT

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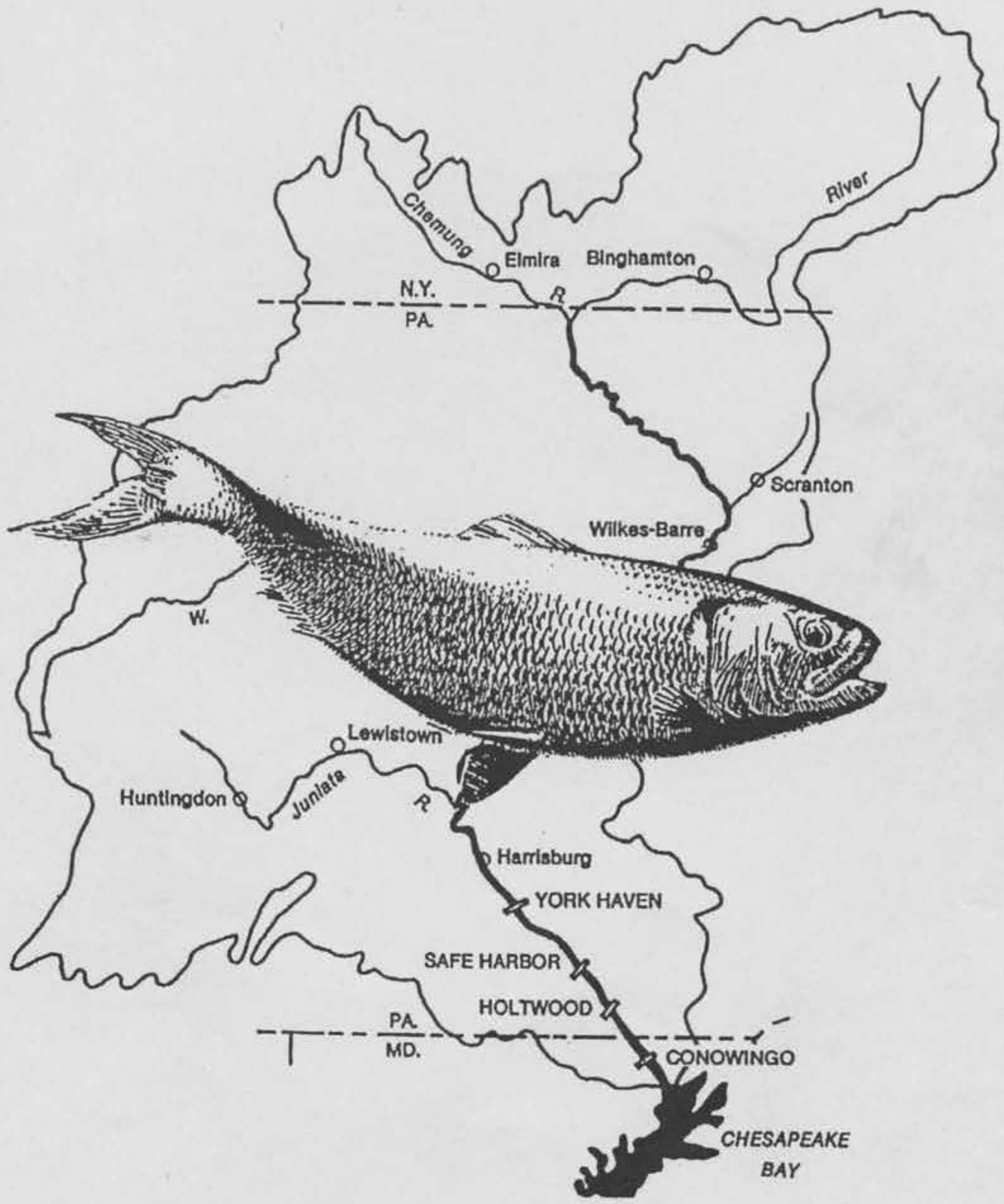

Susquehanna River

Anadromous Fish Restoration Committee

February 1995

RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER

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SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COMMITTEE

MARYLAND DEPARTMENT OF NATURAL RESOURCES
UNITED STATES FISH AND WILDLIFE SERVICE
NEW YORK DIVISION OF FISH AND WILDLIFE
PENNSYLVANIA FISH AND BOAT COMMISSION
PENNSYLVANIA POWER & LIGHT COMPANY
SAFE HARBOR WATER POWER CORPORATION
SUSQUEHANNA RIVER BASIN COMMISSION
YORK HAVEN POWER COMPANY
PECO ENERGY COMPANY.

FEBRUARY 1995

EXECUTIVE SUMMARY

The 1994 Annual Report of the Susquehanna River Anadromous Fish Restoration Committee presents results from numerous activities and studies directed at restoring American shad to the Susquehanna River. This was the tenth year of a program, largely funded by three upstream hydroproject licensees, to rebuild stocks based on hatchery releases and natural reproduction of adult shad collected at the Conowingo Dam fish lifts and transferred upstream to spawn. The restoration program represents a continuing commitment of state and federal fishery resource agencies and private utility companies to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1994 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 129,482 fish (Petersen Index). This was based on recapture of 152 shad from a tagged population of 598 fish. Tagging was conducted by the Maryland Department of Natural Resources using pound nets at the head of the Bay and angling in the Conowingo tailrace. All of the tag returns used in this analysis came from the Conowingo lifts. Estimated stock size in 1994 was 172% larger than in 1993 and was within 12,000 fish of matching the record from 1991. The Conowingo tailrace population estimate for shad was a record 94,770.

Trapping operations began at the East lift on 22 April and the West lift on 30 April with both continuing daily until 12 June. A total of 1.626 million fish representing 49 taxa was handled. This was a slight increase over 1993, but down considerably from almost 4 million fish trapped in 1992. Gizzard shad comprised 94% of the total catch. Alosa species included 32,330 American shad, 2,851 blueback herring, 75 alewives, and one hickory shad.

American shad catch in 1994 was a new record high, exceeding 1993 by 18,784 fish. Blueback and alewife numbers continued a downward trend to the lowest levels seen since 1984. The West lift usually accounts for most river herring collected at Conowingo, and attraction flows at this device in 1994 were less than optimal due to the outage of one of the two house units which supplies water. The West lift accounted for 5,615 American shad, 2,603 bluebacks and 70 alewives. The East lift took 26,715 American shad, 248 bluebacks and 5 alewives. Catch per fishing hour for shad at the East lift in 1994 averaged 51.6, compared to only 19.5 in 1993.

A total of 28,681 American shad was transported to potential upstream spawning areas with less than 2% observed transport and delayed mortality. Most shad (17,522) were stocked at the Tri-County Boat Club above York Haven Dam, with smaller numbers being released at Columbia (9,880) and Muddy Creek (412). Only 344 river herring were stocked at Middletown and 1,945 bluebacks were provided to Maryland DNR for release into the Patapsco River which is undergoing restoration.

Overall sex ratio of shad in lift collections was 1.8 to 1 favoring males. Males ranged in age from III to VI (84% @ IV-V), and females were IV to VII (86% @ V-VI). Based on scale analysis of 348 shad, 22 (6.4%) were repeat spawners. Otoliths were successfully examined from 287 adult shad sacrificed at the fish lifts. Of these, 28 (10%) showed wild microstructure and no tetracycline (TC) tags. All remaining samples had hatchery microstructure and 242 of 259 also exhibited TC marks including single, double, triple, and quadruple immersion treatments. Three otoliths additionally displayed feed tags.

Since 1989, the corrected hatchery component of the return population at Conowingo has ranged from 67% to 1994's high of 90%. The dominant components of the hatchery marked population (70%) carried triple immersion tags indicating that they originated as

Hudson or Delaware River fry released in the Juniata River since 1988. A second otolith sample from 59 shad taken in pound nets in the Upper Chesapeake Bay were 44% wild and 56% hatchery. The largest component of the marked cohort carried double immersion tags, indicating that they were stocked as fry below Conowingo Dam.

The Pennsylvania Fish and Boat Commission (PFBC) operated the intensive shad culture facility at Van Dyke and rearing ponds at Thompsontown and Upper Spring Creek. During the period 4 May to 16 June, 20.65 million shad eggs were delivered to Van Dyke from the Delaware River (10.27 M), the Hudson River (6.29 M), and the Connecticut River (4.09 M). Overall viability of these eggs was 47%, and production for the Susquehanna amounted to 6.42 million fry and 139,500 fingerlings. Additionally, Van Dyke reared 80,500 Pamunkey and Mattaponi River fry for stocking in Virginia and 642,200 Delaware source fry were stocked into the Lehigh River.

Shad fry produced at Van Dyke were distinctively marked with one, three or five separate immersions in 200 ppm tetracycline. Pond-reared fingerlings also received feed tags. All fish produced by PFBC for the Susquehanna program in 1994 were stocked in the Juniata River at Thompsontown.

Maryland DNR's Joseph Manning Hatchery received 93.5 liters of fertile shad eggs from the Delaware, Hudson and Connecticut rivers of which 59.2 (63%) were viable. An estimated 2.05 M larvae hatched and 1.3 M were double-tagged and stocked at Port Deposit, MD on 9 June. Manning also received 171 green adult shad from Conowingo and induced spawning in four tank trials. This resulted in production of 600,000 fertile eggs and 400,000 larvae. Most of these were stocked into utility and private ponds for grow-out. Ultimately, 23,000 tetracycline-marked phase II fingerling shad were stocked into the Patuxent River in September and 14,000 of these carried coded wire tags.

3500 eggs/shad
7000 eggs/♀ @ 1:1

As in past years, considerable effort was devoted to assessing abundance, growth, instream movements, and source of juvenile shad during summer nursery and autumn outmigration from the river. In 1994, shad were sampled with seines at several sites above and below York Haven Dam; with lift nets at Holtwood; from cooling water intake strainers and screens at Conowingo and Peach Bottom; and by electrofishing in the upper Chesapeake Bay.

River flows during summer months were erratic and generally above average. Autumn flows were normal. Good numbers of shad were collected with seines at Marietta, Columbia, Wrightsville, and Pequea during late July through September and most (63%) were naturally produced. Outmigration from the river peaked during the first 3-weeks of October and otolith analysis of shad from lower river lift net samples noted the shift in abundance to hatchery fish (81%) as this component passed.

Both wild and hatchery shad grew well in the Susquehanna (0.6-0.7 mm/day) from an average of about 80 mm in late July to 125 mm in mid-October. Catch per unit effort (CPUE) of juvenile shad with seines in 1994 (3.24) was considerably greater than that measured during the prior 3 years. However, CPUE at Holtwood was only about one-sixth of the long-term average with catch effectiveness being adversely affected by unusual water clarity. Maryland DNR collected 58 juvenile shad in the upper Chesapeake Bay by electrofisher (36) and seines (22). This compares to 67 shad taken in 1993 and only 4 in 1992.

A total of 525 juvenile shad from collections at Amity Hall, Three Mile Island, Marietta, Columbia, Wrightsville, Pequea, Holtwood, and Peach Bottom were returned to Benner Spring for tetracycline mark analysis. Otoliths from 249 fish (47%) were unmarked and displayed wild microstructure. This compares to 58% wild fish in

1993 and 39% in 1992. Sixty-three percent of fish examined from upper Bay collections were wild compared to 100% in 1993.

As in past years, rate of recovery of Hudson, Connecticut, and Delaware River fish was disproportionate to their stocking numbers. Hudson fish comprised 59% of total fry stocked at Thompsontown, but 91% of all marked recoveries above Conowingo. Connecticut and Delaware River fry made up 29% and 12% of the total release but only 1% and 3%, respectively, of juvenile returns. Pond-reared fingerlings released at Thompsontown made up the remaining 5% of the TC-marked recaptures. Experimental paired stockings of Hudson River fry were differentially marked and stocked at 7 and 20 days of age. Based on stocking and recovery rates, it appeared that releasing larvae at a younger age improved survival by as much as a factor of seven.

In a special study co-funded by Susquehanna Electric Company (SECO) and upstream utilities, 80 adult shad were radio-tagged and released into the exit flume at Conowingo East fish lift in four batches during 4-11 May. Purpose of this study was to determine rate of drop-back through adjacent turbines. Forty-five fish exited the trough within 12 hours and a total of 13 fish (29%) dropped back through operating turbines within 48 hours. Four of 22 fish were re-entrained with adjacent Unit 11 on and 9 of 23 fish fell back with Unit 11 off.

American shad egg collections, hatchery culture and marking in Pennsylvania, juvenile shad recovery above Conowingo, otolith mark analysis, and most costs associated with the turbine re-entrainment study at Conowingo were funded from the 1985 settlement agreement with upstream utilities. This funding source committed $447,000 of which about $347,000 was spent in 1994.

Upstream licensees cooperated with SECO in separately covering costs associated with Conowingo lift operations, collection, sorting and trucking of shad. 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, juvenile shad electrofishing and seining in the upper Chesapeake Bay, and shad culture and marking operations at their Manning hatchery.

Throughout the year, Fish Passage Technical Advisory Committees for Holtwood and Safe Harbor met to develop and discuss plans for fish passage facilities at these projects. Final designs were produced and construction is expected to begin at both dams in summer 1995.

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. SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM FISH PASSAGE FACILITIES IN SPRING 1994

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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.

Prior to installation and operation of the East lift, SECO had responsibility for funding the trap and transport operations. Completion of the East lift shifted funding responsibility for trap and transport operations to Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company (collectively termed Upstream Licensees). However, funding for the 1994 operation and maintenance of the East and West lifts remained with SECO.

Objectives of 1994 operation were to: (1) continue to assess the operation of the East lift, (2) continue restoration efforts by the trap and transport of pre-spawned American shad and river herring, (3) monitor species composition and relative abundance of alosids, (4) obtain life history information from selected migratory fishes, (5) assist the Maryland Department of Natural Resources (MD DNR) in assessing the American shad population in the upper Chesapeake Bay, and (6) collect American shad for stock assessment and special studies.

The primary focus of the 1994 report is discussion on species targeted for active restoration, namely American shad and river herrings. The report discusses lift operation, catch statistics, and transport of these species. Catch data for other fishes were collected but are not reported. However, these data are stored on 3½ inch diskette in ASCII format and copies are available upon request from SECO or any of the Upstream Licensees.

1.0 METHODS

High river flows, which delayed fish trap operations, created conditions that limited the reconnaissance surveys to detect the arrival of alosids into areas below Conowingo Dam prior to mid-April. Personal communications with MD DNR personnel indicated that river herring were present in the upper Chesapeake Bay in late March. Reconnaissance surveys were conducted on 18 and 19 April at Shures Landing below Conowingo Dam, from the bridge over Deer Creek, along Stafford Road south along Deer Creek, and at Octoraro Creek along Route 222. River herring were observed on both surveys at the mouth of Deer Creek. In addition, anglers were observed catching American and hickory shad at the mouth of and near the bridge over Deer Creek during both surveys. Water temperatures during these surveys varied slightly by area and ranged from 55.4°F to 58.1°F.

Modifications and repairs to both lifts began in September of 1993 to ensure efficient and reliable operation during the 1994 season. Preseason work on the East Lift was completed on 22 April and included maintenance and repairs of numerous lift components and operating systems. Major tasks undertaken included replacement of the hopper sheave block and hose change out, overhaul of cylinders and associated software in the crowder, hopper, and viewing room pneumatic systems, repair of the downstream weir gate operator and shafts, overhaul of spillway gates A and B operators, replacement of the crowder screen hoist cable and the installation of an upper and lower limit switch (proximity type), improvements to the service water supply system, and relocation of controls for trash and separation gates.

Final preseason preparations to the West lift were completed on 29 April, 5 days after an extended period of spill. Work on the lift included repair of the crowder drive electrical system, installation of a rigging platform to close valves 4 and 5, repairs to wiring and components in the control and conductor panels, removal/repair of underwater components including gratings, baffles, and the pressure relief valve, improvements to the ambient lighting system, and installation of ground fault circuit breakers.

During spring 1994, one of two service units (Service Unit #1), which supplies attraction flow, was inoperable due to a failure of the unit main shaft. Attraction water for the West lift was provided from Service Unit #2. Although attraction velocities used at the lift were similar to those used in previous years, the volume of attraction water used was approximately half that used in previous years.

Pursuant to the settlement agreement between SECO and the resource agencies, turbine units 1 and 2 were shut down when river flows were less than 65,000 cfs. Lift operation was consistent with the 1994 Susquehanna River Technical Committee Work Plan.

The PC-based data management and reporting system, developed in 1993, was utilized to provide project data and reports. The system was composed of IBM compatible equipment (386 PC, 4 M RAM, one 3½ inch diskette drive) and incorporated PC-SAS and the use of the Scriptwriter II Data Entry System (RMC 1993).

1.1 East and West Lift Operation

Lift operation was delayed until late April due to a long period of sustained high natural river flow (>150,000 cfs). Daily lift operation (0700 to 1900h) at the East lift commenced on 22

April and on 30 April at the West lift and continued through 12 June. American shad were captured at each lift on their respective first day of operation. Reduced operation occurred from 13 to 15 June at both lifts. Lift operations were terminated on 15 June.

Work stoppages due to mechanical/electrical failures or maintenance occurred infrequently. The lifts were operated efficiently to maximize the alosid catch. At the East lift outages occurred on 29 April, 11-13 May, and 26 May and totaled some 24 hours. Minor outages occurred at the West lift that involved the crowder or the hopper travel motors. Again, repairs were quickly made and resulted in minimal down time.

The mechanical aspects of West lift operation in 1994 were similar to that described in RMC (1983), while East lift operation was similar to that described in RMC (1992). Fishing time and/or lift frequency was determined by fish abundance and the time required to process the catch. The hopper was lifted at least hourly throughout the day. Two modifications to normal operation were utilized at both facilities (excepting design differences between the East and West lifts) to reduce the large numbers of gizzard shad and/or common carp attracted to the lifts. First, operation "Fast Fish"[1] (RMC 1986) was employed during periods of high fish density to reduce mechanical delays. Second, the weir gate settings were adjusted to increase attraction velocities and operation in the "Fast Fish" mode was continued until the fish density was reduced. On rare occasions at the West lift when weir gate modifications proved ineffective, one of the weir gates was closed to prevent overcrowding of fish in the holding channel. As required, mechanical delays at the East lift are reduced by controlling access of fish over the hopper by operation of the crowder screen. Normal lift operation resumed when conditions returned to a level which did not unduly stress the collected fish. These conditions were determined by the lift supervisor.

At the East lift, efforts to improve lift efficiency continued in 1994. Matrix charts, developed during past years, were expanded upon and used during 1994. These matrices contain

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[1]Operation "Fast Fish" involves leaving the crowder in its normal fishing position and raising the hopper frequently to remove fish that accumulate in the holding channel.

pond and tailrace elevations, turbine unit operation, and list the various gate settings for efficient lift operation. These settings are changed throughout the day to correspond to changes in hydraulic conditions and fish abundance in an effort to maximize the catch of American shad.

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 and 3.0 to 8.0 fps at the entrances.

Attraction velocities at the West lift were similar to those maintained since 1982 (RMC 1983). Hydraulic conditions, primarily laminar flows, were maintained in the area of the lift between the crowder and weir gate entrances similar to that reported in RMC (1983). Modifications to weir gate settings to adjust attraction velocity and to the house service unit setting were made during periods of high fish density and were similar to those previously reported (RMC 1986).

Minimum flow releases followed the schedule outlined in the settlement agreement. Due to the high river flow in early spring, station discharges exceeded the minimum flow requirement (10,000 cfs) for the entire month of April. Minimum flows of 7,500 and 5,000 cfs were maintained from 1 through 31 May, and 1 through 15 June, respectively. Generally, units 5 and 6 were used to maintain minimum flow releases in May. Either Unit 3 or 5 was used in June.

1.2 Disposition of Catch

Fishes were processed according to procedures described in RMC (1983). Fish were either counted or estimated (when large numbers were present) at each lift and released back to the tailrace. Data (i.e., length, weight, sex, spawning condition, scales and/or otolith) on American shad were taken from those sacrificed, or those that died in handling and transport. Per the 1994 SRTC Work Plan, every 100th shad collected in each Lift was sacrificed to obtain otoliths for stock identification study by the Pennsylvania Fish and Boat Commission (PFBC). In addition, muscle and ovarian tissue, scale samples, lengths, and weights from American shad were provided to researchers from Virginia Commonwealth University for mitochondrial DNA analysis to determine the genetic origin (hatchery vs wild) of shad.

American shad scales were cleaned, mounted, and aged according to Cating (1953). The procedures employed to determine age structure and spawning history were similar to those used by MD DNR, and were validated previously.

1.3 Holding and Transport of Shad and River Herring (East and West Lift)

The primary objective of this project is to trap migratory fish at Conowingo and transport American shad upstream of the uppermost hydroelectric project (York Haven) on the Susquehanna River. Generally, transport occurred whenever ≥ 100 green or gravid shad were collected in a day, or at the supervisor's discretion if fewer shad were collected. As feasible, 5,000 or more river herring were scheduled for transport to Upper Chesapeake Bay tributaries to assist MD DNR with their restoration activities. When possible, river herring were also transported upriver. The primary release site for American shad and river herring was the Tri-County Boat Club Marina (Tri-County) located on the east shore of the Susquehanna River above York Haven Dam (Dauphin County). The PFBC access at Columbia (Lancaster County) was also utilized. Early in the season, the Columbia access was utilized to maximize the number of shad transported based on catch and equipment availability. Late season transport to the Columbia access reduced transport time and stress on fish, particularly during periods of elevated water temperatures (>70°F). The PFBC access at Muddy Creek (York County) was utilized on an emergency basis when and if problems with transport equipment occurred. In addition, several other stocking locations were utilized to release radio tagged American shad for fishway siting studies sponsored by each of the Upstream Licensees.

Improvements were made to equipment to enhance shad transport survival. The East lift transport trailer units were fitted with new fiberglass inner doors and channels. To prevent water loss during transport, thereby reducing churning within the tanks, the tank tops were epoxy sealed. The West lift transport tanks were also fitted with new fiberglass inner doors and the inner door channels were reinforced.

Beginning on 1 June, in order to minimize the effects of increased temperature on fish survival, transport units were iced. In addition, to provide further enhancement, a tarp was installed over the East Lift holding facility on 4 June.

To increase the efficiency of the transport program at both lifts, American shad and river herring were held until sufficient numbers were collected for transport. Holding facilities at each lift consisted of black circular tanks (two 1,000 gallon capacity tanks at the East lift; four tanks: two 1,000 gallon and two 800 gallon capacity at the West lift), continually supplied with river water. Each tank was fitted with an aeration system that utilized bottled oxygen. Each tank was fitted with a cover to prevent fish escape and reduce stress.

Fish were transported in 1,000 gallon circular truck mounted transfer units from the West lift while those collected at the East lift were transported in 750 gallon circular trailer mounted units. As stated earlier, improvements were made to enhance East lift handling, holding and transport, however, the basic procedures employed at both lifts in 1994 were similar to those used previously (RMC 1986, 1992).

2.0 RESULTS

2.1 Relative Abundance (East and West Lift)

The relative abundance of fishes at each lift is presented in Table 1. Although sustained high river flow in April delayed operation of the lifts until 22 April and 30 April at the East and West Fish lifts, respectively, a record number of American shad (32,330) was captured. No new species were collected in 1994 as compared to previous years of operation (RMC 1992).

A combined total of 1,626,407 fish was collected (Table 1). The East lift accounted for 1,062,634 fish of 36 taxa while the West lift collected 563,773 fish of 46 taxa. A total of 32,330

American shad (East=26,715; West=5,615) was captured. Alosids (American shad, hickory shad, blueback herring, and alewife) comprised 2.1% of the total catch. One hickory shad was captured at each lift, while 70 of the 75 total alewife were captured at the West lift. Gizzard shad dominated the catch and comprised 94% of the total. Although carp comprised less than 1% of the total combined catch, they were a nuisance species at both lifts during the latter part of the season and interfered with efficient capture and sorting of alosids.

2.2 American Shad Catch (East and West Lift)

In 55 days of operation at the East lift, a total of 26,715 American shad was captured (Table 2). The West lift operated a total of 47 days and captured 5,615 American shad (Table 3). Approximately 90% of the total shad captured were transported. A total of 2,634 shad was released back to the tailrace due to advanced maturation of fish and hooking injury. The remainder consisted of shad released from holding, MD DNR recaptures, holding and lift mortalities, and those sacrificed.

Each lift collected American shad on their respective first days of operation. Nearly 57% (18,357 shad) of the shad were collected between 15 May and 4 June. The peak day occurred on 24 May when 894 shad were captured at the East lift and the West lift collected 823 shad. On 5 occasions in May, the East lift captured more than 1,200 American shad in a single day. Less than 6% of the total shad catch was collected after 4 June while slightly more than 37% of the total shad catch was collected prior to 15 May.

American shad were collected at water temperatures of 55.9°F to 78.8°F and at natural river flows of 15,500 to 88,800 cfs (Figures 3 and 4). Seventy percent of the shad were collected at water temperatures <65°F (Table 4). River water temperatures did not consistently rise above 65°F until 25 May.

The catch per effort (CPE) of American shad at the East lift varied by station generation, weekend or week day, and time of day. Upstream weir gate A and the downstream weir gate were the primary entrances utilized and their operation was dependent upon station generation (Table 5). The downstream weir gate was normally utilized when two or more large units were operating, particularly units 10 and 11. Upstream weir gate A was used when only one large turbine was operating (usually Unit No. 8) or when generation was limited to the small units.

The overall CPE was lower on weekdays (45.3) than on weekends (65.5) (Table 6). Generally, during both periods, catches were greatest between 1500 and 2000 h. Some relatively high catch rates were observed prior to 1100 h for both periods, particularly when generation ranged from 6,000-10,000 cfs (2 small units operating).

Catch rates were independent of the operation of turbine units 10 and 11 at station discharge of 5,000 to 65,000 cfs (Table 7). The highest average catch rate (103.0) occurred when both large units 10 and 11 were off and generation was between 6,000-10,000 cfs. Although catch rates were highest at discharges less then 20,000 cfs most shad were captured at higher station discharges.

2.3 Sex Ratios (East and West Lifts)

Sex of American shad was determined by visual macroscopic examination; the resulting data were used to calculate the sex ratios at each lift. The sex ratios are provided in Table 8. Differences in sex ratios between the lifts were minimal and thus were pooled for examining a general trend. Generally, when the daily catch exceeded 100 shad, a minimum subsample of 100 fish per lift was examined; when the daily catch was less than 100 shad all were examined. A total of 8,745 shad was sexed. The combined male/female ratio was 1.8:1. Males comprised 69% of the total catch in April and May and 50% in June.

2.4 Age Composition of American Shad (East and West Lifts)

Scale samples of 348 shad were read (Table 9). Males were III to VII years old while females were IV to VII years old. Almost all the males were IV and V years old, while most females were V and VI years old. The 1989 year class was the most abundant year class sampled.

More than 93% of males and females were virgins (Table 9). Of the 238 males, 16 (6.7%) were single repeat spawners while 6 (5.4%) of the 110 females were single repeat spawners. No multiple repeat spawners were observed. Overall, repeat spawners comprised 6.3% of the total sample.

Females were larger than males (Table 9). The smallest male measured 298 mm fork length, the smallest female was 330 mm. The average length of males and females were 392 and 454 mm, respectively.

2.5 Maryland Tag-Recapture (East and West Lifts)

Including multiple recaptures, 224 MD DNR tagged American shad were recaptured; 161 at the East lift and 63 at the West lift (Table 10). Of the 224 shad recovered, 2 were tagged by MD DNR in previous years. The MD DNR tagged 639 shad in 1994; 197 from pound nets in the upper Chesapeake Bay and 442 by hook and line in the Conowingo tailrace. Of the 150 first time verified MD DNR recaptures, 142 were tagged in the tailrace and 8 in the pound nets. The 8 shad from pound nets averaged 17.6 days free before capture, while those in the tailrace averaged 10.8 days free. The combined mean was 11.2 days free.

2.6 Other Alosids (East and West Lifts)

A total of 2,851 blueback herring was collected (Tables 1, 2, and 3). More than 91% of the blueback herring were captured at the West lift. Of those captured at the East lift, 83% were collected from 3 to 9 June. Blueback herring were present in West lift catches on 36 of 47 days of operation with the highest catch (652) occurring on 17 May.

A total of 75 alewife was collected, only 5 at the East lift (Tables 1, 2, and 3). Alewife were captured only during the first 7 days of East lift operation and during the first 2 days of West lift operation. Alewife were captured at water temperatures from 55.3°F to 62.6°F.

The combined catch of river herring (blueback herring, alewife, and hickory shad) from both lifts was 2,928 and was lower than the total catch observed in recent years (RMC 1992, 1993). One hickory shad was captured at each lift.

2.7 Transport of American Shad (East and West Lifts)

Pre-spawned American shad were transported from 24 April through 13 June. Nearly 89% of the American shad catch was transported to upstream spawning areas with an observed stocking survival of 99.9% (Table 11). A total of 28,681 shad was transported; 23,186 from the East lift, 4,062 from the West lift, and 1,433 in combined transports. Some 17,522 shad were stocked directly to the Susquehanna River at Tri-County Marina. Additionally, 9,880 shad were released at the PFBC Columbia access and 412 shad were stocked at the PFBC Muddy Creek access sites. Smaller schools of shad totalling 867 fish were released at other upstream locations as part of a radio telemetry study funded by the Upstream Licensees. The MD DNR transported 175 shad to the Manning Hatchery for spawning purposes. In addition, the New Jersey Aquarium acquired 37 shad for use in a public display.

Transportation of shad occurred on 44 and 29 days from the East and West lifts, respectively, while combined transports occurred on 15 days (Table 11). The number of transport trips per day at the East lift ranged from 1 to 11, while West lift transports ranged from 1 to 4 per day. East transport-load size varied from 40 to 138 shad per trip. The load size of transports originating from the West lift ranged from 25 to 212 shad per trip. Transport survival ranged from 89.5 to 100% from the East lift while West lift transport survival ranged from 97.5 to 100%. Shad were transported at water temperatures of 57.2 to 79.0°F.

A total of 1,433 shad was transported upstream in combined transports. The average transport survival for these trips was 98.5%; load size ranged from 28 to 130 shad per trip. More than 78% of the shad from combined transports were released at the Columbia PFBC access.

Holding facilities at both lifts were utilized to reduce stress, maximize transport operations, and release larger schools of fish. A total of 3,671 shad was held over at the East lift with 117 (3.2%) holding mortalities, while 1,271 shad were held over at the West facility with a total of 4

(0.3%) holding mortalities. A total of 88 shad perished during an East lift overnight holding event due to a supply pump failure that allowed water to drain from the holding tank. If this event is excluded from the calculations the total East lift holding mortalities were about 0.8%, similar to those observed at the West lift.

2.8 River Herring Transport

A total of 344 river herring (11.7% of total catch) was transported upstream and released at Tri-County Marina or Columbia PFBC access (Table 12). The transports included 58 alewife and 286 blueback herring. Herring were transported between 1 May and 10 June with 100% survival.

A total of 1,945 blueback herring was transported to Chesapeake Bay tributaries by the MD DNR. All of the herring were stocked in the Patapsco River drainage, which is undergoing fish passage development, concurrent with anadromous fish re-introduction.

2.9 Delayed Transport Mortality

In 1992, a monitoring program was instituted to collect any dead shad observed at the release sites (Tri-County, Columbia, etc.). This program was continued in 1994. Two biologists searched the shoreline at least three times weekly above and below each release site for evidence of dead or dying fish.

The release sites were checked on a total of 52 days beginning 28 April and continued until after transport ceased from both fish lifts. These efforts resulted in the recovery of 368 dead shad (1.2%) of the total shad transported. When delayed mortalities are included with transport mortalities, the transport survival rate for the season was estimated at 98.2%.

3.0 DISCUSSION

The American shad run is primarily dictated by natural river flow and water temperature. The catch at the fish lifts was primarily dictated by variations in station discharge (peak load versus reduced generation), natural river flow, and water temperatures.

Although sustained high natural river flows delayed fish lift operations until late April, a record number of American shad (32,330) was captured in 1994. Over 82% of the total shad catch was collected at the East lift. In previous years (1991 to 1993) 39% to 49% of the season shad catch was captured at the West lift. Although it is not possible to determine the exact cause of the shift in capture rates, West lift efficiency was undoubtedly reduced by the outage of Service Unit #1 and the resultant reduction in the volume of attraction flow. Even though the volume of attraction flow was reduced it should be noted that the West lift shad catch in 1994 (5,615) was higher than the 1993 catch (5,343).

Nearly 89% of the American shad catch was transported to upstream spawning areas with an overall transport survival rate of 98.2%. Continued improvements to transport procedures combined with modifications to equipment greatly improved efficiency and survival of American shad. Although several improvements were made that enhanced East lift transport operations the trailer units were plagued with wheel and axle problems that hampered transport efficiency. These problems have been addressed and are expected to be resolved by post season preventative maintenance and monitoring/lubrication programs to be implemented in 1995. Based on the 1994 experience if all 5 transport trailer units are available on a daily basis, particularly between 1500-2000 h, at least 825 shad could be captured and transported from the East lift during this five hour period. This should maximize shad transport to upriver spawning areas since catch rates are usually highest during this period.

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Table 1 **Comparison of annual catch of fishes at the Conowingo Dam Fish Lifts, 22 April through 15 June 1994.**

YEAR	*1994*	*1994*
LOCATION	*EAST*	*WEST*
NO. OF DAYS	*55*	*47*
NO. OF LIFTS	*955*	*964*
OPERATING TIME (HRS)	*574.8*	*534.8*
FISHING TIME (HRS)	*517.7*	*441.1*
NO. OF TAXA	*36*	*46*
American eel	54	128
Blueback herring	248	2,603
Hickory shad	1	1
Alewife	5	70
American shad	26,715	5,615
Gizzard shad	1,025,418	511,139
Rainbow trout	5	3
Brown trout	42	48
Brook trout	1	4
Muskellunge	5	11
Common carp	5,042	7,403
Golden shiner	45	6
Comely shiner	433	13,973
Longnose dace	1	.
Quillback	2,507	1,576
White sucker	42	36
Creek chubsucker	1	.
Shorthead redhorse	242	1,994
Channel catfish	544	3,551
White perch	133	9,537
Striped bass	506	4,261
Rock bass	1	34
Redbreast sunfish	24	165
Green sunfish	8	11
Pumpkinseed	3	22
Bluegill	45	244
Smallmouth bass	212	132
Largemouth bass	27	78
Black crappie	1	8
Yellow perch	7	48
Logperch	1	.
Walleye	255	653
Atlantic needlefish	1	8
Sea lamprey	5	11
Striped bass x white	53	114
Brook trout x lake trout	1	2
Chain pickerel	.	3
Northern pike	.	1
Spottail shiner	.	6
Spotfin shiner	.	13
Northern hogsucker	.	5
White catfish	.	187
Yellow bullhead	.	17
Brown bullhead	.	9
Margined madtom	.	3
White crappie	.	36
Tessellated darter	.	1
Banded darter	.	2
Tiger muskie	.	1
TOTAL	**1,062,634**	**563,773**

Table 2 Daily summary of selected fishes collected at the Conowingo Dam East Lift, 22 April through 15 June 1994.

DATE	*22 Apr*	*23 Apr*	*24 Apr*	*25 Apr*	*26 Apr*	*27 Apr*	*28 Apr*	*29 Apr*	*30 Apr*	*1 May*
NO OF LIFTS	*12*	*20*	*22*	*18*	*21*	*18*	*17*	*8*	*14*	*12*
FIRST LIFT	*8:17*	*7:49*	*7:53*	*7:40*	*7:38*	*8:54*	*8:22*	*11:47*	*8:02*	*7:35*
LAST LIFT	*18:52*	*18:45*	*18:52*	*18:13*	*18:55*	*19:26*	*18:20*	*18:30*	*18:10*	*17:43*
OPERATING TIME (HRS)	*10.6*	*10.9*	*11.0*	*10.6*	*11.3*	*10.5*	*10.0*	*6.7*	*10.1*	*10.1*
FISHING TIME (HRS)	*9.9*	*9.5*	*9.3*	*9.2*	*9.7*	*10.1*	*6.8*	*6.5*	*9.8*	*9.8*
AVG WATER TEMP (C)	*12.9*	*13.0*	*13.2*	*14.5*	*14.7*	*15.2*	*16.0*	*17.0*	*17.5*	*18.0*
BLUEBACK HERRING	.	.	1	1	.	.	.	.	.	15
HICKORY SHAD	.	.	.	.	1	.	.	.	.	.
ALEWIFE	2	.	.	.	2	.	1	.	.	.
AMERICAN SHAD	40	26	275	470	181	382	536	849	766	851
GIZZARD SHAD	17,345	79,702	33,052	27,806	30,022	42,403	28,895	12,803	12,100	9,513
COMMON CARP	1	2	1	4	7	11	23	5	45	28
STRIPED BASS	6	1	.	.	1	.	.	.	.	.
OTHER SPP	46	32	18	121	145	198	57	21	141	58
TOTAL	**17,440**	**79,763**	**33,347**	**28,402**	**30,359**	**42,994**	**29,512**	**13,678**	**13,052**	**10,465**

DATE	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*	*10 May*	*11 May*
NO OF LIFTS	*19*	*22*	*21*	*23*	*21*	*20*	*22*	*19*	*23*	*15*
FIRST LIFT	*7:15*	*7:57*	*7:25*	*7:28*	*7:15*	*7:37*	*7:25*	*7:22*	*7:33*	*7:37*
LAST LIFT	*17:35*	*18:20*	*18:57*	*19:04*	*17:55*	*19:01*	*18:47*	*18:40*	*19:10*	*17:45*
OPERATING TIME (HRS)	*10.3*	*10.4*	*11.5*	*11.6*	*10.7*	*11.4*	*11.4*	*11.3*	*11.6*	*10.1*
FISHING TIME (HRS)	*8.6*	*9.1*	*10.4*	*9.9*	*8.9*	*9.0*	*10.5*	*10.1*	*10.6*	*9.3*
AVG WATER TEMP (C)	*18.1*	*17.0*	*17.0*	*16.3*	*16.0*	*16.0*	*15.7*	*16.1*	*16.0*	*16.0*
BLUEBACK HERRING	.	.	.	1	.	.	.	.	.	10
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	673	499	308	206	233	443	75	398	940	291
GIZZARD SHAD	13,921	33,400	45,025	53,650	24,405	7,234	34,003	37,608	23,730	16,085
COMMON CARP	14	7	9	7	10	11	24	4	55	17
STRIPED BASS	.	2	1	4	.	.	.	.	3	.
OTHER SPP	49	69	120	440	31	19	51	61	110	65
TOTAL	**14,657**	**33,977**	**45,463**	**54,308**	**24,679**	**7,707**	**34,153**	**38,071**	**24,838**	**16,468**

Table 2 Continued.

DATE	12 May	13 May	14 May	15 May	16 May	17 May	18 May	19 May	20 May	21 May
NO OF LIFTS	4	19	18	16	17	18	17	23	19	17
FIRST LIFT	16:35	8:28	7:48	7:52	7:30	7:44	9:38	7:27	7:37	7:48
LAST LIFT	19:20	19:10	19:45	19:25	19:05	19:15	19:00	18:45	17:30	18:25
OPERATING TIME (HRS)	2.7	10.7	12.0	11.6	11.6	11.5	9.4	11.3	9.9	10.6
FISHING TIME (HRS)	2.4	9.3	10.9	11.1	11.4	10.3	8.3	10.0	8.7	9.7
AVG WATER TEMP (C)	16.6	16.3	17.0	16.7	19.0	17.0	16.9	16.4	17.0	16.8
BLUEBACK HERRING	.	.	.	.	3	1	.	.	.	.
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	308	525	1,224	1,276	843	762	420	329	595	942
GIZZARD SHAD	7,600	18,440	6,100	8,211	29,302	16,472	8,688	46,751	49,872	27,453
COMMON CARP	1	10	5	1	60	8	12	14	13	.
STRIPED BASS	1	.	.	.	1	1	1	1	.	.
OTHER SPP	31	57	20	45	212	78	35	9	23	6
TOTAL	**7,941**	**19,032**	**7,349**	**9,533**	**30,421**	**17,322**	**9,156**	**47,104**	**50,503**	**28,401**

DATE	22 May	23 May	24 May	25 May	26 May	27 May	28 May	29 May	30 May	31 May
NO OF LIFTS	14	11	24	20	13	22	12	17	15	19
FIRST LIFT	8:10	13:02	7:30	7:43	8:30	7:37	7:33	7:41	8:15	7:17
LAST LIFT	17:36	19:17	19:14	18:58	19:02	19:10	19:25	19:20	18:52	18:49
OPERATING TIME (HRS)	9.4	6.2	11.7	11.3	10.5	11.6	11.9	11.7	10.6	11.5
FISHING TIME (HRS)	9.2	6.1	11.5	9.9	9.8	9.8	11.7	11.6	10.1	10.2
AVG WATER TEMP (C)	17.4	18.4	17.0	19.1	18.8	19.5	20.4	.	21.1	22.7
BLUEBACK HERRING	.	1	3	.	.	.	.	.	3	.
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	1,372	440	894	512	563	207	1,214	1,364	713	692
GIZZARD SHAD	19,983	22,950	25,645	10,120	15,760	15,918	14,750	12,360	10,743	7,310
COMMON CARP		956	337	208	34	141	.	57	8	717
STRIPED BASS	.	1	.	2	.	1	2	4	14	5
OTHER SPP	9	112	187	188	735	52	10	25	21	40
TOTAL	**21,364**	**24,460**	**27,066**	**11,030**	**17,092**	**16,319**	**15,976**	**13,810**	**11,502**	**8,764**

Table 2 **Continued.**

DATE	1 Jun	2 Jun	3 Jun	4 Jun	5 Jun	6 Jun	7 Jun	8 Jun	9 Jun	10 Jun
NO OF LIFTS	20	18	20	21	21	21	17	21	20	20
FIRST LIFT	7:27	7:37	7:07	7:12	7:15	7:12	7:15	7:12	7:40	7:28
LAST LIFT	19:04	18:40	18:45	18:50	19:00	18:45	18:24	18:32	18:42	18:35
OPERATING TIME (HRS)	11.6	11.1	11.6	11.6	11.8	11.6	11.2	11.3	11.0	11.1
FISHING TIME (HRS)	10.4	9.3	11.2	10.2	10.3	10.0	10.3	10.4	9.5	9.6
AVG WATER TEMP (C)	23.5	22.6	22.0	21.9	21.9	22.6	23.3	24.0	23.7	23.9
BLUEBACK HERRING	1	.	48	2	44	20	3	87	3	.
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	761	324	407	378	299	190	28	186	124	133
GIZZARD SHAD	13,660	10,655	3,991	2,701	3,581	4,305	12,271	6,706	3,220	1,845
COMMON CARP	250	85	39	42	193	190	130	163	101	309
STRIPED BASS	6	9	4	5	8	9	75	47	43	50
OTHER SPP	104	51	6	26	11	107	69	65	70	62
TOTAL	**14,782**	**11,124**	**4,495**	**3,154**	**4,136**	**4,821**	**12,576**	**7,254**	**3,561**	**2,399**

DATE	11 Jun	12 Jun	13 Jun	14 Jun	15 Jun	TOTALS
NO OF LIFTS	13	14	12	8	7	955
FIRST LIFT	7:23	7:10	7:01	8:03	7:23	.
LAST LIFT	18:05	17:40	14:47	14:35	13:00	.
OPERATING TIME (HRS)	10.7	10.5	7.8	6.5	5.6	574.8
FISHING TIME (HRS)	9.8	9.6	7.1	6.0	5.2	517.7
AVG WATER TEMP (C)	24.9	23.7	24.2	24.9	26.0	.
BLUEBACK HERRING	.	.	.	1	.	**248**
HICKORY SHAD	.	.	.	.	.	**1**
ALEWIFE	.	.	.	.	.	**5**
AMERICAN SHAD	53	53	104	23	15	**26,715**
GIZZARD SHAD	1,737	1,042	1,924	454	196	**1,025,418**
COMMON CARP	50	103	466	53	1	**5,042**
STRIPED BASS	83	7	3	96	9	**506**
OTHER SPP	195	56	96	15	19	**4,699**
TOTAL	**2,118**	**1,261**	**2,593**	**642**	**240**	**1,062,634**

Table 3 Daily summary of selected fishes collected at the Conowingo Dam West Fish Lift, 30 April through 15 June 1994.

DATE	*30 Apr*	*1 May*	*2 May*	*3 May*	*4 May*	*5 May*	*6 May*	*7 May*	*8 May*	*9 May*
NO OF LIFTS	*15*	*24*	*23*	*16*	*20*	*22*	*22*	*23*	*21*	*20*
FIRST LIFT	*8:00*	*7:25*	*7:30*	*7:13*	*7:30*	*6:53*	*7:09*	*7:00*	*7:15*	*7:00*
LAST LIFT	*18:50*	*18:07*	*19:00*	*18:50*	*19:00*	*18:50*	*19:00*	*18:50*	*18:55*	*18:47*
OPERATING TIME (HRS)	*10.8*	*10.7*	*11.5*	*11.6*	*11.5*	*12.0*	*11.9*	*11.8*	*11.7*	*11.8*
FISHING TIME (HRS)	*6.4*	*8.8*	*8.9*	*10.1*	*8.2*	*10.0*	*9.9*	*10.0*	*9.9*	*10.2*
AVG WATER TEMP (C)	*17.0*	*17.0*	*18.0*	*15.8*	*18.0*	*16.8*	*16.3*	*15.1*	*15.9*	*16.3*
BLUEBACK HERRING	.	110	41	26	36	21	10	14	50	263
HICKORY SHAD	.	1	.	.	.	.	.	.	.	.
ALEWIFE	55	15	.	.	.	.	.	.	.	.
AMERICAN SHAD	34	273	34	141	93	63	49	18	24	56
GIZZARD SHAD	6,195	20,490	15,300	2,750	6,262	12,165	31,628	11,406	3,232	3,798
COMMON CARP	37	15	469	35	30	42	52	227	1	14
STRIPED BASS	.	2	12	2	6	13	17	18	9	18
OTHER SPP	468	599	1,387	956	377	320	276	556	214	612
TOTAL	**6,789**	**21,505**	**17,243**	**3,910**	**6,804**	**12,624**	**32,032**	**12,239**	**3,530**	**4,761**

DATE	*10 May*	*11 May*	*12 May*	*13 May*	*14 May*	*15 May*	*16 May*	*17 May*	*18 May*	*19 May*
NO OF LIFTS	*23*	*25*	*24*	*22*	*21*	*14*	*22*	*23*	*23*	*22*
FIRST LIFT	*7:15*	*7:08*	*7:05*	*7:13*	*7:10*	*7:00*	*7:08*	*7:03*	*7:00*	*7:10*
LAST LIFT	*18:55*	*19:00*	*18:50*	*18:50*	*18:50*	*18:40*	*19:00*	*19:00*	*18:50*	*18:45*
OPERATING TIME (HRS)	*11.7*	*11.9*	*11.8*	*11.6*	*11.7*	*11.7*	*11.9*	*12.0*	*11.8*	*11.6*
FISHING TIME (HRS)	*9.9*	*10.2*	*9.8*	*10.4*	*10.0*	*10.0*	*10.2*	*10.0*	*9.4*	*9.3*
AVG WATER TEMP (C)	*15.9*	*16.7*	*17.6*	*16.8*	*17.4*	*17.9*	*18.4*	*16.9*	*16.3*	.
BLUEBACK HERRING	223	216	100	69	34	39	115	652	77	5
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	59	103	362	111	223	360	125	72	32	20
GIZZARD SHAD	15,383	16,081	23,005	14,836	9,119	11,680	6,530	16,395	36,350	9,738
COMMON CARP	10	27	36	38	4	29	46	13	17	31
STRIPED BASS	22	18	12	15	15	16	26	24	23	25
OTHER SPP	765	707	742	1,347	816	894	563	712	266	110
TOTAL	**16,462**	**17,152**	**24,257**	**16,416**	**10,211**	**13,018**	**7,405**	**17,868**	**36,765**	**9,929**

Table 3 Continued.

DATE	*20 May*	*21 May*	*22 May*	*23 May*	*24 May*	*25 May*	*26 May*	*27 May*	*28 May*	*29 May*
NO OF LIFTS	*19*	*24*	*24*	*22*	*23*	*21*	*21*	*22*	*21*	*21*
FIRST LIFT	*7:00*	*7:06*	*7:15*	*7:15*	*7:05*	*6:57*	*7:08*	*7:05*	*7:00*	*7:00*
LAST LIFT	*18:55*	*18:55*	*18:55*	*18:45*	*19:20*	*18:50*	*18:25*	*18:50*	*19:00*	*18:45*
OPERATING TIME (HRS)	*11.9*	*11.8*	*11.7*	*11.5*	*12.3*	*11.9*	*11.3*	*11.8*	*12.0*	*11.8*
FISHING TIME (HRS)	*7.2*	*8.8*	*9.5*	*9.6*	*11.2*	*10.1*	*9.5*	*9.6*	*8.1*	*10.1*
AVG WATER TEMP (C)	*16.8*	*16.0*	*16.0*	*16.4*	*17.0*	*18.3*	*18.0*	*18.6*	*19.1*	*19.5*
BLUEBACK HERRING	2	132	5	11	159	4	1	.	.	.
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	18	113	166	225	823	108	130	52	22	29
GIZZARD SHAD	35,250	24,810	19,300	5,320	17,530	8,911	16,790	22,550	20,580	11,880
COMMON CARP	11	.	12	151	70	24	65	233	184	264
STRIPED BASS	27	10	19	16	63	74	38	122	82	48
OTHER SPP	123	107	1,239	442	2,322	296	375	438	1,411	7,884
TOTAL	**35,431**	**25,172**	**20,741**	**6,165**	**20,967**	**9,417**	**17,399**	**23,395**	**22,279**	**20,105**

DATE	*30 May*	*31 May*	*1 Jun*	*2 Jun*	*3 Jun*	*4 Jun*	*5 Jun*	*6 Jun*	*7 Jun*	*8 Jun*
NO OF LIFTS	*22*	*22*	*21*	*23*	*21*	*23*	*21*	*22*	*21*	*22*
FIRST LIFT	*7:10*	*7:10*	*7:00*	*7:00*	*7:10*	*7:00*	*7:06*	*7:00*	*6:55*	*7:00*
LAST LIFT	*18:55*	*19:00*	*18:47*	*18:50*	*18:55*	*19:00*	*18:50*	*19:00*	*18:25*	*19:00*
OPERATING TIME (HRS)	*11.8*	*11.8*	*11.8*	*11.8*	*11.8*	*12.0*	*11.7*	*12.0*	*11.5*	*12.0*
FISHING TIME (HRS)	*9.8*	*9.9*	*9.8*	*10.0*	*9.9*	*10.1*	*9.9*	*10.3*	*9.9*	*10.2*
AVG WATER TEMP (C)	*20.4*	*21.6*	*22.3*	*22.8*	*21.9*	*22.3*	*21.3*	*22.5*	*24.0*	*24.1*
BLUEBACK HERRING	2	6	2	8	7	2	28	95	37	.
HICKORY SHAD	.	.	.	.	.	.	.	.	.	.
ALEWIFE	.	.	.	.	.	.	.	.	.	.
AMERICAN SHAD	160	50	88	147	173	431	229	142	44	19
GIZZARD SHAD	15,450	8,094	5,588	3,915	4,788	1,547	3,620	746	4,610	1,431
COMMON CARP	343	219	190	351	42	219	721	208	75	65
STRIPED BASS	346	666	334	242	245	44	107	240	321	104
OTHER SPP	370	238	338	202	155	136	118	204	369	232
TOTAL	**16,671**	**9,273**	**6,540**	**4,865**	**5,410**	**2,379**	**4,823**	**1,635**	**5,456**	**1,851**

Table 3 Continued.

DATE	*9 Jun*	*10 Jun*	*11 Jun*	*12 Jun*	*13 Jun*	*14 Jun*	*15 Jun*	***TOTALS***
NO OF LIFTS	*18*	*22*	*17*	*19*	*11*	*9*	*7*	***964***
FIRST LIFT	*7:02*	*7:00*	*7:00*	*7:00*	*7:00*	*7:54*	*7:00*	.
LAST LIFT	*18:45*	*18:55*	*17:55*	*17:50*	*14:50*	*14:50*	*13:00*	.
OPERATING TIME (HRS)	*11.7*	*11.9*	*10.9*	*10.8*	*7.8*	*6.9*	*6.0*	***534.8***
FISHING TIME (HRS)	*10.0*	*10.2*	*8.9*	*9.1*	*7.0*	*6.3*	*4.7*	***441.1***
AVG WATER TEMP (C)	*24.0*	*23.1*	*22.7*	*23.5*	*23.9*	*24.8*	*26.4*	.
BLUEBACK HERRING	.	1	.	.	.	.	.	**2,603**
HICKORY SHAD	.	.	.	.	.	.	.	**1**
ALEWIFE	.	.	.	.	.	.	.	**70**
AMERICAN SHAD	80	27	67	12	3	5	.	**5,615**
GIZZARD SHAD	2,060	938	959	549	860	490	230	**511,139**
COMMON CARP	799	134	289	732	63	35	731	**7,403**
STRIPED BASS	109	102	140	31	255	81	102	**4,261**
OTHER SPP	1,030	507	177	288	497	299	197	**32,681**
TOTAL	**4,078**	**1,709**	**1,632**	**1,612**	**1,678**	**910**	**1,260**	**563,773**

Table 4 **Catch of American shad by water temperature at the Conowingo Dam Fish Lifts (East and West), 22 April through 15 June 1994. Clean-out lifts excluded.**

Water Temp. (F)	Hours Fishing	Number	Catch/Effort	Percent
< 65	563.1	22,187	39.4	68.7
> 65	395.7	10,113	25.6	31.3
TOTAL	**958.8**	**32,300**	**33.7**	**100**

Table 5 Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam East Fish Lift, 1994.

Date		Weir Gate Settings				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
22 Apr	# Shad	.	.	38	2	40
	Hrs Fishing	.	.	2.0	7.9	9.9
	Catch / Hr Fishing	.	.	18.5	0.3	4.0
23 Apr	# Shad	.	.	19	7	26
	Hrs Fishing	.	.	8.5	1.0	9.5
	Catch / Hr Fishing	.	.	2.2	7.0	2.7
24 Apr	# Shad	.	.	263	12	275
	Hrs Fishing	.	.	7.6	1.8	9.3
	Catch / Hr Fishing	.	.	34.7	6.9	29.5
25 Apr	# Shad	.	.	470	.	470
	Hrs Fishing	.	.	9.2	.	9.2
	Catch / Hr Fishing	.	.	51.2	.	51.2
26 Apr	# Shad	.	.	176	5	181
	Hrs Fishing	.	.	8.7	1.0	9.7
	Catch / Hr Fishing	.	.	20.3	5.0	18.7
27 Apr	# Shad	.	.	290	92	382
	Hrs Fishing	.	.	5.5	4.5	10.1
	Catch / Hr Fishing	.	.	52.4	20.4	38.0
28 Apr	# Shad	.	.	535	1	536
	Hrs Fishing	.	.	5.9	0.9	6.8
	Catch / Hr Fishing	.	.	91.2	1.1	79.0
29 Apr	# Shad	.	.	714	135	849
	Hrs Fishing	.	.	5.4	1.1	6.5
	Catch / Hr Fishing	.	.	132.2	122.7	130.6
30 Apr	# Shad	122	.	199	445	766
	Hrs Fishing	0.6	.	3.3	5.9	9.8
	Catch / Hr Fishing	215.3	.	60.0	75.6	78.4
1 May	# Shad	56	.	489	306	851
	Hrs Fishing	0.5	.	3.2	6.1	9.8
	Catch / Hr Fishing	112.0	.	150.5	50.4	86.7
2 May	# Shad	.	.	647	26	673
	Hrs Fishing	.	.	7.2	1.3	8.6
	Catch / Hr Fishing	.	.	89.2	19.5	78.4
3 May	# Shad	.	.	477	22	499
	Hrs Fishing	.	.	8.7	0.4	9.1
	Catch / Hr Fishing	.	.	55.0	52.8	54.9
4 May	# Shad	.	.	190	118	308
	Hrs Fishing	.	.	5.6	4.7	10.4
	Catch / Hr Fishing	.	.	33.6	25.1	29.8

Table 5 Continued.

Date		Weir Gate Settings				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
5 May	# Shad	.	.	188	18	206
	Hrs Fishing	.	.	9.1	0.8	9.9
	Catch / Hr Fishing	.	.	20.7	22.0	20.8
6 May	# Shad	.	.	145	88	233
	Hrs Fishing	.	.	7.7	1.3	8.9
	Catch / Hr Fishing	.	.	18.9	70.4	26.1
7 May	# Shad	.	.	434	9	443
	Hrs Fishing	0.3	.	7.7	1.0	9.0
	Catch / Hr Fishing	.	.	56.6	9.0	49.2
8 May	# Shad	.	.	52	23	75
	Hrs Fishing	.	.	8.4	2.1	10.5
	Catch / Hr Fishing	.	.	6.2	10.8	7.1
9 May	# Shad	.	.	344	54	398
	Hrs Fishing	.	.	8.0	2.1	10.1
	Catch / Hr Fishing	.	.	42.9	25.9	39.4
10 May	# Shad	.	.	834	106	940
	Hrs Fishing	.	.	9.2	1.4	10.6
	Catch / Hr Fishing	.	.	90.5	74.8	88.4
11 May	# Shad	.	.	162	129	291
	Hrs Fishing	.	.	4.2	5.2	9.3
	Catch / Hr Fishing	.	.	38.9	25.0	31.2
12 May	# Shad	.	.	96	209	305
	Hrs Fishing	.	.	1.8	0.6	2.4
	Catch / Hr Fishing	.	.	52.4	358.3	126.2
13 May	# Shad	324	.	124	77	525
	Hrs Fishing	1.0	.	3.5	4.7	9.3
	Catch / Hr Fishing	324.0	.	35.4	16.2	56.8
14 May	# Shad	24	.	748	452	1,224
	Hrs Fishing	2.7	.	4.9	3.3	10.9
	Catch / Hr Fishing	9.0	.	152.1	135.6	112.1
15 May	# Shad	261	.	376	639	1,276
	Hrs Fishing	1.5	.	3.6	6.0	11.1
	Catch / Hr Fishing	174.0	.	104.9	106.5	115.1
16 May	# Shad	.	.	722	121	843
	Hrs Fishing	.	.	8.2	3.2	11.4
	Catch / Hr Fishing	.	.	88.2	38.2	74.3
17 May	# Shad	543	.	140	79	762
	Hrs Fishing	3.6	.	4.6	2.0	10.3
	Catch / Hr Fishing	150.1	.	30.1	39.8	74.3

Table 5 Continued.

Date		Weir Gate Settings				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
18 May	# Shad	169	.	49	202	420
	Hrs Fishing	1.4	.	3.4	3.5	8.3
	Catch / Hr Fishing	119.3	.	14.3	57.7	50.4
19 May	# Shad	1	.	285	43	329
	Hrs Fishing	0.5	.	5.7	3.8	10.0
	Catch / Hr Fishing	2.0	.	49.9	11.3	32.8
20 May	# Shad	224	.	185	186	595
	Hrs Fishing	2.0	.	4.3	2.3	8.7
	Catch / Hr Fishing	112.0	.	42.7	79.7	68.7
21 May	# Shad	651	.	32	259	942
	Hrs Fishing	4.7	.	1.8	3.2	9.7
	Catch / Hr Fishing	137.1	.	18.3	81.8	97.4
22 May	# Shad	62	.	.	354	1,372
	Hrs Fishing	1.2	.	.	2.4	9.2
	Catch / Hr Fishing	52.4	.	.	147.5	148.9
23 May	# Shad	34	.	151	254	439
	Hrs Fishing	0.7	.	3.0	2.4	6.1
	Catch / Hr Fishing	48.6	.	49.5	107.3	71.8
24 May	# Shad	111	.	666	116	893
	Hrs Fishing	2.6	.	7.4	1.6	11.5
	Catch / Hr Fishing	43.2	.	90.4	73.3	77.5
25 May	# Shad	30	.	342	116	512
	Hrs Fishing	0.8	.	4.0	4.4	9.9
	Catch / Hr Fishing	38.3	.	85.5	26.6	51.9
26 May	# Shad	65	.	299	199	563
	Hrs Fishing	1.9	.	2.5	5.3	9.8
	Catch / Hr Fishing	33.9	.	117.3	37.4	57.5
27 May	# Shad	150	.	32	25	207
	Hrs Fishing	2.9	.	4.3	2.7	9.8
	Catch / Hr Fishing	52.3	.	7.5	9.4	21.1
28 May	# Shad	281	.	.	597	1,214
	Hrs Fishing	6.3	.	.	2.4	11.7
	Catch / Hr Fishing	44.8	.	.	248.8	104.1
29 May	# Shad	676	.	.	250	1,362
	Hrs Fishing	5.6	.	.	1.7	11.6
	Catch / Hr Fishing	120.7	.	.	148.5	117.6
30 May	# Shad	478	.	.	235	713
	Hrs Fishing	7.1	.	.	3.0	10.1
	Catch / Hr Fishing	67.5	.	.	78.3	70.7

Table 5 Continued.

Date		Weir Gate Settings				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
31 May	# Shad	123	.	210	161	692
	Hrs Fishing	1.0	.	3.3	3.6	10.2
	Catch / Hr Fishing	123.0	.	63.3	44.7	67.8
1 Jun	# Shad	109	.	256	380	761
	Hrs Fishing	1.0	.	3.6	5.0	10.4
	Catch / Hr Fishing	109.0	.	70.1	76.5	73.2
2 Jun	# Shad	256	.	47	21	324
	Hrs Fishing	4.0	.	2.6	2.7	9.3
	Catch / Hr Fishing	64.0	.	18.2	7.6	34.7
3 Jun	# Shad	227	.	19	113	407
	Hrs Fishing	3.0	.	2.7	5.1	11.2
	Catch / Hr Fishing	74.8	.	7.1	22.2	36.3
4 Jun	# Shad	224	.	.	154	378
	Hrs Fishing	7.0	.	.	3.2	10.2
	Catch / Hr Fishing	32.2	.	.	47.6	37.1
5 Jun	# Shad	294	.	.	5	299
	Hrs Fishing	9.8	.	.	0.5	10.3
	Catch / Hr Fishing	30.2	.	.	10.0	29.2
6 Jun	# Shad	102	.	39	47	190
	Hrs Fishing	3.0	.	3.1	3.4	10.0
	Catch / Hr Fishing	33.8	.	12.7	13.8	19.0
7 Jun	# Shad	11	.	3	14	28
	Hrs Fishing	1.0	.	4.5	4.8	10.3
	Catch / Hr Fishing	11.0	.	0.7	2.9	2.7
8 Jun	# Shad	126	.	28	32	186
	Hrs Fishing	5.4	.	2.5	2.5	10.4
	Catch / Hr Fishing	23.3	.	11.2	12.6	17.8
9 Jun	# Shad	81	.	12	31	124
	Hrs Fishing	3.6	.	3.0	2.0	9.5
	Catch / Hr Fishing	22.6	.	4.0	15.1	13.1
10 Jun	# Shad	89	.	12	32	133
	Hrs Fishing	3.0	.	3.1	2.5	9.6
	Catch / Hr Fishing	29.7	.	3.9	12.8	13.9
11 Jun	# Shad	26	.	.	23	53
	Hrs Fishing	4.8	.	.	4.2	9.8
	Catch / Hr Fishing	5.4	.	.	5.4	5.4
12 Jun	# Shad	50	.	.	3	53
	Hrs Fishing	8.8	.	.	0.8	9.6
	Catch / Hr Fishing	5.7	.	.	3.9	5.5

Table 5 Continued.

Date		Weir Gate Settings A Only Open	B Only Open	Down Only Open	Changing	TOTAL
13 Jun	# Shad	76	.	19	9	104
	Hrs Fishing	4.8	.	1.3	1.0	7.1
	Catch / Hr Fishing	15.8	.	15.2	8.9	14.7
14 Jun	# Shad	10	.	.	12	22
	Hrs Fishing	2.5	.	1.0	2.5	6.0
	Catch / Hr Fishing	4.0	.	.	4.8	3.7
15 Jun	# Shad	.	.	.	8	15
	Hrs Fishing	0.5	.	.	3.0	5.2
	Catch / Hr Fishing	.	.	.	2.7	2.9
TOTAL*	**# Shad**	**6,066**	.	**11,558**	**7,056**	**26,707**
	Hrs Fishing	**111.0**	.	**228.9**	**155.8**	**517.7**
	Catch / Hr Fishing	**54.6**	.	**50.5**	**45.3**	**51.6**

* American shad captured in clean-out lifts excluded from calculations.

Table 6 Comparison of catch per effort (hr) of American shad on weekdays versus weekend days by generation (cfs) at the Conowingo Dam East Fish Lift, 22 April through 15 June 1994.

		CATCH/HOUR						TOTAL
	LIFT TIME	5,000 CFS	6-10,000 CFS	11-20,000 CFS	21-40,000 CFS	> 40,000 CFS	VARYING CFS	CATCH/HOUR
WEEKDAYS	05:00-09:00	41.8	99.8	42.0	6.3	10.5	16.3	31.9
WEEKDAYS	09:01-11:00	33.0	45.8	62.1	23.9	13.2	20.6	23.4
WEEKDAYS	11:01-15:00	17.1	-	17.0	30.8	43.7	29.8	39.1
WEEKDAYS	15:01-19:00	24.0	112.6	56.1	25.3	77.2	56.6	74.0
MEAN		**34.6**	**97.6**	**41.5**	**25.4**	**46.4**	**34.0**	**45.3**
WEEKEND	05:00-09:00	16.6	116.8	31.1	6.0	1.4	106.3	51.9
WEEKEND	09:01-11:00	26.5	33.7	34.5	9.3	30.9	33.8	30.3
WEEKEND	11:01-15:00	23.1	123.7	113.0	101.4	51.7	76.2	68.7
WEEKEND	15:01-19:00	18.5	111.8	166.3	128.6	47.0	138.0	91.4
MEAN		21.2	106.7	100.1	106.7	41.3	84.3	65.5
TOTAL		**28.4**	**103.0**	**71.6**	**61.8**	**45.4**	**45.8**	**51.6**

Table 7 Summary of American shad catch by constant generation levels (varying generation during a lift was grouped separately) at the Conowingo East Fish Lift, 22 April through 15 June 1994.

Total Discharge	Unit 11	Unit 10	Number of Lifts	Time (hours)	Total Shad	Shad/Hour
5,000 cfs	OFF	OFF	125	72.8	2,065	28.4
TOTAL			**125**	**72.8**	**2,065**	**28.4**
6-10,000 cfs	OFF	OFF	75	49.4	5,093	103.0
TOTAL			**75**	**49.4**	**5,093**	**103.0**
11-20,000 cfs	OFF	OFF	47	29.3	2,438	83.1
TOTAL			**47**	**29.3**	**2,438**	**83.1**
21-40,000 cfs	OFF	OFF	21	13.0	636	48.9
21-40,000 cfs	ON	OFF	18	13.2	1,251	95.1
TOTAL			**39**	**26.2**	**1,887**	**72.2**
> 40,000 cfs	OFF	OFF	1	0.5	34	68.0
> 40,000 cfs	OFF	ON	35	18.4	541	29.4
> 40,000 cfs	ON	OFF	4	2.0	27	13.3
> 40,000 cfs	ON	ON	466	249.4	11,696	46.9
TOTAL			**506**	**270.4**	**12,298**	**45.5**
VARYING	CHG	CHG	36	23.7	795	33.5
VARYING	CHG	OFF	6	3.0	209	68.9
VARYING	OFF	CHG	4	2.5	5	2.0
VARYING	OFF	OFF	33	23.2	1,400	60.5
VARYING	OFF	ON	1	0.9	5	5.5
VARYING	ON	CHG	11	5.5	110	20.2
VARYING	ON	OFF	4	4.3	124	28.6
VARYING	ON	ON	13	6.5	278	42.6
TOTAL			**108**	**69.6**	**2,926**	**42.0**
GRAND TOTAL			**900**	**517.7**	**26,707**	**51.6**

Table 8 Daily sex ratio of American shad at the Conowingo Dam Fish Lifts, 1994.

Date	Daily Catch	Number Sexed	Number of Males	Number of Females	Ratio (M/F)
22 Apr	40	40	28	12	2.3 to 1
23 Apr	26	26	18	8	2.2 to 1
24 Apr	275	104	69	35	2.0 to 1
25 Apr	470	113	81	32	2.5 to 1
26 Apr	181	100	74	26	2.8 to 1
27 Apr	382	138	99	39	2.5 to 1
28 Apr	536	145	117	28	4.2 to 1
29 Apr	849	94	76	18	4.2 to 1
30 Apr	800	136	98	38	2.6 to 1
1 May	1,124	212	148	64	2.3 to 1
2 May	707	143	106	37	2.9 to 1
3 May	640	233	175	58	3.0 to 1
4 May	401	195	149	46	3.2 to 1
5 May	269	163	116	47	2.5 to 1
6 May	282	168	115	53	2.2 to 1
7 May	461	129	92	37	2.5 to 1
8 May	99	96	72	24	3.0 to 1
9 May	454	169	109	60	1.8 to 1
10 May	999	168	122	46	2.7 to 1
11 May	394	217	157	60	2.6 to 1
12 May	670	218	160	58	2.8 to 1
13 May	636	232	177	55	3.2 to 1
14 May	1,447	214	138	76	1.8 to 1
15 May	1,636	230	163	67	2.4 to 1
16 May	968	204	148	56	2.6 to 1
17 May	834	175	117	58	2.0 to 1
18 May	452	132	88	44	2.0 to 1
19 May	349	122	87	35	2.5 to 1
20 May	613	164	103	61	1.7 to 1
21 May	1,055	222	144	78	1.8 to 1
22 May	1,538	209	142	67	2.1 to 1
23 May	665	203	149	54	2.8 to 1
24 May	1,717	232	139	93	1.5 to 1
25 May	620	217	140	77	1.8 to 1
26 May	693	204	124	80	1.6 to 1
27 May	259	161	105	56	1.9 to 1
28 May	1,236	125	64	61	1.0 to 1
29 May	1,393	149	104	45	2.3 to 1
30 May	873	206	121	85	1.4 to 1
31 May	742	194	112	82	1.4 to 1
1 Jun	849	191	98	93	1.1 to 1
2 Jun	471	209	104	105	1.0 to 1
3 Jun	580	263	133	130	1.0 to 1
4 Jun	809	215	116	99	1.2 to 1
5 Jun	528	217	110	107	1.0 to 1
6 Jun	332	215	110	105	1.0 to 1
7 Jun	72	71	33	38	0.9 to 1
8 Jun	205	122	52	70	0.7 to 1
9 Jun	204	180	92	88	1.0 to 1
10 Jun	160	127	48	79	0.6 to 1
11 Jun	120	120	60	60	1.0 to 1
12 Jun	65	63	33	30	1.1 to 1
13 Jun	107	107	57	50	1.1 to 1
14 Jun	28	28	15	13	1.2 to 1
15 Jun	15	15	7	8	0.9 to 1
TOTAL	**32,330**	**8,745**	**5,614**	**3,131**	**1.8 to 1**

Table 9 Age and spawning history of the American shad collected at the Conowingo Dam Fish Lifts in 1994.

Sex	Age	Spawning History			Fork Length (mm)		
		N	Virgins	Repeats Once	Mean	Min	Max
MALE	III	6	6	-	322	298	345
	IV	63	58	5	372	326	423
	V	138	131	7	393	350	498
	VI	30	26	4	437	400	480
	VII	1	1	-	472	472	472
	TOTAL	**238**	**222**	**16**	**392**	**298**	**498**
FEMALE	IV	4	4	-	380	330	413
	V	48	43	5	431	389	479
	VI	47	46	1	475	428	514
	VII	11	11	-	491	475	515
	TOTAL	**110**	**104**	**6**	**454**	**330**	**515**
	GRAND TOTAL	**348**	**326**	**22**	**411**	**298**	**515**

Table 10 Summary of American shad tagged by Maryland DNR and recaptured at the Conowingo Fish Lifts, 1994.

Date	Daily Catch		Number of Maryland DNR Recaptures	
	East	West	East	West
22 Apr	40	-	-	-
23 Apr	26	-	-	-
24 Apr	275	-	-	-
25 Apr	470	-	-	-
26 Apr	181	-	-	-
27 Apr	382	-	1	-
28 Apr	536	-	-	-
29 Apr	849	-	-	-
30 Apr	766	34	2	-
1 May	851	273	1	1
2 May	673	34	1	-
3 May	499	141	-	1
4 May	308	93	-	-
5 May	206	63	-	-
6 May	233	49	3	-
7 May	443	18	1	-
8 May	75	24	-	-
9 May	398	56	2	1
10 May	940	59	2	-
11 May	291	103	-	1
12 May	308	362	3	1
13 May	525	111	1	-
14 May	1,224	223	-	1
15 May	1,276	360	2	4
16 May	843	125	3	-
17 May	762	72	3	-
18 May	420	32	2	-
19 May	329	20	2	-
20 May	595	18	3	2
21 May	942	113	4	1
22 May	1,372	166	5	2
23 May	440	225	6	1
24 May	894	823	4	5
25 May	512	108	4	-
26 May	563	130	4	1
27 May	207	52	3	1
28 May	1,214	22	11	-
29 May	1,364	29	18	-
30 May	713	160	6	-
31 May	692	50	8	-
1 Jun	761	88	16	3
2 Jun	324	147	6	2
3 Jun	407	173	4	3
4 Jun	378	431	8	12
5 Jun	299	229	10	5
6 Jun	190	142	1	4
7 Jun	28	44	1	2
8 Jun	186	19	4	3
9 Jun	124	80	1	-
10 Jun	133	27	3	1
11 Jun	53	67	1	3
12 Jun	53	12	-	1
13 Jun	104	3	1	-
14 Jun	23	5	-	1
15 Jun	15	-	-	-
TOTAL	26,715	5,615	161	63

Table 11 Summary of American shad transported from the Conowingo Dam Fish Lifts, 1994.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM BOTH LOCATIONS COMBINED					
6 May	-	17.0	47	Safe Harbor Forebay	0	100.0	12.0	12.0	17.0
13 May	-	17.0	123	Tri-County Marina	0	100.0	8.5	12.0	17.0
18 May	-	17.0	130	Columbia PFC	1	99.2	7.4	12.2	17.1
27 May	-	21.0	35	York Haven Forebay	0	100.0	12.0	12.6	21.0
27 May	-	21.0	65	Columbia PFC	0	100.0	11.4	12.4	21.0
1 Jun	-	22.9	50	Columbia PFC	0	100.0	15.8	10.5	25.0
2 Jun	-	23.5	115	Columbia PFC	0	100.0	11.2	10.5	23.7
5 Jun	-	23.0	105	Columbia PFC	0	100.0	13.1	11.1	23.3
5 Jun	-	22.9	76	Columbia PFC	2	97.4	12.2	10.2	24.0
6 Jun	-	23.5	82	Columbia PFC	0	100.0	10.4	8.8	23.7
7 Jun	-	26.1	28	Columbia PFC	0	100.0	12.0	10.0	26.2
8 Jun	-	26.0	82	Columbia PFC	0	100.0	10.0	13.2	26.0
8 Jun	-	25.0	84	Columbia PFC	7	91.7	13.2	10.9	25.3
9 Jun	-	25.0	102	Tri-County Marina	0	100.0	11.6	12.2	25.2
9 Jun	-	24.2	39	Columbia PFC	0	100.0	6.5	8.8	24.2
10 Jun	-	26.0	41	Columbia PFC	2	95.1	12.8	11.2	26.0
11 Jun	-	22.8	90	Columbia PFC	1	98.9	8.5	9.9	23.7
12 Jun	-	24.7	50	Columbia PFC	0	100.0	8.4	9.0	25.0
13 Jun	-	25.8	89	Columbia PFC	9	89.9	10.2	8.6	26.0
TOTAL			1,433		22				

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
24 Apr	275	14.9	138	Tri-County Marina	6	95.7	14.2	10.8	14.0
24 Apr	275	14.0	125	Columbia PFC	1	99.2	10.2	13.0	14.0
25 Apr	470	15.0	120	Tri-County Marina	0	100.0	11.2	11.8	16.5
25 Apr	470	15.5	125	Tri-County Marina	0	100.0	11.8	11.6	16.0
25 Apr	470	16.0	128	Tri-County Marina	0	100.0	11.4	12.0	17.0
26 Apr	181	15.0	125	Tri-County Marina	0	100.0	12.6	13.6	15.5
26 Apr	181	15.1	86	PFC Muddy Cr.	9	89.5	9.5	3.2	15.1
27 Apr	382	16.5	125	Tri-County Marina	3	97.6	12.4	14.2	17.0
27 Apr	382	16.2	123	Tri-County Marina	3	97.6	9.5	10.8	19.5
27 Apr	382	-	124	Tri-County Marina	1	99.2	12.5	11.5	-
28 Apr	536	17.0	125	Columbia PFC	0	100.0	13.8	14.4	17.5
28 Apr	536	17.5	125	Tri-County Marina	0	100.0	12.0	13.5	18.0
28 Apr	536	17.5	135	Tri-County Marina	4	97.0	15.0	13.1	19.5
28 Apr	536	17.0	125	Columbia PFC	0	100.0	15.0	12.0	17.2
29 Apr	849	17.0	125	Columbia PFC	2	98.4	12.5	10.2	17.0
29 Apr	849	17.0	125	Columbia PFC	0	100.0	13.6	13.4	17.5
29 Apr	849	17.8	114	Tri-County Marina	1	99.1	11.8	12.2	18.0
29 Apr	849	17.8	100	Tri-County Marina	0	100.0	10.8	9.5	17.2
29 Apr	849	17.5	107	Tri-County Marina	0	100.0	10.0	10.2	17.0
29 Apr	849	18.0	109	Columbia PFC	0	100.0	12.6	13.4	18.0
30 Apr	766	18.5	125	Columbia PFC	0	100.0	12.0	10.5	17.5
30 Apr	766	18.0	125	Tri-County Marina	0	100.0	9.5	11.0	17.8
30 Apr	766	19.0	100	Tri-County Marina	0	100.0	13.0	17.0	18.0
30 Apr	766	9.2	125	Tri-County Marina	0	100.0	8.5	11.2	18.0
30 Apr	766	19.2	124	Tri-County Marina	0	100.0	12.0	13.0	18.0
1 May	851	18.0	129	Columbia PFC	0	100.0	13.9	9.5	17.8
1 May	851	18.5	103	Columbia PFC	0	100.0	12.0	12.2	18.8
1 May	851	18.2	110	Columbia PFC	0	100.0	11.5	11.5	18.2
1 May	851	19.0	109	Columbia PFC	0	100.0	11.0	15.1	19.0
1 May	851	18.5	110	Columbia PFC	0	100.0	9.6	13.8	19.0
1 May	851	19.0	110	Tri-County Marina	1	99.1	11.3	9.4	17.0
1 May	851	19.0	125	Tri-County Marina	1	99.2	12.2	12.9	19.0
1 May	851	18.0	125	Tri-County Marina	0	100.0	17.2	12.2	18.0
2 May	673	18.4	125	Tri-County Marina	0	100.0	11.8	10.6	16.0
2 [illegible]	673	[illegible]	125	Tri-County Marina	0	100.0	12.9	10.5	17.0

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
2 May	673	19.0	131	Tri-County Marina	0	100.0	13.4	13.8	19.0
2 May	673	18.8	125	Tri-County Marina	0	100.0	11.0	11.4	16.5
3 May	499	17.5	125	Columbia PFC	0	100.0	12.2	9.3	16.0
3 May	499	18.5	125	Tri-County Marina	0	100.0	10.4	12.4	19.0
3 May	499	18.8	128	Tri-County Marina	1	99.2	9.8	10.0	14.8
4 May	308	17.2	105	Tri-County Marina	1	99.0	10.5	11.2	13.8
4 May	308	17.3	118	Tri-County Marina	0	100.0	10.0	11.5	14.1
4 May	308	17.0	121	Tri-County Marina	0	100.0	11.5	11.5	14.0
5 May	206	18.2	112	Tri-County Marina	0	100.0	11.8	13.0	16.0
6 May	233	16.2	107	Tri-County Marina	1	99.1	13.8	13.8	16.1
6 May	233	16.0	111	Tri-County Marina	0	100.0	15.0	12.5	16.0
7 May	443	15.0	125	Tri-County Marina	0	100.0	9.5	12.0	14.0
7 May	443	16.0	130	Tri-County Marina	0	100.0	15.5	12.0	16.0
7 May	443	15.0	130	Tri-County Marina	2	98.5	13.5	11.0	14.5
9 May	398	17.2	124	Tri-County Marina	0	100.0	12.0	13.0	17.2
9 May	398	17.0	40	Safe Harbor Forebay	0	100.0	12.7	8.5	15.0
9 May	398	17.4	136	Tri-County Marina	0	100.0	10.8	9.8	15.0
9 May	398	17.0	123	Tri-County Marina	0	100.0	15.5	12.0	17.0
10 May	940	16.5	125	Columbia PFC	0	100.0	12.0	10.5	16.0
10 May	940	16.1	125	Columbia PFC	0	100.0	10.6	12.0	16.9
10 May	940	16.8	125	Tri-County Marina	1	99.2	12.0	13.0	16.8
10 May	940	17.1	125	Tri-County Marina	0	100.0	10.8	10.0	16.0
10 May	940	16.5	120	Tri-County Marina	0	100.0	12.5	11.0	15.5
10 May	940	16.5	125	Tri-County Marina	0	100.0	12.5	11.4	15.8
11 May	291	21.0	125	Columbia PFC	0	100.0	9.5	8.6	20.9
11 May	291	16.9	100	Tri-County Marina	0	100.0	12.8	12.4	17.1
11 May	291	17.5	125	Tri-County Marina	0	100.0	11.8	13.9	18.0
12 May	308	17.0	125	Tri-County Marina	0	100.0	12.2	12.0	17.1
12 May	308	16.9	125	PFC Muddy Cr.	4	96.8	10.9	11.0	16.0
12 May	308	16.1	132	Columbia PFC	0	100.0	14.0	12.0	16.1
13 May	525	16.8	111	Tri-County Marina	1	99.1	10.5	12.4	17.2
13 May	525	17.0	125	Tri-County Marina	1	99.2	13.6	12.8	17.0
13 May	525	16.3	125	Tri-County Marina	0	100.0	10.8	12.0	16.2
14 May	1,224	17.0	95	Tri-County Marina	0	100.0	12.0	10.5	15.0
14 May	1,224	18.8	122	Tri-County Marina	0	100.0	11.7	12.2	17.0

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
14 May	1,224	18.0	125	Columbia PFC	0	100.0	10.0	11.9	16.5
14 May	1,224	18.8	126	Tri-County Marina	0	100.0	12.4	12.4	16.8
14 May	1,224	18.0	125	Tri-County Marina	1	99.2	13.8	13.2	18.5
14 May	1,224	19.6	125	Tri-County Marina	0	100.0	10.2	12.0	19.8
14 May	1,224	19.0	135	Tri-County Marina	0	100.0	9.5	12.0	16.0
14 May	1,224	19.5	136	Tri-County Marina	0	100.0	13.2	13.8	20.0
15 May	1,276	18.0	124	Tri-County Marina	0	100.0	12.6	10.6	15.2
15 May	1,276	19.0	125	Tri-County Marina	0	100.0	12.8	12.0	19.2
15 May	1,276	18.0	125	Columbia PFC	0	100.0	10.0	11.0	16.0
15 May	1,276	18.0	125	Columbia PFC	0	100.0	14.0	12.2	18.1
15 May	1,276	19.0	125	Tri-County Marina	1	99.2	11.8	11.8	18.2
15 May	1,276	19.4	127	Columbia PFC	0	100.0	11.9	11.9	19.5
15 May	1,276	12.7	125	Tri-County Marina	0	100.0	18.5	13.0	17.0
15 May	1,276	18.1	124	Tri-County Marina	0	100.0	17.3	13.8	16.0
15 May	1,276	17.8	135	Tri-County Marina	0	100.0	12.2	11.4	16.5
15 May	1,276	19.2	134	Tri-County Marina	0	100.0	17.9	12.0	19.2
15 May	1,276	18.0	124	Columbia PFC	0	100.0	8.4	12.0	18.1
16 May	843	19.0	119	Tri-County Marina	0	100.0	13.8	12.8	19.5
16 May	843	19.0	125	Tri-County Marina	1	99.2	12.8	11.4	19.0
16 May	843	18.9	125	Tri-County Marina	0	100.0	15.5	13.5	17.0
16 May	843	18.5	125	Tri-County Marina	0	100.0	10.8	12.6	18.5
16 May	843	18.0	132	Tri-County Marina	0	100.0	12.0	9.5	16.5
17 May	762	17.0	125	Columbia PFC	0	100.0	10.0	10.1	16.0
17 May	762	17.0	114	Tri-County Marina	0	100.0	12.0	13.6	17.0
17 May	762	17.2	129	Tri-County Marina	0	100.0	12.6	13.0	17.0
17 May	762	17.5	125	Tri-County Marina	0	100.0	11.0	13.2	18.0
17 May	762	16.5	125	Tri-County Marina	0	100.0	11.9	10.4	14.0
17 May	762	17.5	125	Tri-County Marina	0	100.0	10.5	10.0	15.0
18 May	420	17.0	125	Columbia PFC	0	100.0	12.0	13.0	17.0
18 May	420	16.0	125	Tri-County Marina	0	100.0	13.6	12.4	17.0
18 May	420	16.9	126	Tri-County Marina	0	100.0	14.5	12.0	16.9
18 May	420	16.2	125	Tri-County Marina	0	100.0	11.7	10.0	14.0
19 May	329	16.5	123	Tri-County Marina	1	99.2	9.0	12.4	16.8
19 May	329	16.0	125	Tri-County Marina	0	100.0	11.2	12.5	16.0
2[illegible]y	595	[illegible]	127	Tri-County Marina	2	98.4	13.0	12.8	15.5

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
20 May	595	17.0	124	Tri-County Marina	1	99.2	12.6	13.6	17.0
20 May	595	16.5	129	Tri-County Marina	0	100.0	13.0	12.1	15.2
20 May	595	15.8	129	Tri-County Marina	0	100.0	11.3	12.7	16.1
21 May	942	17.0	112	Tri-County Marina	0	100.0	12.5	12.5	16.5
21 May	942	18.0	125	Tri-County Marina	0	100.0	10.0	12.1	18.0
21 May	942	18.8	134	Tri-County Marina	3	97.8	11.0	12.5	19.0
21 May	942	18.0	125	Tri-County Marina	0	100.0	10.8	12.6	18.5
21 May	942	18.0	125	Tri-County Marina	0	100.0	11.6	12.6	19.0
21 May	942	18.0	125	Tri-County Marina	1	99.2	11.0	11.0	17.0
22 May	1,372	17.5	125	Tri-County Marina	0	100.0	11.6	12.9	18.0
22 May	1,372	17.1	124	Tri-County Marina	1	99.2	10.2	12.8	18.9
22 May	1,372	18.0	125	Columbia PFC	0	100.0	8.6	12.2	18.4
22 May	1,372	18.5	127	Columbia PFC	0	100.0	9.5	19.0	13.5
22 May	1,372	19.8	125	Tri-County Marina	0	100.0	9.8	12.8	20.2
22 May	1,372	18.5	125	Tri-County Marina	0	100.0	9.4	12.4	19.0
22 May	1,372	19.5	125	Tri-County Marina	0	100.0	11.5	12.2	19.1
22 May	1,372	19.8	125	Tri-County Marina	0	100.0	9.5	11.8	19.4
22 May	1,372	20.0	125	Tri-County Marina	0	100.0	10.5	11.5	20.2
22 May	1,372	20.0	125	PFC Muddy Cr.	0	100.0	13.0	11.8	17.0
23 May	440	21.0	124	Tri-County Marina	0	100.0	14.2	13.8	21.4
23 May	440	20.0	103	Columbia PFC	0	100.0	12.4	8.0	21.0
23 May	440	19.5	125	Tri-County Marina	2	98.4	11.7	11.2	21.2
23 May	440	20.5	125	Tri-County Marina	0	100.0	12.5	13.0	21.0
24 May	894	20.0	125	Tri-County Marina	0	100.0	12.8	13.5	21.0
24 May	894	20.0	112	Tri-County Marina	0	100.0	10.9	13.3	20.5
24 May	894	21.2	112	Tri-County Marina	4	96.4	10.0	11.6	22.2
24 May	894	21.0	125	Columbia PFC	1	99.2	12.8	12.0	21.3
24 May	894	20.0	125	Tri-County Marina	0	100.0	12.0	13.8	21.0
24 May	894	22.0	125	Tri-County Marina	0	100.0	11.0	10.0	22.0
25 May	512	20.0	125	Tri-County Marina	0	100.0	12.0	13.6	20.0
25 May	512	19.5	125	Tri-County Marina	0	100.0	5.6	12.8	20.0
25 May	512	21.5	107	Columbia PFC	0	100.0	10.5	10.0	21.5
25 May	512	20.5	120	Columbia PFC	0	100.0	10.6	9.2	10.8
25 May	512	22.8	125	Tri-County Marina	1	99.2	13.0	12.2	22.8
25 May	512	21.0	86	Tri-County Marina	1	98.8	12.2	8.5	21.0

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
26 May	563	20.5	114	Tri-County Marina	1	99.1	12.2	9.0	20.5
26 May	563	21.0	115	Columbia PFC	0	100.0	12.2	13.6	21.0
26 May	563	21.5	115	Tri-County Marina	1	99.1	13.2	5.5	19.0
26 May	563	21.0	81	Tri-County Marina	0	100.0	14.3	13.0	21.0
26 May	563	21.0	103	Tri-County Marina	0	100.0	14.4	12.3	21.5
27 May	207	20.6	110	Tri-County Marina	0	100.0	13.2	12.3	21.0
28 May	1,214	20.5	114	Columbia PFC	1	99.1	12.0	11.3	21.0
28 May	1,214	20.6	115	Columbia PFC	0	100.0	14.4	12.2	20.9
28 May	1,214	21.0	115	Columbia PFC	0	100.0	12.8	13.0	21.5
28 May	1,214	21.0	115	Columbia PFC	0	100.0	12.6	12.1	22.0
28 May	1,214	21.0	115	Columbia PFC	0	100.0	8.5	10.9	21.2
28 May	1,214	21.0	115	Tri-County Marina	0	100.0	9.9	9.2	19.0
28 May	1,214	21.5	115	Tri-County Marina	0	100.0	9.0	8.4	19.0
28 May	1,214	21.0	115	Tri-County Marina	0	100.0	11.4	11.8	21.5
28 May	1,214	20.4	115	Tri-County Marina	0	100.0	15.0	13.0	21.0
29 May	1,364	22.0	111	Columbia PFC	0	100.0	9.8	12.8	22.1
29 May	1,364	22.5	110	Columbia PFC	0	100.0	13.6	13.2	22.5
29 May	1,364	23.0	110	Columbia PFC	2	98.2	10.2	12.4	23.2
29 May	1,364	22.0	110	Columbia PFC	0	100.0	7.8	12.4	22.2
29 May	1,364	23.0	110	Tri-County Marina	1	99.1	10.0	12.2	23.5
29 May	1,364	22.5	110	Tri-County Marina	9	91.8	12.0	9.2	20.0
29 May	1,364	22.1	110	Tri-County Marina	1	99.1	10.5	9.4	19.9
29 May	1,364	22.5	110	Tri-County Marina	0	100.0	10.8	11.0	23.0
29 May	1,364	22.0	115	Tri-County Marina	0	100.0	10.2	12.0	22.5
30 May	713	22.0	115	Columbia PFC	0	100.0	12.0	13.2	22.0
30 May	713	22.2	115	Columbia PFC	0	100.0	12.8	11.5	22.8
30 May	713	22.4	115	Columbia PFC	0	100.0	12.4	11.3	23.0
30 May	713	24.0	115	Columbia PFC	0	100.0	12.0	13.2	24.0
30 May	713	24.0	115	Columbia PFC	0	100.0	9.2	11.5	24.2
30 May	713	24.0	114	Columbia PFC	1	99.1	10.4	11.0	24.0
30 May	713	23.5	115	Columbia PFC	0	100.0	12.0	13.6	23.5
31 May	692	24.5	109	Columbia PFC	0	100.0	10.4	13.6	24.5
31 May	692	23.0	110	Columbia PFC	0	100.0	10.2	11.0	23.1
31 May	692	23.5	110	Columbia PFC	0	100.0	7.0	11.9	24.0
31 May	692	26.0	110	Columbia PFC	0	100.0	12.0	13.8	26.0

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM EAST LIFT					
31 May	692	24.0	110	Columbia PFC	0	100.0	10.1	10.7	24.0
31 May	692	24.4	74	Tri-County Marina	0	100.0	12.0	11.2	24.9
31 May	692	22.9	103	Tri-County Marina	0	100.0	13.4	12.5	23.2
1 Jun	761	23.0	115	Columbia PFC	0	100.0	8.4	10.2	23.1
1 Jun	761	24.0	115	Columbia PFC	1	99.1	9.5	10.0	24.2
1 Jun	761	24.0	120	Columbia PFC	4	96.7	9.0	9.8	24.2
1 Jun	761	24.0	105	Columbia PFC	0	100.0	9.6	9.5	24.5
1 Jun	761	23.2	115	Columbia PFC	1	99.1	11.6	9.3	23.5
1 Jun	761	24.2	114	Columbia PFC	0	100.0	9.8	12.6	24.7
2 Jun	324	23.5	115	Columbia PFC	0	100.0	11.2	10.2	24.0
2 Jun	324	23.2	115	Columbia PFC	1	99.1	10.0	10.0	22.0
3 Jun	407	22.5	110	Columbia PFC	1	99.1	12.6	10.8	22.5
3 Jun	407	22.9	110	Columbia PFC	0	100.0	11.0	9.8	23.0
3 Jun	407	23.4	110	Tri-County Marina	1	99.1	12.6	11.2	23.9
3 Jun	407	24.5	58	Columbia PFC	2	96.6	12.2	9.8	24.5
4 Jun	378	23.8	101	Columbia PFC	0	100.0	10.0	10.5	24.0
4 Jun	378	24.0	104	Columbia PFC	0	100.0	20.0	12.0	23.5
4 Jun	378	23.2	105	Columbia PFC	0	100.0	9.8	10.8	23.5
4 Jun	378	23.0	46	Columbia PFC	0	100.0	13.5	12.8	23.0
5 Jun	299	23.5	110	Columbia PFC	0	100.0	12.0	9.6	23.0
6 Jun	190	23.0	92	Columbia PFC	0	100.0	12.0	11.7	23.0
10 Jun	133	25.8	100	Columbia PFC	0	100.0	11.2	9.6	25.8
TOTAL			23,186		93				

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM WEST LIFT					
1 May	273	19.5	40	Safe Harbor Forebay	1	97.5	16.0	12.5	19.5
1 May	273	19.5	212	Tri-County Marina	1	99.5	11.0	11.0	16.0
3 May	141	17.5	40	Safe Harbor Forebay	1	97.5	13.0	-	-
4 May	93	18.0	114	Tri-County Marina	0	100.0	10.6	12.2	18.0
8 May	24	15.0	25	PFC Muddy Cr.	0	100.0	16.5	18.5	15.0
10 May	59	18.0	67	Tri-County Marina	0	100.0	10.4	11.2	15.5
11 May	103	17.0	44	Safe Harbor Forebay	0	100.0	10.5	13.5	18.0
12 May	362	17.5	208	Bainbridge	0	100.0	14.8	10.4	16.5
12 May	362	9.0	192	Tri-County Marina	0	100.0	10.0	11.9	8.9
14 May	223	18.1	40	Safe Harbor Forebay	0	100.0	12.5	12.0	17.9
14 May	223	18.0	178	Tri-County Marina	0	100.0	12.5	10.9	16.0
15 May	360	18.0	34	Safe Harbor Forebay	0	100.0	11.4	12.0	18.0
15 May	360	18.5	178	Tri-County Marina	0	100.0	13.1	12.1	17.0
16 May	125	19.8	199	Tri-County Marina	1	99.5	13.6	11.2	20.0
17 May	72	17.5	26	PFC Muddy Cr.	0	100.0	12.1	13.0	16.9
18 May	32	17.5	40	Safe Harbor Forebay	0	100.0	10.0	17.5	11.9
21 May	113	17.5	36	Safe Harbor Forebay	0	100.0	9.2	12.6	17.2
22 May	166	18.0	153	Tri-County Marina	0	100.0	11.0	11.8	19.5
23 May	225	18.8	35	Safe Harbor Forebay	0	100.0	11.0	8.0	18.8
23 May	225	20.0	207	Tri-County Marina	2	99.0	10.8	12.0	20.0
24 May	823	18.5	175	Tri-County Marina	0	100.0	12.2	12.0	19.0
24 May	823	19.0	175	Tri-County Marina	1	99.4	8.2	12.4	19.4
24 May	823	19.3	175	Tri-County Marina	0	100.0	10.3	12.6	20.0
24 May	823	19.5	200	Tri-County Marina	0	100.0	14.4	12.2	20.0
25 May	108	19.5	35	Safe Harbor Forebay	0	100.0	11.0	9.8	19.5
25 May	108	20.0	43	Bainbridge	0	100.0	12.2	12.2	20.1
26 May	130	20.1	25	PFC Muddy Cr.	0	100.0	9.2	10.0	20.1
26 May	130	21.0	108	Tri-County Marina	0	100.0	12.0	12.0	21.0
30 May	160	22.0	35	Safe Harbor Forebay	0	100.0	12.0	11.5	22.5
30 May	160	21.2	122	Tri-County Marina	0	100.0	8.5	8.2	20.2
31 May	50	23.5	25	Holtwood Forebay	0	100.0	11.0	11.0	23.5
1 Jun	88	23.9	30	Safe Harbor Forebay	0	100.0	9.5	9.7	24.0
2 Jun	147	23.8	25	Holtwood Forebay	0	100.0	10.8	10.6	23.8
3 Jun	173	23.0	153	Columbia PFC	0	100.0	10.6	11.2	23.5
4 Jun	431	24.0	150	Columbia PFC	0	100.0	11.0	8.0	22.0

Table 11 Continued.

Date	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				TRANSPORTED FROM WEST LIFT					
4 Jun	431	24.0	145	Columbia PFC	0	100.0	10.8	11.0	24.5
4 Jun	431	23.0	105	Columbia PFC	0	100.0	10.0	10.2	23.5
5 Jun	229	23.0	35	Safe Harbor Forebay	0	100.0	11.8	8.8	23.5
5 Jun	229	23.0	118	Columbia PFC	0	100.0	9.2	10.8	23.0
6 Jun	142	23.0	115	Columbia PFC	0	100.0	9.1	9.2	23.0
TOTAL			**4,062**		**7**				
GRAND TOTAL			**28,681**		**122**				

Table 12 Summary of river herring transported from the Conowingo Dam Fish Lifts, 22 April through 15 June, 1994.

Date	Species	Number Collected	Water Temp (C)	Number Transported	Location	Observed Mortality	Percent Survival	DO (ppm) Start	DO (ppm) Finish	Water Temp (C) at Stocking Location
				COMBINED TRANSPORT						
6 Jun	BLUEBACK HERRING	115	23.5	3	Columbia PFC	0	100	10.4	8.8	23.7
7 Jun	BLUEBACK HERRING	40	26.1	3	Columbia PFC	0	100	12.0	10.0	26.2
8 Jun	BLUEBACK HERRING	87	26.0	24	Columbia PFC	0	100	10.0	13.2	26.0
9 Jun	BLUEBACK HERRING	3	25.0	3	Tri-County Marina	0	100	11.6	12.2	25.2
10 Jun	BLUEBACK HERRING	1	26.0	1	Columbia PFC	0	100	12.8	11.2	26.0
	TOTAL			**34**		**0**				
				TRANSPORTED FROM EAST LIFT						
5 Jun	BLUEBACK HERRING	44	23.5	26	Columbia PFC	0	100	12.0	9.0	6 23.0
6 Jun	BLUEBACK HERRING	20	23.0	19	Columbia PFC	0	100	12.0	11.0	7 23.0
10 Jun	BLUEBACK HERRING	0	25.8	1	Columbia PFC	0	100	11.2	9.0	6 25.8
	TOTAL			**46**		**0**				
				TRANSPORTED FROM WEST LIFT						
1 May	BLUEBACK HERRING	110	19.5	99	Tri-County Marina	0	100	11.0	11.0	16.0
1 May	ALEWIFE	15	19.5	58	Tri-County Marina	0	100	11.0	11.0	16.0
5 Jun	BLUEBACK HERRING	28	23.0	15	Columbia PFC	0	100	9.2	10.8	23.0
6 Jun	BLUEBACK HERRING	95	23.0	92	Columbia PFC	0	100	9.1	9.2	23.0
	TOTAL			**264**		**0**				
	GRAND TOTAL			**344**		**0**				

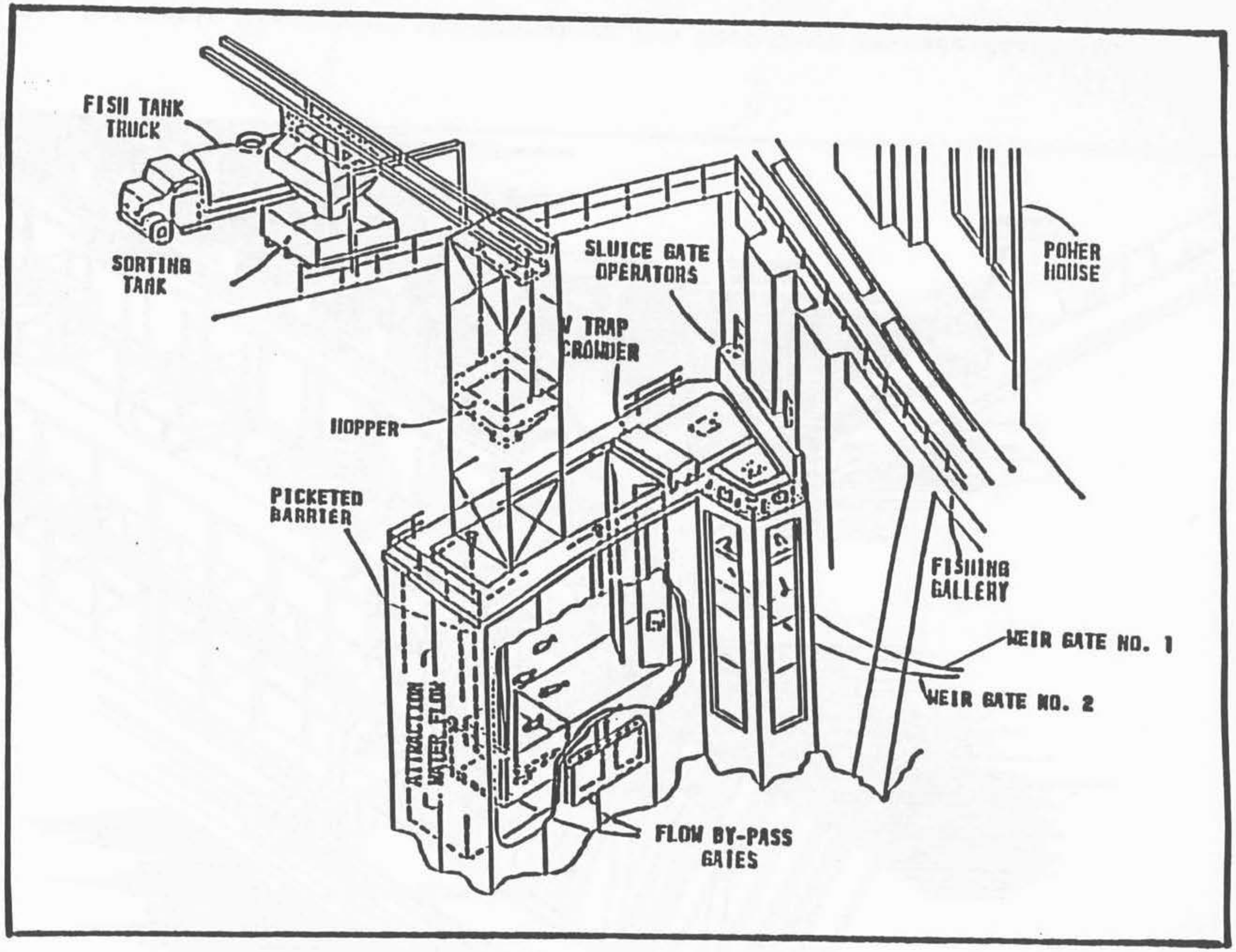

Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

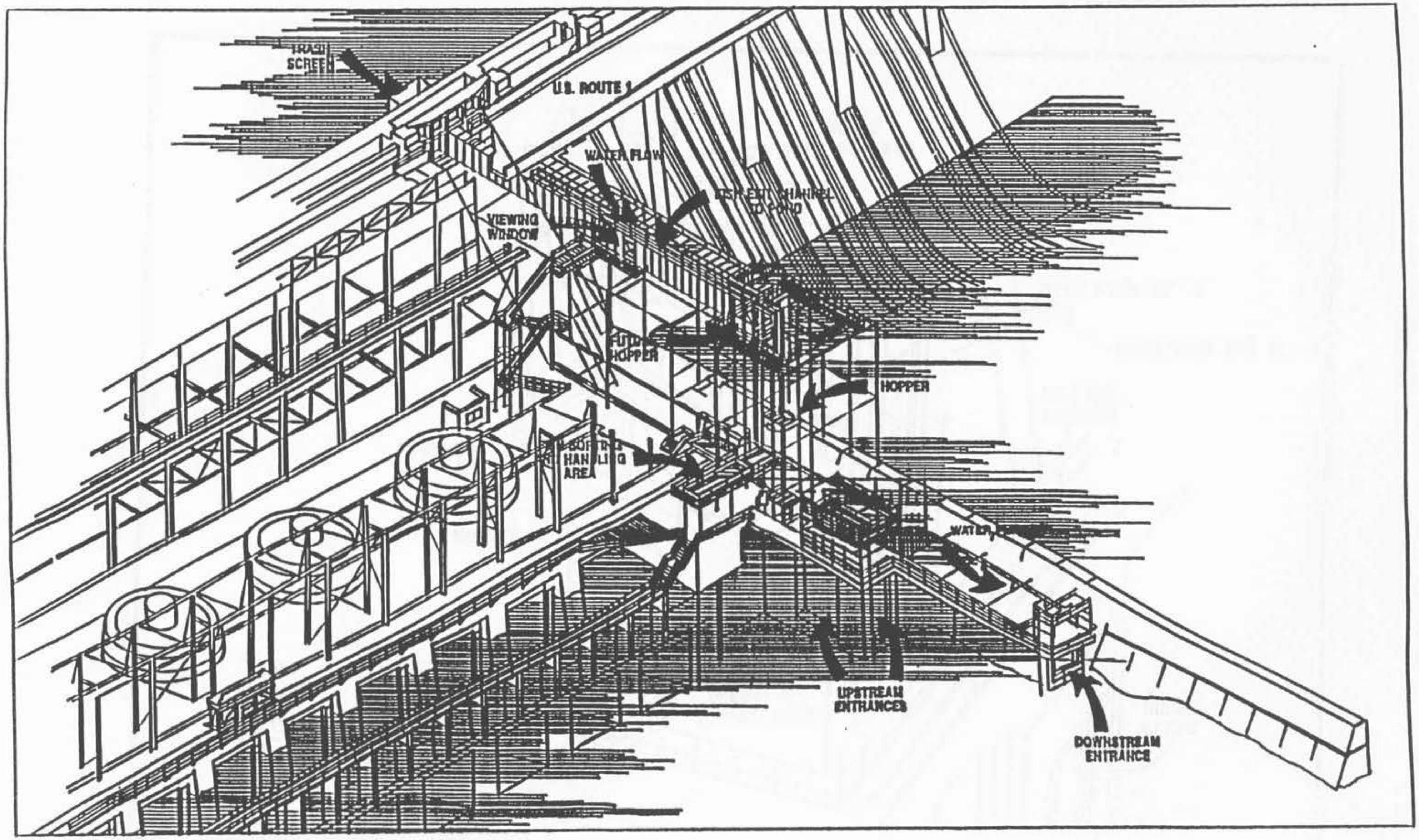

Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

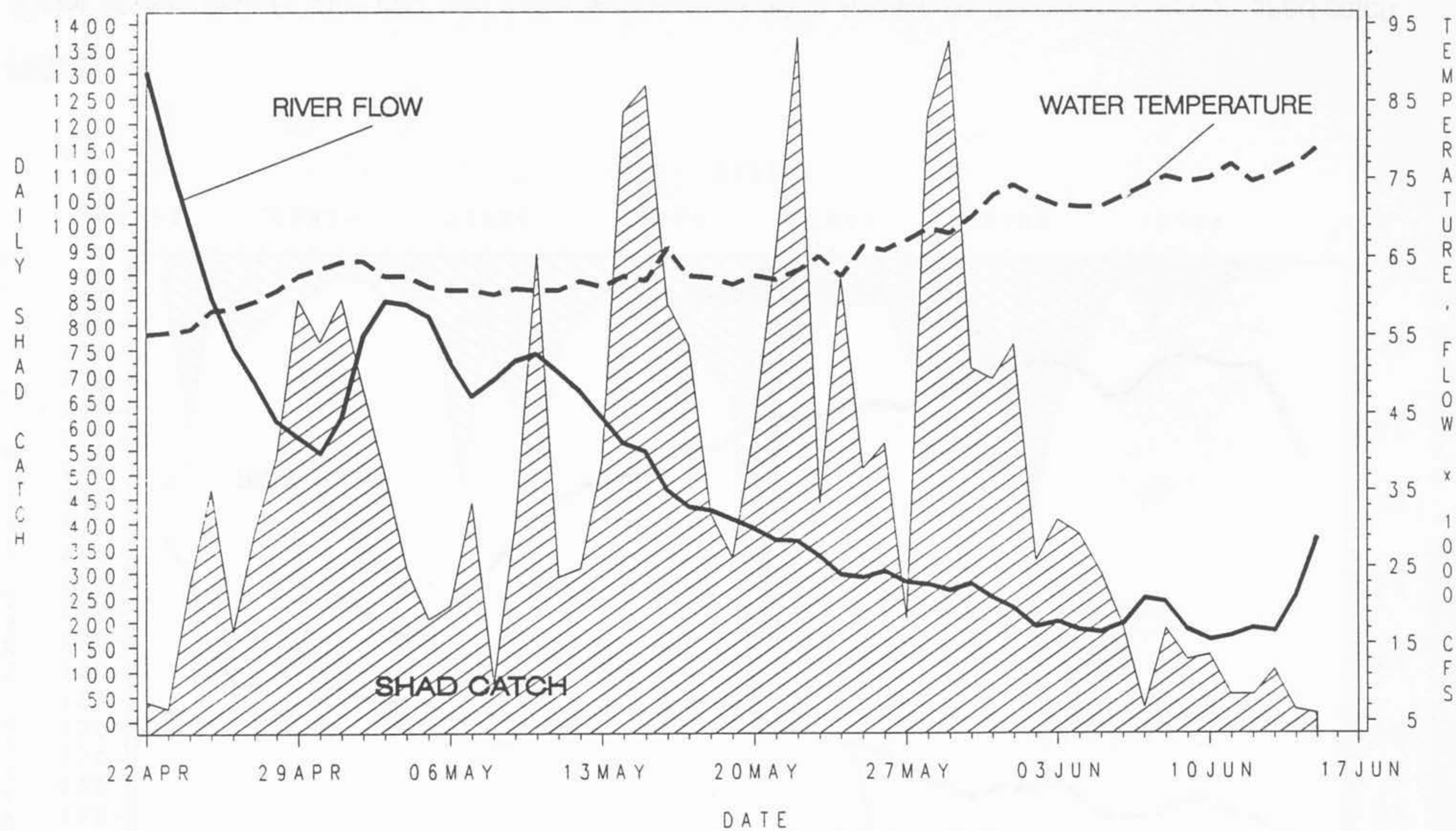

FIGURE 3

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch at the Conowingo East Lift, 1994.

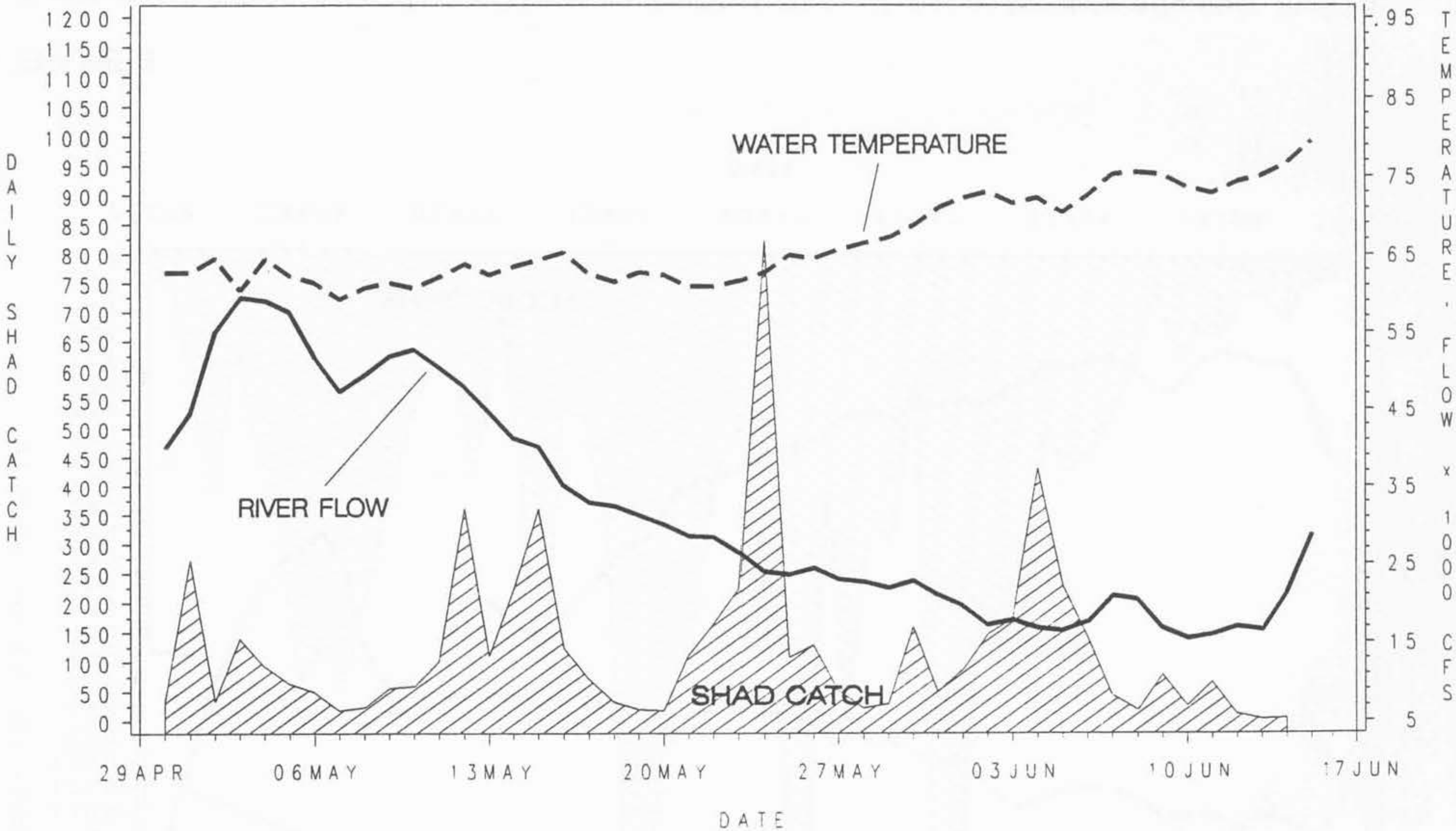

FIGURE 4

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch at the Conowingo West Lift, 1994.

JOB II.

AMERICAN SHAD EGG COLLECTION PROGRAM

THE WYATT GROUP, Inc.

Lancaster, Pennsylvania

INTRODUCTION

This report is a synopsis of egg collection efforts in the spring of 1994. The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) goal for 1994 was to obtain a minimum of 30 million shad eggs over the two-month period (May-June). In the last 21 years (1973-1994) over 500 million eggs have been collected for the program. In the period during which the hatchery operation has become well established (1980 to the present) some 431 million eggs have been obtained (Table 1). Annual production has ranged from 11 million to 52 million eggs per year.

FIELD COLLECTION PROCEDURES

The shad egg collection schedule is based on past experience, communications with commercial fisherman, advice of resource agency biologists and water temperature. Collection activities begin when water temperature is 55-58°F. The 1994 schedule of collection activities is shown in Table 2. Collection is terminated on a river when either (1) the production goal for that river is reached or (2) when it is obvious that quantities of eggs obtained over several days (usually less than five liters per day) are not sufficient to justify shipments to the Van Dyke Hatchery.

Egg Collection

Every attempt is made to obtain eggs and sperm from shad as soon after capture as possible. Ability to do so varies according to the method of capture, e.g., whether shad are caught by contractors or commercial fishermen.

On the Delaware River, gill-netted shad are brought to the shoreline where ripe shad are processed by biologists. This method delays egg fertilization if there are no ripe males in the catch and smaller meshed gill-net must be specifically set to catch males.

All shad caught on the Hudson and Connecticut Rivers are processed on board the fishing boat, often while a net is being fished. Ripe males and females are sorted from the catch and placed into separate tubs. Live male shad are placed in a tank with cold water to keep them alive if they are not going to be immediately used to fertilize eggs. It appears that sperm are more susceptible to rapid mortality than eggs. Therefore, sperm is not taken until eggs are ready to be fertilized. On the other hand, eggs may be held, without water hardening (dry), in pans for short periods prior to fertilization.

Egg Fertilization

Ideally, eggs from four to six spawning females are squeezed into a dry collecting pan and fertilized with sperm from up to six live males. Eggs and sperm from fewer fish are often fertilized, rather than defer the effort to obtain a specific number of fish. After dry mixing eggs and sperm for about one minute, a small amount of water is then added to the mixing pan to activate sperm and eggs to ensure fertilization. The fertilized eggs are then allowed to settle for two to four minutes, after which the water is decanted and clean water added to the mixing pan.

The washing/decanting process is repeated until water over the eggs appears clear, indicating reduction of dead sperm, unfertilized and broken eggs, and debris. Rinsing may be repeated four or more times. Eggs are then poured slowly into large plastic buckets containing at least ten gallons of clean river water and allowed to soak for a minimum of one hour to become hardened. Again, water is periodically decanted and clean water added.

Once the eggs are hardened (about one hour), the water is decanted through the mouth of a filtering cloth (approximately 2.0 millimeter aperture) that is held over the rim of the egg container. Five liters each of eggs and fresh river water are then placed in double plastic bags. The primary plastic bag is squeezed shut by hand and pure oxygen injected into the bag. Each bag is then secured with a rubber O-ring. The bags are placed in styrofoam containers that have a cardboard box outer liner. Each box is labeled to show river name, date, volume of eggs, and water temperature. The fertilized eggs are then ready for shipment.

Egg Viability

Each year, improvements are made to enhance egg survival. The delicate handling of fish and eggs in the field is crucial to egg viability. Progressively better handling techniques have evolved through the cooperation of the field biologists and hatchery staff. Only ripe running females on the verge of extruding eggs are used. Eggs are delicately squeezed during stripping. If blood appears with the eggs, the squeezing process is terminated and the blood (which contains lactic acid detrimental to survival) is quickly removed. Sperm is obtained only from live males.

Disposal of Shad

Although efforts are made to return shad back to the river alive, most die soon after eggs are obtained. Shad gill-netted and stripped of eggs are disposed of according to conditions of the scientific collecting permit or commercial fishing permit. They are either sold at local market, returned to the river (usually to mid-channel), or buried.

Transportation of Eggs to Hatchery

Shad eggs are packaged and shipped nightly by automobile to the Van Dyke Hatchery. This method of delivery, sometimes requiring up to eight hours, has been followed since 1983. A designated person notifies the hatchery nightly as to the number of liters shipped and estimated time of arrival at the hatchery.

FACTORS THAT AFFECT THE EGG COLLECTION PROGRAM

Weather Conditions

Weather conditions can have a significant impact on the egg collection program, especially since spawning may occur over only a few nights. High winds and rain storms create water conditions that make netting difficult. Extensive rain can increase river flow and alter water temperatures. American shad spawning seems to occur within a ten-degree range (58°F to 68°F). Barometric pressure and winds out of the north appear to influence spawning but we do not yet understand the reason(s).

Water Temperature

Water temperature is an important factor in stimulating the spawning of shad, and thus the availability of mature eggs. Although differences occur between rivers, ripe shad are not collected until water temperature is consistently above 58°F. Spawning is concluded by the time water temperature reaches about 68°F. Monitoring water temperature on rivers where eggs are to be collected is very important in determining the appropriate time to begin collecting efforts. The initial availability of eggs (spawning) can vary one to two weeks annually due to water temperature.

Water temperature can decrease as much as 10°F in a few days, or 5°F in a matter of 24 hours. When water temperature decreases to less than 55°F, spawning ceases and ripe shad cannot be netted consistently until water temperature again increases to 58°F or higher.

Tidal Conditions

On some rivers, such as the Delaware and Connecticut, netting is conducted in non-tidal areas. Thus a sampling program can be established which is repeatable. However, the method of capturing shad is different in tidal and non-tidal areas. Anchor nets in non-tidal areas accumulate too much debris and provide the shad with both visual and pressure field net references conducive to net avoidance. Commercial fisherman state that the limper a net hangs in the water (producing no pressure head) the more effective the net is in catching fish. Anchor nets can be set parallel to shore; this method has worked well in the Delaware River.

The tidal cycle includes an ebb (descending) and flood (ascending) phase that reverses direction every 4-6 hours. For a short period, usually a few minutes to some portion of one hour, this transition in the direction of water flow produces still or slack water. Slack water occurs after both flood and ebb tides. There are usually two high and two low tides per 24-hours with corresponding tidal changes occurring approximately one hour later each day. The factors that influence the tidal system (river flow, weather, lunar cycle, etc.) are important to the success of fishing in any estuarine ecosystem, e.g. the Hudson River. The effects of several days of abnormally high or low barometric pressure, several days of continual north or south winds, or a period of heavy rain can alter the timing and strength (current) of the tide. These natural events can change the times shown in tidal charts by up to 90 minutes. Thus, it is best to fish according to observation of the natural system.

The specific spawning requirements of shad, such as time of day and location, must be coordinated with tidal factors to be most successful at capturing shad with gill nets. Gill-netting for running ripe shad is most productive with the occurrence of slack water, usually after a flood tide, immediately after dark and when river water is warmest in a 24-hour period. Shad move into relatively quiet and shallow areas to spawn and that activity usually continues for two to three hours.

LOCATION OF EGG COLLECTION EFFORT

Through the years since 1971, the rivers chosen each year for sampling have changed. All East Coast rivers from the Connecticut (Massachusetts) south to the Savannah (South Carolina-Georgia) have been explored to determine feasibility of providing eggs. No rivers south of Virginia provided sufficient quantities of eggs to warrant continuation of efforts. The James and Pamunkey rivers (Virginia), reliable sources of eggs for 20 years, were abandoned as an egg source in 1991 due to a decline in shad populations. The Columbia River (Oregon-Washington) was eliminated in the

1990 program, and presumably all future years, due to poor fry survival (as indicated by otolith analysis) and the potential presence of viral hemorrhagic septicemia (VHS). Thus, in 1994 the program included the Delaware, Hudson and Connecticut rivers which were previously demonstrated to be reliable sources of eggs.

Delaware River (Pennsylvania-New Jersey)

The egg collection program continues to be conducted at Smithfield Beach, about eight miles upstream from East Stroudsburg, PA. The area of the river is characterized as non-tidal with a moderate downstream flow of fresh water.

SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative (New Jersey), to collect some 15 million shad eggs from the Delaware River. Biologists from the Pennsylvania Fish and Boat Commission and Ecology III, Inc. (Berwick, PA) conducted the collection program. Shad were captured with gill-nets set parallel to the current. Nets were set between dusk and midnight.

Hudson River (New York)

The Hudson is a relatively large estuarine system which is simple in configuration but very complex in physical and chemical characteristics. Egg collection efforts fell into two categories: collections by anchored gill-nets and haul seine. These two techniques were alternated in accordance with the changing tidal conditions; the haul seine was used during periods of low water and gill-nets were used at all other times. The Wyatt Group's 1994 efforts were concentrated in two primary areas, Rogers Island (River Mile 114) for haul seining and off Cheviot, NY (River Mile 106) for gill-netting.

Connecticut River (Massachusetts)

The collection program on the Connecticut River began in 1990 on an experimental basis near the Holyoke Dam. Egg collection activities in 1994 were located approximately 1 mile downstream from the confluence of the Connecticut and Deerfield rivers in Deerfield, Massachusetts. The site was one quarter mile in length and each drift took about 15 minutes, depending on river current. If river conditions were good, up to 10 drifts per boat were made each evening. No other potential spawning sites were fished in 1994. Biologists from Normandeau Associates (Bedford, New Hampshire) directed 1994 Connecticut River egg collection efforts.

RESULTS OF 1994 FIELD COLLECTION EFFORTS

This section provides the results of the efforts in the spring of 1994. In addition, discussion is presented when explanation is useful in describing events or in consideration of making plans for the future.

Delaware River (Pennsylvania-New Jersey)

Egg collection on the Delaware River began 10 May 1994. Biologists from Ecology III and the Pennsylvania Fish and Boat Commission conducted the spawning and fertilization of American shad captured in gill nets. Ten to seventeen nets were set each night, each net measuring 200-foot x 6-foot with meshes ranging from 4.5 inches to 5.5 inches.

A total of 10.36 million eggs was shipped to the Van Dyke Hatchery on sixteen dates (Table 3). An additional 1.36 million eggs were delivered to Manning Hatchery in Maryland. The first shipment was on 10 May and the last on 3 June. Ripe shad were caught at water temperatures which ranged from 55 to 70°F (mean = 63°F). The total number of shad captured was 1,279.

Hudson River (New York)

In 1994, monofilament gill-nets 600- foot x 6-foot with 4.5 to 5.5- inch stretch mesh were set beginning just before dark, tide permitting. Up to 2400 feet of net were set each night. The favored method was to anchor nets perpendicular to the shoreline at slack tide or during a slow-moving flood tide. Nets were also anchored and drifted in deeper waters at the onset of the main channel. Water depth for set nets ranged from 4-9 feet.

A 500-foot x 12- foot haul seine with 2-inch stretch mesh was also used to collect shad. Seine operations were conducted on an ebb tide, between late afternoon and dusk at a time when the tidal conditions provided a landing site where the catch could be effectively beached.

The Wyatt Group field crew initiated field sampling by gill-net off Cheviot, NY on 1 May when the water temperature was 53°F. The first shipment of eggs was made on 4 May at a temperature of 53°F. On 6 May, tidal conditions at Cheviot required that efforts be made with the haul seine. The Wyatt Group field crew assisted Mr. Everett Nack in capturing shad by haul seine off the northwest corner of Rogers Island on 6-7 May and 22-26 May.

A total of 6.29 million eggs was obtained on the Hudson River and shipped to the Van Dyke Hatchery (Table 4). This included 2.87 million eggs from shad captured by gill-net and 3.42 million eggs from shad captured by haul seine. An additional 0.82 million were shipped to Manning Hatchery. The Hudson River egg collection program began on 1 May and continued until 30 May. In this period, the program included 21 efforts of gill-netting and seven efforts of haul seining.

Connecticut River (Massachusetts)

Normandeau Associates began fishing on 26 and 27 May, after river temperature had reached 61°F and 115,668 shad had been lifted at the Holyoke Dam. However, few shad were caught on these dates, so fishing was temporarily suspended. Sampling resumed on 31 May, with two full crews using separate boats and gear. This level of effort continued through 16 June. Egg collections were usually conducted between 2000 and 2400 hours each day.

Egg production began on the night of 31 May with a shipment of 9.8 liters of eggs. A total of 4.09 million eggs was collected and delivered to the Van Dyke Hatchery (Table 5). The Maryland Department of Natural Resources was provided with 1.47 million eggs. Egg production ended on 16 June. Two boats, each drifting 300-foot x 5-foot deep monofilament gill nets were used to capture spawning shad. Each net was constructed with 200 feet of 5-inch stretch mesh and 100 feet of 4.5-inch stretch mesh. In addition to these gill nets, field crews also deployed a 300-foot x 6-foot gill net with 4.5-inch stretch mesh to capture more males.

The shad population on the Connecticut differs from other rivers in that spawning occurs only for a period of several hours (from darkness to approximately 2400 hours). Water temperature and river flow influence the success of egg collection operation on the Connecticut. When flows increase dramatically, shad spawning diminishes and egg collection drops.

Summary of Egg Collection

A total of 20.66 million eggs was delivered to the Van Dyke Hatchery from the Delaware, Hudson, and Connecticut rivers in the spring of 1994. An additional 3.71 million eggs were collected and provided to the cooperative program between SRAFRC and Manning Hatchery.

The Delaware River egg production has remained steady for the past several years. An extremely low egg viability during the fourth week of the 1994 season may have been influenced by high water temperature.

Egg production on the Hudson River was 47% higher in 1994 compared to 1993. River temperatures on the Hudson remained consistently cool during the first week of May which may have protracted the spawning period.

The number of eggs collected from the Connecticut River was lower in 1994 than in 1993. This reduced number of eggs may be related to the lower numbers of shad that are being lifted above Holyoke Dam during the past three years. In 1994, 180,810 shad were counted at Holyoke, compared with 340,341 shad lifted in 1993 and 721,369 in 1992.

Relatively high (61.6%) viability was obtained when eggs were collected at water temperatures of 62-67° F. The vialbility decreased sharply in the temperature range of 67-70° F (Table 6). Smaller egg size in shipments corresponds to the low viabilities. The smaller eggs may be related to lack of fertilization (poor sperm survival or motility), ineffective water-hardening, immaturity of eggs in late season, or all of these. A similar phenomena can be observed on the Connecticut River (Table 6). On the Hudson, lower viability was obtained when shad were collected before the water temperature reached 57° F. The results from all rivers confirms that the best viability is obtained when shad are collected in the temperature range of 57-67° F.

TABLE 1. Total number (millions) of American shad eggs collected from various rivers and delivered to the Van Dyke Hatchery, 1980-1994.

Year	Delaware	Hudson	Connecticut	Columbia	Other*	Totals
1980	-	-	-	-	13.56	13.56
1981	-	-	-	5.78	5.84	11.62
1982	-	-	-	22.57	3.28	25.85
1983	2.40	1.17	-	19.51	11.40	34.48
1984	2.64	-	-	27.88	10.57	41.09
1985	6.16	-	-	12.06	7.33	25.55
1986	5.86	-	-	39.97	6.69	52.52
1987	5.01	-	-	23.53	4.46	33.00
1988	2.91	-	-	26.92	1.97	31.80
1989	5.96	11.18	-	23.11	2.44	42.69
1990	13.15	14.53	-	-	0.94	28.62
1991	10.74	17.66	1.10	-	0.31	29.81
1992	9.60	3.00	5.71	-	0.17	18.48
1993	9.30	2.97	7.44	-	1.78	21.49
1994	10.27	6.29	4.10	-	0.56	21.22
TOTALS	84.00	56.80	18.35	201.33	71.30	431.78

*Primarily the Pamunkey River and the James River.

TABLE 2. Collecting periods for eggs of American shad, 1994.

River	Dates	Fishing Efforts
Delaware	10 May - 2 June	17
Hudson	1 May - 30 May	28
Connecticut	26 May - 16 June	19

TABLE 3. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1994.

Date		Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May	10	8.5	256,535	7	58	58.7
	11	22.2	551,253	8	58	76.6
	12	4.3	126,914	9	57	66.9
	15	19.2	493,921	12	58	62.7
	16	10.0	Manning*	13	59	-
	17	22.0	Manning*	15	57	-
	18	1.9	66,031	18	56	59.9
	22	45.2	1,304,428	21	64	55.0
	23	33.1	1,586,340	23	67	6.7
	24	16.8	1,162,240	26	69	1.7
	25	11.2	821,437	28	69	6.1
	30	31.3	1,282,905	30	67	6.2
	31	14.1	1,352,780	31	69	15.7
June	1	11.7	582,364	33	70	8.6
	2	11.7	686,613	35	69	1.5
Total		231.2	10,273,763	Mean =	63	22.0

* Delivered to Manning Hatchery

TABLE 4. Collection data for American shad eggs taken on the Hudson River, New York, 1994.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability	Gear
May 4	23.2	569,280	4	53	52.3	Gill
5	24.8	637,982	5	53	44.0	Gill
6	9.3	285,963	6	55	58.6	Seine
14	6.8	194,036	10	57	88.4	Gill
15	14.0	394,981	11	57	89.9	Gill
16	13.0	Manning*	14	57	-	Gill
17	16.0	Manning*	16	57	-	Gill
18	12.1	329,970	17	56	65.6	Gill
19	12.1	333,677	19	57	65.3	Gill
21	13.8	407,305	20	58	87.2	Gill
22	7.8	232,803	22	58	92.0	Seine
23	34.5	1,029,704	24	59	82.8	Seine
24	28.8	878,895	25	61	89.9	Seine
25	24.4	688,396	27	61	91.6	Seine
26	10.5	303,020	29	62	83.9	Seine
Total	222.1	6,286,012		Mean = 57	76.4	

*Obtained for Maryland Department of Natural Resources.

TABLE 5. Collection data for American shad eggs taken on the Connecticut River, Massachusetts, 1994.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May 31	9.8	418,014	32	63	79.2
June 1	5.1	268,446	34	62	83.5
2	9.0	391,542	36	62	86.8
3	11.4	387,847	37	62	87.4
4	9.6	333,632	38	63	83.8
5	10.2	413,891	39	65	82.8
6	9.0	Manning*	40	65	-
7	10.0	Manning*	41	65	-
8	8.5	Manning*	42	65	-
9	7.0	Manning*	43	67	-
10	5.6	319,937	44	67	77.0
11	7.6	374,741	45	65	42.7
12	6.2	269,729	46	67	30.9
13	5.2	381,382	47	70	35.1
14	4.7	301,108	48	70	22.9
16	3.1	231,141	49	73	23.7
Total	87.5	4,091,410		Mean = 66	63.6

*Obtained for Maryland Department of Natural Resources.

TABLE 6. Comparison of shad egg viability and egg size as expressed in numbers per liters for early and late season collections from the Delaware, Connecticut, and Hudson Rivers in 1994.

River/Dates	Temp (°F)	Volume (Liters)	#Eggs (Millions)	#Viable (Millions)	%Viable	Eggs/Liter
Delaware						
5/10-5/22	57-64	101.3	2.8	1.7	61.6	27,632
5/23-6/02	67-70	129.9	7.5	0.5	7.1	57,542
Connecticut						
5/31-6/10	62-67	60.7	2.5	2.1	83.0	41,735
6/11-6/16	65-73	26.8	1.5	0.5	32.2	58,138
Hudson						
5/04-5/06	53-55	57.3	1.5	0.8	51.6	26,059
5/14-5/26	57-62	164.8	4.8	4.0	83.6	29,082

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1994

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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 system. The objectives of the Van Dyke Station were to research culture techniques for American shad and to rear juveniles, both fry and fingerlings, 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 1994 included the stocking of 10-20 million 18-day old shad fry, and 50-100 thousand fingerlings. All Van Dyke hatchery-reared American shad fry were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared outmigrants from juveniles produced by natural spawning of transplanted adults. American shad fingerlings produced in Pennsylvania ponds were also marked by feeding of tetracycline laced feed to distinguish them from hatchery-reared fry.

Procedures were continued in 1994 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources. Research conducted in 1994 involved comparison of egg viability for Delaware River eggs water hardened in Van Dyke water vs controls water hardened in Delaware River water (Appendix 1), comparison of fry survival for eggs incubated in old vs. new open-cell foam bottom egg incubation jars (Appendix 2), efficacy of marking larvae by two, four and six hour immersion in 200mg/L tetracycline hydrochloride (Appendix 3), and relative survival of Hudson River larvae released at 7 days of age vs. controls released at 20 days of age (Appendix 4).

EGG SHIPMENTS

A total of 21.2 million eggs (551 L) were received in 49 shipments in 1994 (Table 1). This represented the second lowest number of eggs received since 1981 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 45.9%.

Egg collection efforts in Virginia Rivers were undertaken by the Commonwealth of Virginia to support shad restoration in the James River. The bulk of the eggs collected were shipped to the newly constructed shad facility at Virginia Department of Game and Inland Fisheries' King and Queen Hatchery. Three egg shipments were sent to Van Dyke when the King and Queen facility reached its capacity, including two shipments of eggs from the Pamunkey River (534 thousand eggs) and one shipment of eggs from the Mattaponi River (29 thousand eggs).

Fifteen shipments of eggs were received at Van Dyke from the Delaware River (10.3 million eggs) with a viability of 22.0%. The overall low viability of the Delaware River shipments was due to low viability in six shipments received after May 22, 1994. River temperature at egg take for those six shipments exceeded 66.8F and probably accounted for the low viability. Viability for the other nine Delaware River shipments was 61.9%.

The Hudson River produced 15 shipments (6.3 million eggs) with a viability of 76.4%. Sixteen shipments of eggs were received from the Connecticut River (4.1 million eggs) with a viability of 63.6%.

Eight shipments of eggs were delivered to MDNR's Manning Hatchery for culture there.

SURVIVAL

Overall survival of fry was 78%, compared to 66% in 1993, 41% in 1992 and a range of 70% to 90% for the period 1984 through 1991. Survival of individual tanks followed four patterns (Figure 1). Thirty-five tanks exhibited 18d survival averaging 84%, typical of survival in the past. Two tanks (E11, F41) suffered high mortality between 9 and 14 days of age which resulted in mean 18d survival of approximately 54%. One tank (I11) exhibited high mortality at 5 and 6 days of age and again between 11 and 15 days of age, resulting in 18d survival of 54%. Another tank (F31) suffered high mortality at 5 and 6 days of age and was stocked at 7 days of age with a resultant survival of 78%. Tank H11 (not included in the tabulations for Figure 1) was stocked at 14d of age and experienced survival of 73.4%.

As in 1993, early indications were that the mortality problems experienced in 1992 and 1993 (Hendricks and Bender, 1993; 1994) would not be repeated, however, tank E11 was the first of four tanks to experience mortality problems and symptoms associated with the "Van Dyke Syndrome." The cause of these mortality problems remains unknown. New open-cell foam bottom screens were used on all egg jars not involved in research projects (see Appendix 2) including the four tanks which experienced the "Van Dyke syndrome." This suggests that "old" foam was not the cause of the mortalities as was speculated by Hendricks and Bender (1994).

All foam bottom screens are routinely disinfected in iodophor before and after use. The iodophor penetrates the foam and is difficult to rinse out. Iodine toxicity is another potential cause of these mortalities.

We attempted to re-create the conditions which we thought would promote the occurrence of the "Van Dyke Syndrome" by using old foam, disinfected with concentrated iodophor, and not rinsed (see Appendix 2). These attempts were unsuccessful and we could not intentionally cause the syndrome to occur.

The frequency of occurrence of the syndrome declined from 28 tanks in 1992 to 26 tanks in 1993 and 4 tanks in 1994. We are hopeful that continued vigilance in fish culture hygiene will result in continued low frequency of the syndrome. In the future, we plan to construct new foam bottom screens each year and not re-use them or disinfect them with iodophor.

FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 7.6 million. A total of 6.4 million was released in the Juniata River and 642 thousand in the Lehigh River. Some 56 thousand fry were transferred to the Virginia Department of Game and Inland Fisheries for release in the York River. An additional 430 thousand were transferred to ponds in Pennsylvania for grow-out and release as fingerlings. Twenty-two thousand were transferred to raceways or ponds for mark retention analysis.

TETRACYCLINE MARKING

All American shad fry produced at Van Dyke received marks produced by immersion in tetracycline (Table 5). Immersion marks were administered by bath treatments in 200 ppm tetracycline hydrochloride for 6h duration. All fry releases took place in the Juniata River. Fry originating from Delaware River eggs received a triple mark on days 3, 13, and 17. Hudson River fry received a triple mark on days 5, 9, and 13. Connecticut River fry received a quintuple mark on days 5, 9, 13, 17, and 21. Two tanks of Connecticut River fry received experimental marks by 2h or 4h immersion on days 9 and 17, in addition to 6h immersions on days 5, 13 and 21 (see Appendix 3). Ten tanks of Hudson River fry were involved in a study to compare survival of uniquely marked fry released at 7 or 20 days of age (see Appendix 4).

Fingerling shad received additional tetracycline marks by feeding tetracycline laced feed at a rate of 40g tetracycline (active ingredient) per pound of food. Marks were produced by feeding the TC laced feed for three days, preceded by two days of starvation. Multiple marks were produced at 5 day intervals.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways or ponds and examining otolith samples collected during harvest. Retention of tetracycline marks for American shad was 100% for all groups analyzed except one, including the experimental 2 and 4h marks (Table 6). A single specimen from Benner Spring Raceway E2, marked on days 5, 9, 13, 17, and 21; exhibited fluorescence on days 5, 9, 13, 14, 15, 16, 17, 19, and 21. We have not seen this before and have no explanation.

FINGERLING PRODUCTION

American shad fingerlings were produced in the Canal Pond (Thompsontown) and Upper Spring Creek Ponds. A mark-recapture population estimate was planned prior to the release of fingerlings from the Canal Pond. The estimate was postponed for one week due to high, muddy water. The following week a sample of fish was collected for marking but the fish suffered complete mortality overnight due to clogging of the tank intake by several fish which had swum up into the intake pipe. Logistical concerns prevented further postponement of the effort and the fish were estimated visually at 40,000 and stocked on August 26, 1994.

The Canal Pond was harvested as in 1992 and 1993, with some improvements in technique. The catch basin had been modified in early Spring by the pouring of a new, sloped concrete base which would prevent the fish from stranding in the catch basin during release. All pond boards were removed except a single set in the front of the catch basin. The catch basin was then cleared of ashes and debris. Boards were reinstalled in the rear of the catch basin with a quick release board on the bottom. A six inch clear flexible hose was attached to the quick release and extended halfway into the 24 inch concrete effluent pipe which led from the pond to Delaware Creek. The top 5 or 6 front boards were removed and the catch basin allowed to fill with water. Juvenile shad were then lured into the catch basin using feed. When a large school of shad entered the catch basin, a screen was temporarily installed to trap the fish and boards were reinstalled in front of the catch basin. The quick-release was then activated and the catch basin emptied into Delaware Creek. The remaining water in the pond was held back by the front boards. The quick-release was then reset and the catch basin allowed to re-fill with pond water. The front boards were again removed and the process repeated. The majority of the fish in the pond were released by repeating the process 5 or 6 times. The few remaining fish were released by further draining of the pond and eventual quick-release to Delaware Creek.

This was the most successful Canal Pond harvest to date. More and larger (mean TL= 78.3mm) American shad fingerlings were released than ever before. The addition of the sloped concrete bottom in the catch basin appeared to improve the condition of the fish at release by decreasing scale loss. Due to recent rains, Delaware Creek was high and muddy, and the shad appeared to be flushed out of the Creek immediately after release. In previous years, many of the juvenile shad remained in Delaware Creek for a day or two before migrating downstream to the Juniata River.

UPPER SPRING CREEK

The three Upper Spring Creek ponds were stocked with approximately 76,000 fry each on June 10, 1994. The fry were 18 days old at the time of stocking and had been given a triple immersion mark on days 3, 13, and 17. The fish did quite well, and at 35 days of age supplemental feeding was initiated. In August, the fish in each pond received unique marks (Table 5) administered by feeding tetracycline laced feed at a rate of 40g (active ingredient) per pound of food. Marks were produced by feeding TC laced feed for three days (10 pounds of food per day) preceded by 2 days of starvation. For fish receiving multiple marks, there was a five day interval between feedings with TC laced feed.

A mark - recapture population estimate was conducted for each of the three ponds using procedures described in Hendricks and Bender (1993). Estimates indicated a pond population of 43,871, 38,688, and 21,298 fingerlings for ponds 1, 2 and 3 respectively. Considering the large number of fish in the ponds this year, it was felt that it would be quicker and less stressful to bucket the fish from the catch basin to the truck rather than using the lift device. Each of the three ponds required two stocking trips; approximately half of the fish were taken on each trip (Table 3).

No problems were encountered with fish harvested and stocked in September (ponds 1 and 3). An early cold spell in October resulted in water temperatures in the mid-forties in Pond 2. The fish became lethargic and would not feed. As a result of the low water temperature approximately 2,400 fish were lost from Pond 2. In addition, approximately 1,300 Pond 2 fish were transported to Benner Spring where water temperature was raised to 62^0 F. These fish were held for about a week and were then transferred to the Mystic Marine Life Aquarium in Mystic, Connecticut by Mr. Mike Johnson, Curator of Collections. Approximately 1,100 of the fish arrived at the Aquarium in good condition and were used in a display.

Overall, fish were smaller this year than in past years, averaging 2-2 1/2 inches in length probably because of higher density in the ponds. A grand total of 103,800 fingerlings were produced in the Upper Spring Creek Ponds during the 1994 season, a 37 percent survival from fry to fingerling. Of those fish produced, 99,500 were released in good condition into the Juniata River at Thompsontown.

SUMMARY

A total of 49 shipments (21.2 million eggs) was received at Van Dyke in 1994. Total egg viability was 45.9% and survival to stocking was 77.7%, resulting in production of 7.6 million fry. The majority of the fry were stocked in the Juniata River (6.4 million). Fry were also released in the Lehigh River (642 thousand), and the York River (56 thousand released by the VDGIF). A total of 139,500 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River.

Overall survival of fry was 78%, up from 66% in 1993 and 41% in 1992. Survival was negatively impacted by minor re-occurrence of the mortality problems ("Van Dyke Syndrome") which occurred in 1992 and 1993. The cause of the problem remains unknown.

All American shad fry cultured at Van Dyke were marked by immersion in 200 ppm tetracycline. Fry released in the Juniata River received unique marks based on egg source river. Delaware

River fry received a triple mark on days 3, 13, 17; Hudson River fry received a triple mark on days 5, 9 and 13; and Connecticut River fry received a quintuple mark on days 5, 9, 13, 17, and 21. Fingerlings grown-out in Pennsylvania ponds received additional multiple feed marks unique to each individual pond.

Retention of tetracycline marks was 100% for all marks with the exception of one specimen which exhibited unexplained additional immersion marks.

Water hardening of Delaware River American shad eggs in Van Dyke water did not result in increased egg viability.

Twenty-one day survival of American shad larvae was slightly higher (no statistical difference) for fry incubated in egg jars with new foam bottom screens than old foam bottom screens. However, we were unable to induce the onset of the "Van Dyke Syndrome" with the use of old foam bottom screens which were disinfected in concentrated iodophor and not rinsed.

Tetracycline marks produced by 2, 4 or 6 hour immersion were detectable on all specimens examined, however, 2 hour marks were less intense than marks produced by 4 or 6 hour immersion.

Relative survival of Hudson River source larvae released at 7 days of age was significantly higher than controls released at 18 days of age or production larvae from the Hudson River, released at 15 to 20 days of age.

Approximately 40,000 (visual estimate) American shad fingerlings were released from the Canal Pond. Mark-recapture population estimates were conducted for fingerling shad reared in the Upper Spring Creek Ponds. An estimated 43,500 fingerlings were released from Upper Spring Creek Pond 1, 35,000 from Upper Spring Creek Pond 2, and 21,000 from Upper Spring Creek Pond 3.

RECOMMENDATIONS FOR 1995

1. Continue to disinfect all egg shipments at 80 ppm free iodine.
2. Continue to utilize Maryland's Manning Hatchery for production of marked fry and fingerlings for release below Conowingo Dam.
3. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
4. Continue to siphon egg shells from the rearing tank within hours of egg hatch.
5. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
6. Construct new foam bottom screens for Van Dyke jars each year.
7. Do not disinfect foam bottom screens prior to use.
8. Continue to hold Virginia and Delaware River eggs until 8:00AM before processing.
9. Modify tetracycline immersion marking to a 4 hour immersion, beginning at 11:00 AM and ending at 3:00 PM.
10. Modify work plan/TC marking regime to maximize the number of fry stocked at 7 days of age.
11. Based on low returns of uniquely marked fingerlings in juvenile and adult collections, discontinue culture of fingerling shad in ponds.

LITERATURE CITED

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

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

Figure 1. Survival of American shad fry, Van Dyke, 1994.

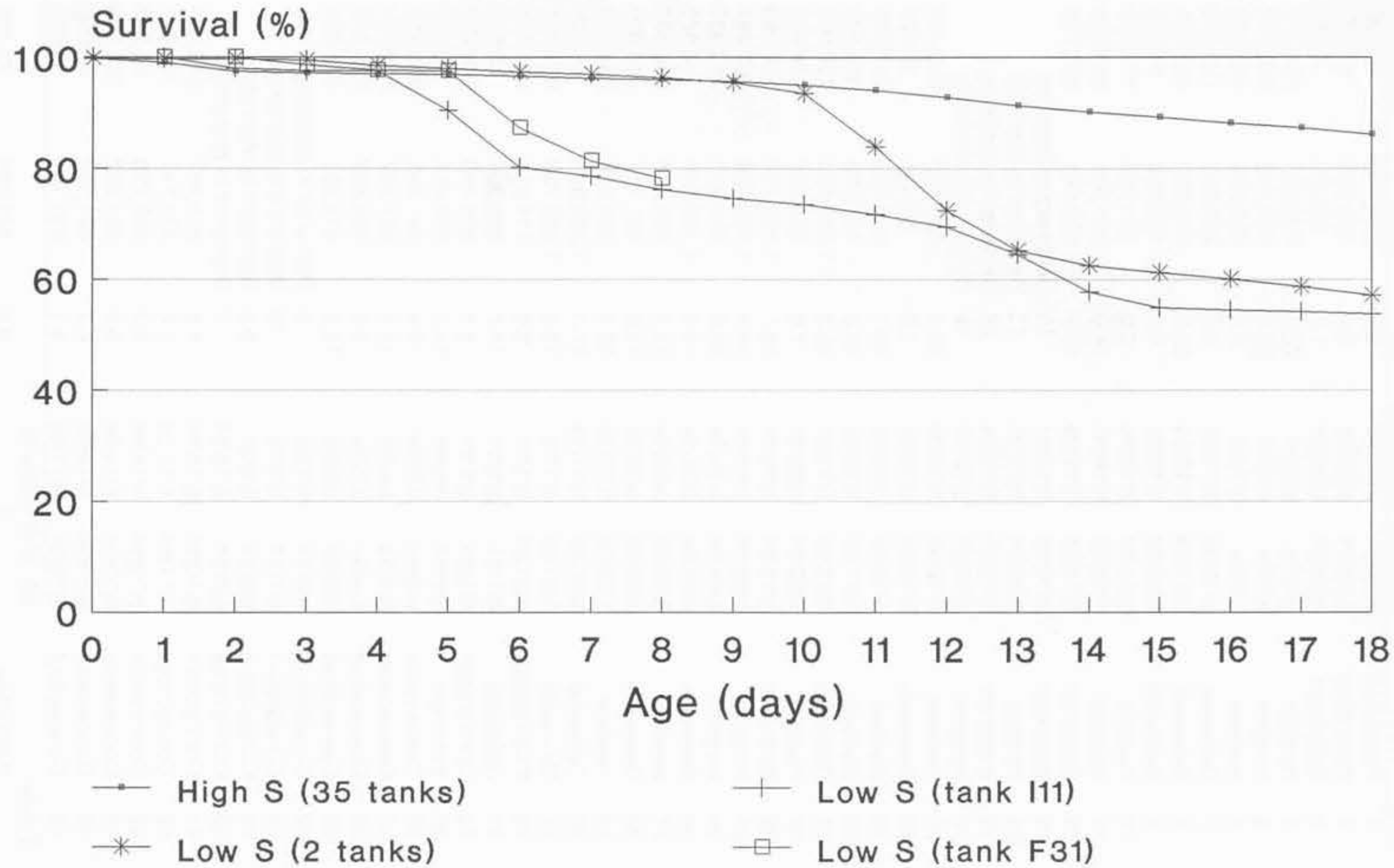

Table 1. American shad egg shipments, 1994.

Shipment No.	River	Date Shipped	Date Received	Vol. Received (L)	Eggs	Viable Eggs	Percent Viable
1	Pamunkey	4/24/94	4/25/94	5.0	342,998	17,520	5.1%
2	Pamunkey	4/25/94	4/26/94	4.6	191,135	55,187	28.9%
3	Mattaponi	4/25/94	4/26/94	1.0	29,186	7,858	26.9%
4	Hudson	5/4/94	5/5/94	23.2	569,280	297,714	52.3%
5	Hudson	5/5/94	5/6/94	24.8	637,982	280,413	44.0%
6	Hudson	5/6/94	5/7/94	9.3	286,963	168,026	58.6%
7	Delaware	5/10/94	5/11/94	8.5	256,535	150,570	58.7%
8	Delaware	5/11/94	5/12/94	22.2	551,253	422,241	76.6%
9	Delaware	5/12/94	5/13/94	4.3	126,914	84,890	66.9%
10	Hudson	5/14/94	5/15/94	6.8	194,036	171,596	88.4%
11	Hudson	5/15/94	5/16/94	14.0	394,981	355,204	89.9%
12	Delaware	5/15/94	5/16/94	19.2	493,921	304,714	61.7%
13	Delaware	5/16/94	5/17/94	10	Delivered to Manning		
14	Hudson	5/16/94	5/17/94	13	Delivered to Manning		
15	Delaware	5/17/94	5/18/94	22	Delivered to Manning		
16	Hudson	5/17/94	5/18/94	16	Delivered to Manning		
17	Hudson	5/18/94	5/19/94	12.1	329,870	216,486	65.6%
18	Delaware	5/18/94	5/19/94	1.9	66,031	39,529	59.9%
19	Hudson	5/19/94	5/20/94	12.1	333,677	217,944	65.3%
20	Hudson	5/21/94	5/22/94	13.8	407,305	355,029	87.2%
21	Delaware	5/22/94	5/23/94	45.2	1,304,428	730,096	56.0%
22	Hudson	5/22/94	5/23/94	7.8	232,803	214,085	92.0%
23	Delaware	5/23/94	5/24/94	33.1	1,586,340	106,169	6.7%
24	Hudson	5/23/94	5/24/94	34.5	1,029,704	852,361	82.8%
25	Hudson	5/24/94	5/25/94	28.8	878,895	790,333	89.9%
26	Delaware	5/24/94	5/25/94	16.8	1,162,240	19,880	1.7%
27	Hudson	5/25/94	5/26/94	24.4	688,396	630,653	91.6%
28	Delaware	5/25/94	5/26/94	11.2	821,437	50,000	6.1%
29	Hudson	5/26/94	5/27/94	10.5	303,020	254,149	83.9%
30	Delaware	5/30/94	5/31/94	31.3	1,282,905	80,000	6.2%
31	Delaware	5/31/94	6/1/94	14.1	1,352,780	212,801	15.7%
32	Connecticut	5/31/94	6/1/94	9.8	418,014	331,078	79.2%
33	Delaware	6/1/94	6/2/94	11.7	582,364	50,000	8.6%
34	Connecticut	6/1/94	6/2/94	5.1	268,446	224,229	83.5%
35	Delaware	6/2/94	6/3/94	11.7	686,613	10,000	1.5%
36	Connecticut	6/2/94	6/3/94	9.0	391,542	339,760	86.8%
37	Connecticut	6/3/94	6/4/94	11.4	387,847	339,032	87.4%
38	Connecticut	6/4/94	6/5/94	9.6	333,632	279,478	83.8%
39	Connecticut	6/5/94	6/6/94	10.2	413,891	342,688	82.8%
40	Connecticut	6/6/94	6/7/94	9	Delivered to Manning		
41	Connecticut	6/7/94	6/8/94	10	Delivered to Manning		
42	Connecticut	6/8/94	6/9/94	8.5	Delivered to Manning		
43	Connecticut	6/9/94	6/10/94	7	Delivered to Manning		
44	Connecticut	6/10/94	6/11/94	5.6	319,937	246,351	77.0%
45	Connecticut	6/11/94	6/12/94	7.6	374,741	160,025	42.7%
46	Connecticut	6/12/94	6/13/94	6.2	269,729	83,263	30.9%
47	Connecticut	6/13/94	6/14/94	5.2	381,382	124,704	32.7%
48	Connecticut	6/14/94	6/15/94	4.7	301,108	68,992	22.9%
49	Connecticut	6/16/94	6/17/94	3.1	231,141	54,790	23.7%
Totals		No. of Shipments					
	Pamunkey	2		9.6	534,134	72,706	13.6%
	Mattaponi	1		1.0	29,186	7,858	26.9%
	Hudson	15		222.1	6,286,914 *	4,803,995 *	76.4% *
	Delaware	15		231.2	10,273,763 *	2,260,890 *	22.0% *
	Connecticut	16		87.5	4,091,410 *	2,603,732 *	63.6% *
	Grand Total	49		551.4	21,215,404 *	9,739,837 *	45.9% *

* Does not include eggs delivered to Manning.

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1994.

Year	Egg Vol. (L)	No. of Eggs (exp.6)	Egg Via–bility (%)	No. of Viable Eggs (exp.6)	No. of shad stocked (all rivers) Fry (exp.3)	Fing–erling (exp.3)	Total (exp.3)	Fish Stocked/ Eggs Rec'd	Fish Stocked/ Viable Eggs
1976	120	4.0	52.0	2.1	518	266	784	0.194	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

*Includes 1,300,000 reared at Manning.

Table 3. American shad stocking and fish transfer activities, 1994.

Date	Tank/ Pond	Number	Mark (days)	Location	Origin	Age	Size
5/19/94	C11	140,300	5	Thompsontown– 7d	Hudson	7	Fry
5/26/94	B31	55,600	3,13,17,21	York River	York	23	Fry
5/30/94	E21	172,700	5	Thompsontown– 7d	Hudson	7	Fry
5/31/94	C21	24,600	5,9,13	Thompsontown	Hudson	18	Fry
5/31/94	C21	100,000	5,9,13	Canal Pond	Hudson	18	Fry
5/31/94	C31	123,400	7,11,15	Thompsontown	Hudson	18	Fry
5/31/94	C41	149,900	6,10,14	Thompsontown	Hudson	17	Fry
6/1/94	B41	126,400	18	Thompsontown– 20d	Hudson	20	Fry
6/1/94	B41	3,000	18	Benner Spring Raceway F1	Hudson	20	Fry
6/4/94	F31	100,000	5	Thompsontown– 7d	Hudson	7	Fry
6/4/94	F31	3,000	5	Benner Spring Raceway F2	Hudson	7	Fry
6/6/94	D11	133,500	3,13,17	Thompsontown	Delaware	19	Fry
6/6/94	D41	108,400	5,9,13	Thompsontown	Hudson	15	Fry
6/6/94	D41	50,000	5,9,13	Canal Pond	Hudson	15	Fry
6/7/94	D21	369,500	3,13,17	Lehigh River	Delaware	18	Fry
6/7/94	D31	70,300	3,13,17	Lehigh River	Delaware	18	Fry
6/7/94	H21	275,900	5	Thompsontown– 7d	Hudson	7	Fry
6/9/94	I21	307,500	5	Thompsontown– 7d	Hudson	7	Fry
6/10/94	E31	279,600	3,13,17	U.S.C. Ponds	Delaware	18	Fry
6/10/94	E41	207,100	5,9,13	Thompsontown	Hudson	16	Fry
6/10/94	F21	196,800	5,9,13	Thompsontown	Hudson	15	Fry
6/12/94	E11	83,500	18	Thompsontown– 20d	Hudson	20	Fry
6/14/94	G31	184,800	5,9,13	Thompsontown	Hudson	16	Fry
6/14/94	H11	209,400	5,9,13	Thompsontown	Hudson	14	Fry
6/15/94	A22	1,000	5	Van Dyke Pond 1	Connecticut	7	Fry
6/16/94	F11	202,400	3,13,17	Lehigh River	Delaware	18	Fry
6/16/94	G11	257,600	3,13,17	Thompsontown	Delaware	18	Fry
6/16/94	G21	206,400	3,13,17	Thompsontown	Delaware	18	Fry
6/17/94	F41	110,200	18	Thompsontown– 20d	Hudson	20	Fry
6/18/94	G41	75,400	3,13,17	Thompsontown	Delaware	18	Fry
6/19/94	H41	373,000	5,9,13	Thompsontown	Hudson	18	Fry
6/19/94	I11	210,300	5,9,13	Thompsontown	Hudson	18	Fry
6/20/94	H31	229,900	18	Thompsontown– 20d	Hudson	20	Fry
6/21/94	J11	216,500	5,9,13	Thompsontown	Hudson	18	Fry
6/22/94	I31	229,400	18	Thompsontown– 20d	Hudson	20	Fry
6/27/94	J41	25,200	3,13,17	Thompsontown	Delaware	20	Fry
6/27/94	A42	7,100	3,13,17	Thompsontown	Delaware	18	Fry
7/1/94	A12	80,000	3,13,17	Thompsontown	Delaware	23	Fry
7/1/94	A22	100,000	5,9,13,17,21	Thompsontown	Connecticut	23	Fry
7/1/94	A22	3,000	5,9,13,17,21	Benner Spring Raceway F2	Connecticut	23	Fry
7/1/94	A32	150,000	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/1/94	A32	3,000	5,9,13,17,21	Benner Spring Raceway F4	Connecticut	22	Fry
7/1/94	J21	3,000	Control	Benner Spring Raceway E1	Connecticut	24	Fry
7/1/94	J31	3,000	3,13,17,21	Benner Spring Raceway F3	Connecticut	24	Fry
7/2/94	B12	302,800	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/3/94	B22	279,700	5,9,13,17,21	Thompsontown	Connecticut	21	Fry

Table 3. American shad stocking and fish transfer activities, 1994.

Date	Tank/ Pond	Number	Mark (days)	Location	Origin	Age	Size
5/19/94	C11	140,300	5	Thompsontown – 7d	Hudson	7	Fry
5/26/94	B31	55,600	3,13,17,21	York River	York	23	Fry
5/30/94	E21	172,700	5	Thompsontown – 7d	Hudson	7	Fry
5/31/94	C21	24,600	5,9,13	Thompsontown	Hudson	18	Fry
5/31/94	C21	100,000	5,9,13	Canal Pond	Hudson	18	Fry
5/31/94	C31	123,400	7,11,15	Thompsontown	Hudson	18	Fry
5/31/94	C41	149,900	6,10,14	Thompsontown	Hudson	17	Fry
6/1/94	B41	126,400	18	Thompsontown – 20d	Hudson	20	Fry
6/1/94	B41	3,000	18	Benner Spring Raceway F1	Hudson	20	Fry
6/4/94	F31	100,000	5	Thompsontown – 7d	Hudson	7	Fry
6/4/94	F31	3,000	5	Benner Spring Raceway F2	Hudson	7	Fry
6/6/94	D11	133,500	3,13,17	Thompsontown	Delaware	19	Fry
6/6/94	D41	108,400	5,9,13	Thompsontown	Hudson	15	Fry
6/6/94	D41	50,000	5,9,13	Canal Pond	Hudson	15	Fry
6/7/94	D21	369,500	3,13,17	Lehigh River	Delaware	18	Fry
6/7/94	D31	70,300	3,13,17	Lehigh River	Delaware	18	Fry
6/7/94	H21	275,900	5	Thompsontown – 7d	Hudson	7	Fry
6/9/94	I21	307,500	5	Thompsontown – 7d	Hudson	7	Fry
6/10/94	E31	279,600	3,13,17	U.S.C. Ponds	Delaware	18	Fry
6/10/94	E41	207,100	5,9,13	Thompsontown	Hudson	16	Fry
6/10/94	F21	196,800	5,9,13	Thompsontown	Hudson	15	Fry
6/12/94	E11	83,500	18	Thompsontown – 20d	Hudson	20	Fry
6/14/94	G31	184,800	5,9,13	Thompsontown	Hudson	16	Fry
6/14/94	H11	209,400	5,9,13	Thompsontown	Hudson	14	Fry
6/15/94	A22	1,000	5	Van Dyke Pond 1	Connecticut	7	Fry
6/16/94	F11	202,400	3,13,17	Lehigh River	Delaware	18	Fry
6/16/94	G11	257,600	3,13,17	Thompsontown	Delaware	18	Fry
6/16/94	G21	206,400	3,13,17	Thompsontown	Delaware	18	Fry
6/17/94	F41	110,200	18	Thompsontown – 20d	Hudson	20	Fry
6/18/94	G41	75,400	3,13,17	Thompsontown	Delaware	18	Fry
6/19/94	H41	373,000	5,9,13	Thompsontown	Hudson	18	Fry
6/19/94	I11	210,300	5,9,13	Thompsontown	Hudson	18	Fry
6/20/94	H31	229,900	18	Thompsontown – 20d	Hudson	20	Fry
6/21/94	J11	216,500	5,9,13	Thompsontown	Hudson	18	Fry
6/22/94	I31	229,400	18	Thompsontown – 20d	Hudson	20	Fry
6/27/94	J41	25,200	3,13,17	Thompsontown	Delaware	20	Fry
6/27/94	A42	7,100	3,13,17	Thompsontown	Delaware	18	Fry
7/1/94	A12	80,000	3,13,17	Thompsontown	Delaware	23	Fry
7/1/94	A22	100,000	5,9,13,17,21	Thompsontown	Connecticut	23	Fry
7/1/94	A22	3,000	5,9,13,17,21	Benner Spring Raceway F2	Connecticut	23	Fry
7/1/94	A32	150,000	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/1/94	A32	3,000	5,9,13,17,21	Benner Spring Raceway F4	Connecticut	22	Fry
7/1/94	J21	3,000	Control	Benner Spring Raceway E1	Connecticut	24	Fry
7/1/94	J31	3,000	3,13,17,21	Benner Spring Raceway F3	Connecticut	24	Fry
7/2/94	B12	302,800	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/3/94	B22	279,700	5,9,13,17,21	Thompsontown	Connecticut	21	Fry

Table 3. (continued).

Date	Tank/ Pond	Number	Mark (days)	Location	Origin	Age	Size
7/4/94	B32	234,700	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/5/94	B42	286,900	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/5/94	B42	3,000	5,9,13,17,21	Benner Spring Raceway E2	Connecticut	22	Fry
7/9/94	C12	110,900	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/9/94	C22	103,600	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/10/94	C32	65,400	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/10/94	C42	55,700	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/11/94	D12	22,900	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/11/94	D22	18,300	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/11/94	D32	82,600	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/13/94	D42	41,400	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
8/26/94	Canal Pond	40,000	5,9,13 + single feed	Thompsontown	Hudson	105	Fing.
9/9/94	Upper	21,000	3,13,17 +	Thompsontown	Delaware	109	Fing.
9/12/94	Spring Creek Pond 1	22,500	single feed	Thompsontown	Delaware	112	Fing.
9/19/94	Upper	10,000	3,13,17 +	Thompsontown	Delaware	119	Fing.
9/20/94	Spring Creek Pond 3	11,000	triple feed	Thompsontown	Delaware	120	Fing.
10/13/94	Upper	18,000	3,13,17 +	Thompsontown	Delaware	143	Fing.
10/14/94	Spring Creek Pond 2	17,000	double feed	Thompsontown	Delaware	144	Fing.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1994.

	Site	Fry	Fingerling
Releases	Juniata River		
	7d old	996,400	
	20d old	779,400	
	Other	4,644,300	139,500
	Total	6,420,100	
	Lehigh River	642,200	
	Sub-Total	7,062,300	139,500
Transfers	Canal Pond	150,000	
	Van Dyke Pond 1	1,000	
	Benner Spring Raceways	21,000	
	Upper Spring Creek Ponds	279,600	
	VDGIF (York River)	55,600	
	Sub-Total	507,200	
	Total Production	7,569,500	
	Viable eggs	9,739,837	
	Survival of fry (%)	77.7%	

Table 5. Tetracycline marking for American shad stocked in the Chesapeake Bay drainage, 1994.

Hatchery	Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Mark (days)	Feed mark	No. Stocked
Van Dyke	Fry	–	York River	Pamunkey	Quadruple (3,13,17,21)	–	55,600
King and Queen	Fry	–	James River	Pamunkey	Quadruple (3,13,17,21)	–	310,000
King and Queen	Fry	–	James River	James	Quadruple (3,7,15,19)	–	1,560,000
Harrison Lake	Fry	–	James River	Pamunkey	Quadruple (3,7,15,17)	–	6,000
Harrison Lake	Fry	–	James River	James	Triple (26,29,39)	–	15,986
Harrison Lake	Fry	–	Pamunkey River	Pamunkey	Double (20,30)	–	151,616
Manning	Fry	–	Below Conowingo	Hudson/ Delaware	Double (3,17)	–	1,300,000
Van Dyke	Fry	–	Thompsontown–7d	Hudson	Single (5)	–	996,400
Van Dyke	Fry	–	Thompsontown– 20d	Hudson	Single (18)	–	779,400
Van Dyke	Fry	–	Thompsontown– Other	Hudson	Triple (5,9,13)	–	2,004,200
Van Dyke	Fry	–	Thompsontown	Delaware	Triple (3,13,17)	–	785,200
Van Dyke	Fry	–	Thompsontown	Connecticut	Quintuple (5,9,13,17,21)	–	1,854,900
Van Dyke	Fingerling	Canal Pond	Thompsontown	Hudson	Triple (5,9,13)	Single	40,000
Van Dyke	Fingerling	Upper Spring Creek Pond 1	Thompsontown	Delaware	Triple (3,13,17)	Single	43,500
Van Dyke	Fingerling	Upper Spring Creek Pond 2	Thompsontown	Delaware	Triple (3,13,17)	Double	35,000

Table 5. (continued).

Hatchery	Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Mark (days)	Feed mark	No. Stocked
Van Dyke	Fingerling	Upper Spring Creek Pond 3	Thompsontown	Delaware	Triple (3,13,17)	Triple	21,000
Manning/PEPCO	Fingerling	PEPCO	Patuxent River	Connecticut	Double (3,7)	Single	81,400 *
Manning/PEPCO	Fingerling	PEPCO	Patuxent River	Susquehanna	Single (7)	Single	23,000

*Includes 14,000 with coded wire tags.

Table 6. Tetracycline mark retention for American shad reared in 1994.

Pond/ Raceway	Egg Source	Attempted Mark Immersion/Feed	Observed Mark Immersion/Feed	Number Exhibiting Mark	Projected Number Stocked	Disposition
Benner Spring Raceway E1	Connecticut	unmarked control	None	30/30(100%)	–	Not Stocked
Van Dyke Pond 1	Hudson	single/0 (5)	various marks observed due to escapement into pond		996,400	Stocked Thompsontown
Benner Spring Raceway F1	Hudson	Single/0 (18)	Single	30/30(100%)	779,400	Stocked Thompsontown
Upper Spring Creek Pond 1	Delaware	Triple/Single (3,13,17)	Triple/Single	30/30(100%)	43,500	Stocked Thompsontown
Upper Spring Creek Pond 2	Delaware	Triple/Double (3,13,17)	Triple/Double	30/30(100%)	35,000	Stocked Thompsontown
Upper Spring Creek Pond 3	Delaware	Triple/Triple (3,13,17)	Triple/Triple	30/30(100%)	21,000	Stocked Thompsontown
Canal Pond	Hudson	Triple/single (5,9,13)	Triple/single	30/30(100%)	40,000	Stocked Thompsontown
Benner Spring Raceway F3	Pamunkey/ Mattaponi	Quadruple/0 (3,13,17,21)	Quadruple	30/30(100%)	55,600	Stocked York River
Benner Spring Raceway E2	Connecticut	Quintuple/0 (5,9,13,17,21)	Quintuple *	29/30(97%) 1/30(3%)	1,551,403 53,497	Stocked Thompsontown
Benner Spring Raceway F2	Connecticut	Quintuple/0 (5,9,13,17,21) (d9– 2h imm.) (d17– 4h imm.)	Quintuple	29/29(100%)	100,000	Stocked Thompsontown
Benner Spring Raceway F4	Connecticut	Quintuple/0 (5,9,13,17,21) (d9– 4h imm.) (d17– 2h imm.)	Quintuple	30/30(100%)	150,000	Stocked Thompsontown

*Appeared to be marked on days 5,9,13,14,15,16,17,19, and 21

Appendix 1.

Water Hardening Delaware River American Shad Eggs with Van Dyke Water

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Introduction

The Delaware River has been a consistent source for American shad eggs for use in restoring shad to the Susquehanna River. Although the Delaware River produces consistently good numbers of eggs, the viability of the eggs has traditionally been below that of other egg source rivers (Table A1-1). In addition, Delaware River egg shipments typically contain small diameter eggs, which have not been fertilized or water hardened, and which do not layer out at the top of the egg jar. As a result, these eggs cannot be removed by siphoning, creating problems with egg enumeration and potential fungus infections. The egg collection crew on the Delaware River has made numerous attempts at improving egg viability which have included construction of an "in river" water hardening box, use of air and water pumps to circulate water during water hardening, use of medical grade oxygen, use of basters for cleaner egg shipments, using only live males, and using less pressure when squeezing the fish (David Arnold, memo to Richard Snyder, 6/28/94). None of these resulted in increased egg viability. The purpose of this study was to determine if use of Van Dyke hatchery water during water hardening would result in increased egg viability.

Materials and Methods

American shad eggs were stripped from gravid females and fertilized by sperm from males as per standard practice. They were then stirred to mix the eggs and sperm. Before water hardening, eggs from each bowl were divided equally. One aliquot was designated as the test lot and water from the Van Dyke hatchery source was added to begin water hardening. The eggs were rinsed several times to remove sperm, blood and fecal material and then transferred to a tub for completion of water hardening in Van Dyke water. The second lot was designated the control and water hardened similarly in Delaware River water. After water hardening, test and control lots were labelled and bagged for transport to Van Dyke.

Upon arrival at Van Dyke, eggs were disinfected as per standard practice, using fresh disinfectant for test and control lots. Test and control lots were then enumerated and incubated in separate incubation jars as per standard practice. The experiment was replicated 6 times, with one replicate per egg shipment. Egg viability was compared for each pair of jars and a small sample Wilcoxin Signed-Rank Test (Ott, 1977) used to test for statistical differences.

Results and Discussion

The experiment was replicated six times, however, one replicate (shipment 23) was eliminated from the analysis due to extremely low viability for both test and control groups (Table A1-2). The low viability in shipment 23 was probably related to high water temperatures (67.5F) at the time of spawning. Viability was higher for test groups in three of the five remaining replicates. Viability in control groups exceeded that for test groups in two replicates, including shipment 12, in which the viability was 21% higher in the control group than the test group. Based on Wilcoxin's small sample Signed-Rank Test (Ott, 1977), there were no significant differences in viability between test and control groups.

The slightly reduced egg viability of Delaware River eggs, as compared to those from the Hudson and Connecticut Rivers is probably due to factors beyond our control. We should continue to strive for the highest quality eggs possible, but further research and experimentation directed at improving egg viability for artificially spawned shad on the Delaware River is unlikely to result in significant benefit.

Literature Cited

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxberry Press, North Scituate, Massachusetts, 730 pp.

Table A1–1. Viability of East Coast American shad eggs by egg source river, Van Dyke, 1988–1994.

	James and Pamunkey Rivers			Delaware River			Hudson River			Connecticut River		
Year	No. of Shipments	No. of Eggs (Exp. 6)	Viability (%)	No. of Shipments	No. of Eggs (Exp. 6)	Viability (%)	No. of Shipments	No. of Eggs (Exp. 6)	Viability (%)	No. of Shipments	No. of Eggs (Exp. 6)	Viability (%)
1988	10	2.0	55.9	4	2.9	63.4	–	–	–	–	–	–
1989	11	2.4	54.3	5	6.0	61.6	13	11.2	57.6	–	–	–
1990	1	0.5	45.7	9	13.1	51.9	18	14.5	62.9	–	–	–
1991	–	–	–	10	10.7	59.3	16	17.7	65.7	3	1.1	7.2
1992	5	3.0	35.3	9	9.6	60.0	5	3.0	75.0	7	5.7	79.5
1993	11	1.8	40.5	14	9.3	57.0	9	3.0	79.2	18	7.4	59.0
1994	3	0.6	14.3	15	10.3	22.0	15	6.3	76.4	16	4.1	63.6
Total	41	10.3	43.9	66	61.9	51.7	76	55.7	65.8	44	18.3	63.3

Table A1–2. Viability of Delaware River American shad eggs water hardened in Van Dyke hatchery water vs. controls water hardened in Delaware River water, Van Dyke, 1994.

	Delaware River (Control)			Van Dyke (Test)			
Egg Shipment	Jar	No. of Eggs	Viability	Jar	No. of Eggs	Viability	Pairwise Comparison
7	2	60,400	54.1%	1	60,400	65.4%	Test
8	307	186,200	82.1%	308	186,200	77.5%	Control
9	6	44,300	67.3%	5	44,300	70.6%	Test
12	8	77,200	76.3%	9	77,200	55.2%	Control
21	15	83,700	52.7%	14	83,700	68.6%	Test
23	19	110,200	5.9%	18	110,200	0.0%	eliminated from analysis

Appendix 2.

The effect of old vs. new open-cell foam bottom screens on the survival of American shad larvae cultured at Van Dyke, 1994

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Introduction

Unusually high mortalities were experienced during culture of larval American shad at the Van Dyke Station for Anadromous Fish in 1992 and 1993 (Hendricks and Bender, 1993; Hendricks and Bender, 1994). These mortalities resulted in overall survival of 41% in 1992 and 66% in 1993, compared to a range of 70 to 90% for the period 1984 to 1991.

Symptoms of the "Van Dyke Syndrome" included lack of feeding and erratic swimming. Before death, the fish became very weak and laid on the bottom of the tank in large numbers. These symptoms hit very early in life (within a day or two after hatch) or at 9 to 14d of age (Hendricks and Bender, 1993).

The cause of these mortalities was unknown. Heavy infestations of motile aeromonad bacteria were isolated in 1992 (Hendricks and Bender, 1993), and Aeromonas hydrophila has been shown to be associated with American shad mortalities in the wild (Haley et al., 1967); however, the aeromonad infections may have been secondary to some other causal factor. Samples collected in 1993 revealed a more diverse bacterial fauna present in the specimens (Hendricks and Bender, 1994). Motile aeromonads were present but the cause of the mortalities was unknown.

The fact that some tanks exhibited high survival, while other concurrently reared tanks exhibited low survival, suggested that water quality was not causing the mortalities. However, as a precautionary measure, we contracted for extensive testing of heavy metals and semi-volatile organics. Two samples, one from the egg battery and one from tank D4 (without fish) were collected in 1993. Tests were conducted for 24 heavy metals, 46 base/neutral extractables and 11 acid extractables. The tests confirmed that Van Dyke source water is extremely pure and the mortalities were not related to water quality.

Analysis of tank by tank survival in 1993 suggested that the use of open cell foam bottom screens on Van Dyke egg incubation jars was associated with the mortalities. Eggs from shipment 40 were incubated in a Van Dyke Jar with an open cell foam bottom screen and in 4 May-Sloan jars with window screen bottom screens. The Van Dyke jar was transferred to tank J41 for hatch while the 4 May-Sloan jars were put on tank J31. Initial densities were 192,000 for J41 and 235,000 for J31. By day 11, tank J41 exhibited total mortality. In contrast, tank J31 experienced 18 day survival of 68%. The only difference in the culture of the two tanks was the type of egg jar and bottom screen used during incubation.

Open cell foam was first used for bottom screens at Van Dyke in 1990. A controlled experiment was conducted with two replicates, each replicate consisted of one jar with a window screen (control) and one jar with a foam screen (Hendricks et al., 1991). In 1991, the study was repeated with four replicates (Hendricks et al., 1992). An additional 25 jars were incubated with foam bottom screens which were not a part of the study. Because these were our first experiences with foam screens, the foam was new, recently purchased and cut to fit the jars. Overall survival of fry was 81% in 1990 and 79% in 1991. Foam screens were exclusively used in 1992 when the mortality problems were first noted. No records were kept of which jars received old screens from 1990 and 1991 and which, if any, received new screens. Although no records of old or new screens were kept in 1993, we recalled that some new screens were constructed in 1993 and used for the first shipments. Coincidently, the first eight tanks reared in 1993 experienced good survival. Based on this information, and the experience with tanks J31 and J41, we believe that the use of old foam bottom screens was related to the unexplained mortalities in 1992 and 1993.

Previously used foam bottom screens were disinfected in iodophor immediately after use and again before they were re-used. They were rinsed in clean water before being inserted into position in the incubation jar. Since the foam is open-cell, the iodophor penetrates deeply and is difficult to rinse out. Residual iodophor in the foam bottom screens constitutes another potential source of the mortalities.

The purpose of this experiment was to determine if the use of old foam bottom screens or residual iodophor in the foam was responsible for the unexplained mortalities experienced in 1992 and 1993.

Materials and Methods

A total of three Connecticut River egg shipments were used for the study. Upon arrival at Van Dyke, the shipments were split and equal numbers of eggs were incubated in Van Dyke jars with old and new foam bottom screens. New foam bottom screens were not disinfected with iodophor before use. Old foam bottom screens in two replicates (shipments 44 and 45) were disinfected in Iodophor II (13.6% active ingredient plus 12.0% phosphoric acid, not buffered). The old foam bottom screen used in shipment 46 was not disinfected before use and was well rinsed to ensure that no residual iodophor remained. Incubation jars were hatched into separate rearing tanks, one jar per tank. All fish culture practices were identical except for the foam bottom screens. Fish culture apparatus were disinfected between each use to prevent the spread of pathogens from tank to tank.

Removal and enumeration of dead eggs and fry was done according to standard Van Dyke protocol. Twenty-one day survival was compared for each pair of tanks.

Results and Discussion

Twenty-one day survival of American shad larvae was higher for jars using new foam when compared to old foam for all three replicates (Table A2-1). Old foam resulted in lower survival in shipment 46, even though it was not disinfected with iodophor. Three replicates was not enough for statistical testing, but additional replication might have adversely affected production and the availability of eggs was limited.

For the jars in which old foam was used, we were attempting to re-create conditions which would promote the occurrence of the "Van Dyke Syndrome." Although survival was lower when eggs were incubated in jars with old foam, we were not able to trigger the onset of the syndrome, as evidenced by the lack of symptoms. Thus, the data suggests that new foam performs better than old foam, but no causal relationship was established between the type of foam and the occurrence of the syndrome.

Based upon the results of this study, I recommend that new foam bottom screens be constructed each year. Additional replication of this study may or may not establish a causal relationship between the condition of the foam bottom screens and the "Van Dyke Syndrome." Further testing is not recommended at this time.

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Table A2-1. Survival of Connecticut River source American shad larvae incubated in Van Dyke jars with new or old foam bottom screens, Van Dyke, 1994.

Ship-ment	Egg Jar	Foam	Disinfected	Rinsed	No. of Eggs	Egg Viability	Tank	21 day Survival	Symptoms of "Van Dyke Syndrome"
44	317	New	No	–	160,000	77.5%	C12	89.0%	No
	318	Old	Yes	No	160,000	76.5%	C22	85.3%	No
45	319	New	No	–	187,400	44.3%	C32	80.0%	No
	320	Old	Yes	No	187,400	41.1%	C42	73.7%	No
46	321	New	No	–	134,900	30.6%	D12	56.6%	No
	322	Old	No	Yes	134,900	31.1%	D22	44.2%	No

Appendix 3.

Efficacy of marking larval American shad otoliths by two, four and six hour immersions in 200mg/L tetracycline hydrochloride.

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Introduction

The Pennsylvania Fish and Boat Commission is participating in a basin-wide effort to restore the anadromous American shad to its former range above dams in the Susquehanna River. The two principle components of the restoration effort are the stocking of hatchery-reared larvae and fingerlings, and the trap and transport of pre-spawn adult shad from Conowingo Dam to upstream spawning areas. In order to evaluate the contribution of hatchery-reared shad to the overall juvenile outmigration, a method was developed to mark the otoliths of larval shad by immersion in tetracycline antibiotics (Lorson and Mudrak, 1991). In 1985 and 1986, larval shad were marked by immersion in 25 or 50 mg/L, 12h/d for 4 or 5 consecutive days. The marks were detected by viewing thin sagittal sections using ultraviolet light microscopy at 400X. The marks produced were faint, diffuse, and difficult to detect (Hendricks et al., 1991). In 1987 and subsequent years, larvae were marked at 200 mg/L, 6h immersion on a single day. Multiple marks were produced at 4d intervals. This marking protocol produced an intense, narrow mark which was confined to one daily otolith increment and was retained in 724 of 725 specimens examined over a three year period (Hendricks et al., 1991).

Under the current six hour immersion marking protocol, the marking process begins at 8:00 AM. Water samples are collected for later pH and dissolved oxygen measurements. Water flow is shut off, an airstone is installed in each tank and pure oxygen bubbled in to maintain desirable levels during marking. Drips of sodium and potassium phosphate buffers are established to maintain pH during marking. When the buffer drips are complete, about 9:00 AM, the tetracycline is added to the tank. At 3:00 PM, flow is restored to the tank, flushing the tetracycline out of the tank with the effluent.

Tank cleaning and siphoning on treated tanks is done by another crewperson prior to marking, since siphoning is more difficult during marking due to the yellow color of the tetracycline.

Tetracycline marking and feeding are assigned to the same individual. The TC marking duties must be initiated before the fish can be fed. As a result, feeding activities do not begin until 9:00AM or later, and feeding is often not complete until Noon.

The impact of tetracycline marking on incidence of feeding has not been studied. Tetracycline marking may impede feeding due to the lack of current to distribute the feed around the tank, low levels of stress associated with the marking, or interference with locating prey due to the yellow color of the tetracycline.

Prior to 1986, a special shift was established to feed the fish, beginning at 6:00AM. Feeding of the fish early in the day was thought to be important to survival (Tom Wiggins, pers. comm.). This shift was discontinued in 1986 to provide for supervision of untrained personnel when our long time feeder, Dave Hampton, did not return. Although no decrease in survival was noted as a result of delayed feeding, it might still be advantageous to feed early in the day, before TC marking. Delaying TC marking would also eliminate the need for immediate tank cleaning and siphoning, and help alleviate the initial "rush" of activities which need to be done immediately after the start of the shift at 8:00AM.

Other researchers have successfully marked larval fish by short duration immersions in tetracycline. Hettler (1984) marked spot larvae by immersion in 250mg/L for 2h and pinfish larvae in 500mg/L for 2h. Tsukamoto (1985) marked ayu larvae by immersion in 200mg/L for 3h. Dabrowski and Tsukamto (1986) marked peled larvae in 600mg/L for 3h. Nagiec et al. (1988) marked whitefish larvae in 300mg/L for 2h. Muth, Nesler and Wasowicz (1988) marked Colorado squawfish larvae in 350mg/L for 4h. Secor, Miller and Dean (1991) marked striped bass larvae in 350mg/L for 3h.

The purpose of this research is to determine if American shad larvae can be successfully marked by two or four hour immersions in 200mg/L tetracycline to permit feeding of the larvae before marking.

Materials and Methods

Two tanks of larvae from the Connecticut River egg source were used for the experiment. Each tank received the standard Connecticut River mark, a quintuple mark on days 5, 9, 13, 17, and 21. One tank (A22) received a 2h immersion on day 9 and a 4h immersion on day 17. The other tank (A32) received a 4h immersion on day 9 and a 2h immersion on day 17. All other immersions were six hours in duration and all immersions were in 200mg/L tetracycline hydrochloride. Six hour immersions began at 9:00AM, four hour immersions began at 11:00AM and two hour immersions began at 1:00PM. All immersions ended at 3:00PM.

Several thousand larvae from each tank were transferred to raceways at Benner Spring for grow-out and mark retention analysis. A minimum of 30 specimens were sacrificed for otolith analysis. Otolith preparation and examination was done as per standard practice (Hendricks et al., 1991). Fluorescent marks were rated based on intensity as follows: 0- no mark, + - faint mark, ++ - better mark, +++ - bright mark. Mark intensity ratings were tested for significant differences by a Chi-square tests of independence (Ott, 1977).

Results and Discussion

Mark intensity ratings for experimental and control groups are presented in Table A3-1. Marks were detectable on all specimens examined. Two hour immersions appeared to produce less intense marks than 4 or 6h marks.

Data from 1992 was included to increase sample size for control groups. Control data (6h immersions) from 1992 and 1994 were pooled by age at marking (Tanks B42, F41) and intensity ratings compared using Chi-square. It was apparent by inspection of the data that day five marks were more intense than the other marks, therefore they were not used for statistical comparison. Total Chi-square was 1.99, compared to the critical value of 12.6 (df=6, a=.05), indicating inability to reject the null hypothesis that mark intensity is independent of age at marking. Therefore, I considered the intensity of marks produced by 6h immersion at 9, 13, 17, or 21d of age as a homogeneous set and pooled them for comparison to 2 and 4h immersions. Total Chi-square was 10.2, compared to the critical value of 9.49 (df=4, a=.05). This resulted in rejection of the null hypothesis that mark intensity is independent of immersion duration, and we can conclude that mark intensity is dependent on immersion duration for 2, 4, and 6h immersions. To isolate the immersion duration which produced less intense marks, I repeated the procedure with a subset of the data which included only 4 and 6h immersions. Total Chi-square was 2.74, compared to the critical value of 5.99 (df=2, a=.05). Therefore, I was unable to reject the null hypothesis that mark intensity is independent of immersion duration for 4 and 6h immersions, and the significant difference in the second test is attributable to less intense marks produced by 2h immersion.

Based on the results of this experiment, I recommend that future tetracycline immersions be for a 4 hour duration.

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Table A3–1. Mark retention and intensity ratings of tetracycline marks produced by 2, 4 and 6h immersions in 200 mg/L tetracycline hydrochloride, Van Dyke, 1994.

Tank	Raceway	Age (days)	Duration (h)	Concentration (mg/L)	Mark Intensity Rating (No. of specimens) 0	+	++	+++	Mean
A22	BSRF2	5	6	200	–	1	2	26	2.86
		9	2	200	–	3	21	5	2.07
		13	6	200	–	–	16	13	2.45
		17	4	200	–	3	26	–	1.90
		21	6	200	–	2	27	–	1.93
A32	BSRF4	5	6	200	–	–	–	30	3.00
		9	4	200	–	–	–	30	3.00
		13	6	200	–	–	2	28	2.93
		17	2	200	–	1	17	12	2.37
		21	6	200	–	2	23	5	2.10
B42	BSRE2	5	6	200	–	–	3	26	2.90
		9	6	200	–	–	15	14	2.48
		13	6	200	–	–	15	14	2.48
		17	6	200	–	2	15	12	2.34
		21	6	200	–	3	15	11	2.28
F41	BSRF1A	5	6	200	–	–	3	26	2.90
	(1992)	9	6	200	–	1	17	11	2.34
		13	6	200	–	1	16	12	2.38
		17	6	200	–	–	17	12	2.41
		21	6	200	–	–	18	11	2.38

Appendix 4.

Relative survival of Hudson River American shad larvae released at 7 days of age vs. those released at 19 days of age.

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Introduction

American shad larvae reared at the Van Dyke Research Station for Anadromous Fish have traditionally been stocked into receiving waters 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 6h immersion in 200ppm tetracycline hydrochloride. Detectable fluorophore from these marks is visible in 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, the approved marking regime called for larvae from the Connecticut River egg source to be marked at 5,9,13,17, and 21 days of age and stocked in the Juniata River at Thompsontown. No group of fish was assigned a single mark at 5d of age. Unusually high mortalities, beginning at 9d of age, were experienced in 1992 and 1993 (Hendricks et al., 1993). In anticipation of these high mortalities, we marked 2 high density tanks (J11, J21) of Connecticut River larvae at 5d of age and released them at 7d of age, before the mortalities could take their toll. A total of

891,700 larvae were marked at 5d of age and released at 7d of age (Table 1). These larvae were released on 6/13 and 6/14/93. One tank of Connecticut River larvae (243,000 larvae) was given an erroneous unique mark at 5, 13, 17 and 21 days of age and released at 22d of age on 6/25/93. The remainder of the Connecticut River larvae (1,802,400 larvae) were given quintuple marks and released between 6/22 and 7/13/93 at 22 to 26d of age. Fish from all three of these groups were recovered in the juvenile sampling, however, recovery rates varied greatly (Table A4-1). Larvae stocked at 7d of age exhibited a recovery rate 1.6 times that of tank I21 and 4.0 times that of the remainder of the Connecticut River fish. These higher recovery rates may be due to more favorable environmental conditions at the time of the release or to improved survival associated with release at 7d of age.

This purpose of this research was to further explore the relationship between age at stocking and survival. Larvae from the Hudson River were been chosen for the experiment since they have consistently achieved the highest relative survival over the past several years (St. Pierre, 1994).

Materials and Methods

Five Hudson River shipments were used for the experiment. Egg shipments were split into paired batches. Each batch was incubated in similar containers, under similar conditions. The egg incubation jars were moved to two adjacent tanks for hatch. A coin flip determined which tank was marked on day 5 and released on day 7 (test) and which tank was marked on day 18 and released on day 20 (control). Only tank pairs with similar egg viabilities and initial densities were used for the study. All fish culture activities were according to standard practice. Tanks of Hudson River larvae not used for the study were marked on days 5, 9, and 13 and stocked between 14 and 18 days of age. On days when study tanks were stocked, no other larvae were stocked at the same site.

Final tank densities were determined by subtracting daily estimates of egg and fry mortalities from the initial Von Bayer estimate of egg shipment size (Van Dyke standard practice). Relative survival of the groups was determined from the estimates of final tank density and frequency of occurrence of unique otolith marks in recaptured juveniles.

Results and Discussion

Results of the experiment are depicted in Table A4-2. Larvae stocked at 7 days of age outperformed those stocked at 20 days of age by 7.8 to 1 and other production larvae released at 14 to 18 days of age by 2.2 to 1.

Increased survival of shad released at 7d of age could be due to factors directly related to age at release or to more favorable environmental conditions at the time of release. We did not have the resources to attempt to measure or account for environmental variables at the time of release. Even if we were able to determine optimum environmental conditions for survival, it is unclear how that information could be used to maximize survival in a real-life situation, given the logistical complexities of managing the hatchery. In reality, we have little choice in which egg sources to use and when to collect eggs; we are using all known sources (except for the Columbia River), and collecting the maximum number of eggs available (or allowed) at the only times they are available. The only real choice we have is, at what age should fry be stocked to achieve maximum survival? The experiment was designed so that control groups would provide an answer to that question. We considered using control groups from other egg shipments, stocked on the same day as the test groups. This would have blocked out effects due to environmental conditions at stocking, but does not provide a direct answer to the question at hand.

Based on the results of this experiment and similar observations with Connecticut River larvae from 1993, I recommend that all production larvae be stocked at 7 days of age. Special studies requiring unique marks should be stocked as soon as possible after the marking sequence is complete. I further recommend that studies be initiated to attempt to apply marks by immersion in tetracycline during the embryonic stage, in order to develop triple marks which could be applied prior to 7 days of age.

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Table A4–1. Relative survival of American shad larvae from various egg source rivers, stocked in the Susquehanna River, 1993.

Egg Source	Tank	Age at Stocking (days)	Release Dates	Fry Released		Juveniles Recovered		Recovery Rate	Relative Survival
				Number	%	Number	%		
Delaware	H21	21	6/22	227,700	3	3	1	0.000013	0.11
Delaware	Others	19–21	6/11–7/2	2,271,700	35	83	35	0.000037	0.32
Delaware	Total	–	6/11–7/2	2,499,400	38	86	37	0.000034	0.30
Hudson	All	18–20	6/3–6/18	1,104,200	17	128	55	0.000116	1.00
Connecticut	I21	22	6/25	243,800	4	2	1	0.000008	0.07
Connecticut	J11,J21	7	6/13–6/14	891,700	14	12	5	0.000013	0.12
Connecticut	Others	22–26	6/22–7/13	1,802,400	28	6	3	0.000003	0.03
Connecticut	Total	–	6/13–7/13	2,937,900	45	20	9	0.000007	0.06

Table A4–2. Relative survival of Hudson River source larval American shad, uniquely marked and stocked at different ages, Van Dyke, 1994.

Egg Ship–ment	Tank	Initial Density	Survival	TC mark (days)	Age at release (days)	Number Stocked	Date Stocked
4	C11	141,400	99.2%	5	7	140,300	5/19
11	E21	173,700	99.4%	5	7	172,700	5/30
20	F31	177,700	78.2% *	5	7	100,000	6/4
24	H21	286,300	96.4%	5	7	275,900	6/7
27	I21	317,900	96.7%	5	7	307,500	6/9
4	B41	156,300	80.9%	18	20	126,400	6/1
11	E11	181,500	46.0% *	18	20	83,500	6/12
20	F41	177,300	62.1% *	18	20	110,200	6/17
24	H31	280,700	81.9%	18	20	229,900	6/20
27	I31	312,700	73.3%	18	20	229,400	6/22
5	C21	141,700	87.3%	5,9,13	18	24,600	5/31
5	C31	137,600	89.6%	5,9,13	18	123,400	5/31
6	C41	167,900	89.2%	5,9,13	17	149,900	5/31
10	D41	171,600	92.3%	5,9,13	15	108,400	6/6
17	E41	216,500	95.7%	5,9,13	16	207,100	6/10
19	F21	217,900	90.3%	5,9,13	15	196,800	6/10
22	G31	214,100	86.3%	5,9,13	16	184,800	6/14
24	H11	276,400	73.4%	5,9,13	14	209,400	6/14
25	H41	397,000	93.5%	5,9,13	18	373,000	6/19
25	I11	391,200	53.8%	5,9,13	18	210,300	6/19
29	J11	251,500	85.2%	5,9,13	18	216,500	6/21

	Age at release (days)	Number Stocked	No. recap-tured	Recap. rate	Rel. Survival
Totals	7	996,400	123	123.4	1.00
	20	779,400	13	16.7	0.14
	other	2,004,200	109	54.4	0.44

*Note low survival resulting from "Van Dyke Syndrome."

123.4×10^{-6}

1994 Experimental American Shad (*Alosa sapidissima*) Culture

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Background

During the 1960's the American shad (*Alosa sapidissima*) in Chesapeake Bay declined drastically. Since that time, there has been some increase in the upper Bay population due to larval stocking efforts, fish passage facilities and a complete harvest moratorium in the Bay and its tributaries since 1980. However, shad runs in other Chesapeake Bay tributaries are still severely depressed. Fisheries Division began a program, in cooperation with Potomac Electric Power Company (PEPCO), to restore viable shad runs in the Patuxent River through stocking of hatchery cultured fish.

Traditional American shad culture has largely consisted of strip spawning ripe fish on the spawning grounds, incubating fertilized eggs in the hatchery and stocking larvae back into the river. All adult fish are gill netted and subsequently sacrificed during expression of eggs and milt. This process is limited by the difficulty in obtaining an ample supply of ripe fish. In addition, shad are sequential spawners so it is theorized that stripping the fish only utilizes a portion of the potential fecundity.

Since American shad are sequential spawners, we surmised that the use of natural spawn techniques could increase production (fecundity) without sacrificing the adults. This allows the control over production that a hatchery situation affords. A detailed protocol was developed for this purpose that relies on techniques refined in the course of striped bass (*Morone saxatilis*) natural spawn production. The process has four components: (1) Intercept adult American shad on their way to the spawning grounds and transport them to the hatchery (2) Implant fish with hormones to aid in the progression of ovarian maturation (3) Incubate fertilized eggs and (4) culture and mark larvae to aid in recognition of hatchery fish recaptures.

Adult fish capture and handling

There are many methods available for capturing migrating adult shad. Possible methods include gill netting, pound netting, electrofishing and hook and lining. All of these methods impart significant stress on the fish which is counter to successful hatchery spawning. We have the ability to obtain adult fish from the fish lift at the Conowingo Dam on the Susquehanna River. This results in less potential stress to the fish and permits "culling" desirable specimens. Fish are collected throughout the day at the lift and large, healthy fish are placed in circular holding tanks at 10 ppt. salinity and held overnight to allow for some recovery from stress. The following day, 30-60 fish (50% male, 50% female) are placed in a circular truck tank (1000 gallons) at 10 ppt. salinity, 10 mg/l minimum D.O. and ambient water temperature. The water is treated with approximately 0.02 ml/gal MS-222 to reduce the effects of stress. This is an extremely light dose and it is unknown if there is any real effect. A heavier dose may be more effective. A circular flow of approximately 25 cm/second is introduced to aid in swimming orientation.

Upon arrival at Joseph Manning State Fish Hatchery (Charles County, Maryland), adult fish are quick dumped into a 12' circular tank. Tank water is flushed with hatchery water for approximately 30 minutes and salt is added to bring salinity up to 5 ppt. minimum.

Adult fish hormone implantation

Adults are placed one at a time into an anesthetic bath. This bath consists of an aerated 250L "cow tank" dosed with 0.25 ml/L 2-Phenoxyethanol (J.T. Baker Inc., Phillipsburg, N.J.). This method insures a minimum of handling of fish that are not under anesthetic.

Processing of adult fish begins with an ovarian biopsy using a 4mm glass catheter. Biopsies have shown consistently among different specimens that ovaries of migrating shad contain eggs at several different stages of development. These include primary-growth oocytes (which will develop during the following spawning season), ripening eggs, mature eggs and overripe eggs (Mylonas et al. In preparation). Fish are then measured (fork length), weighed and implanted with pelletized gonadotropin-releasing hormone analog (GnRHa) obtained from the Center of Marine Biotechnology and Maryland Agricultural Experiment Station of the University of Maryland. This implant is prepared with Ethylene-Vinyl acetate copolymer (EVAc) according to Zohar et al. (In preparation) (Mylonas et al. In preparation). This polymer allows for a constant release of hormone over a period of up to 21 days (Mylonas et al. 1993). This method further reduces the need for handling that would be required if multiple injections become necessary. Males and females are equally distributed among four natural spawn systems. Adult mortality seems to increase with water temperature. Ideal holding temperature seems to be approximately 65°F.

Fish are left in low light and unmolested other than a daily fresh water flush and re-salting. The natural spawn system at Manning hatchery consists of an air lift system which transports all eggs to an egg collection box via the water column of the air lift (Figure 1). Eggs are held in the collection box by a fine mesh screen and are collected daily. Eggs are concentrated into a fine mesh net submerged in the water, scooped out and placed in modified MacDonald hatching jars.

Implanted adults must either be destroyed and properly disposed of or held for a minimum of 72 hours after the drug has been fully metabolized as specified in our compassionate exemption of Investigational New Animal Drug permit. Currently, we don't know the metabolic rate of GnRHa dissolution for American shad. Without this kind of information all shad must be held 21 days to allow for complete metabolization plus three additional days according to INAD requirements. Since this pilot study is currently in the experimental stage, new shipments of fish are delivered every 10 days. Therefore, hatchery space is extremely limited and all implanted fish are sacrificed and incinerated.

Egg incubation

Egg incubation closely follows the protocol used by Van Dyke Hatchery of the Pennsylvania Fish and Boat Commission (Hendricks unpublished). Eggs are placed in 6.5L capacity hatching jars over air diffusing fiber mats. Jars have a continuous flow rate of 2-5 L/min. depending on water capacity (i.e. number of jars in use). Water is supplied to the jars from head tanks. These head tanks enable easy formalin drip treatments to combat disease and fungus. Seventeen minute treatments of 1:600 formalin drips are supplied to each jar daily (may be administered twice daily if necessary).

Egg water temperature is critical to good larval survival. A positive relationship exists between water temperature and egg development. Eggs that develop in less than 5 days tend to exhibit poor larval survival. In order to force an ideal (6-7 day) hatch, water temperature should be held to 64°F (Hendricks).

Dead eggs will separate to the top of the jar volume. Each jar is siphoned daily and dead eggs are counted. In addition, egg samples are taken daily and fertilization rates are calculated.

All jars are placed so jar spillways flow into 7' circular tanks. When several hundred larvae are observed to have hatched, jars are removed from water source and placed outside in direct sunlight. Eggs are stirred with a feather for at least five minutes. The combination of movement, sunlight and lower D.O. will stimulate a simultaneous hatch of nearly all eggs. The reasons for this are not completely understood, but it allows us to maintain discrete stocks of larvae that are all the same age. This is important in the larval marking process. After stirring for 5 minutes the jars are placed back on the larval tanks, flow is resumed and allowed to spill over. Larval tanks are set up as flow-through systems, but due to the large volume of water in these tanks, the potential for higher water temperatures exists. Flow of 64°F water into the tanks should be adjusted accordingly. While water temperatures for larval fish are not as critical as for eggs, they should be kept under 70°F.

Larval rearing and marking

Larval fish are held in the 7' tanks in flow-through mode. At age three, a feed regimen is begun. Larval AP100 is introduced every 10 minutes through automatic feeders for approximately 12 hours per day. This is supplemented with artemia every five minutes (also automatic feeders). Larvae will convert to feed at age 3-5 days and feed aggressively on both the artificial and artemia. Excess feed is siphoned off the bottom of the tanks daily.

All American shad larvae are given tetracycline (TC) otolith marks at predetermined intervals. Larval fish are immersed in a 300 ppm bath for six hours. Water pH is buffered to a neutral 7.0 during the bath. Samples of larvae are analyzed to confirm marks before fish are shipped out.

Larval fish are shipped to PEPCO ponds for grow-out. Optimal survival is reached when larvae are shipped soon after conversion to feed (< 10 days). Larvae are crowded and dipped out into fish shipping boxes with oxygen and 5 ppt. salinity. All ponds are prepared with maximum plankton blooms and larvae take to the natural feed well. Fish are grown for at least 45 days, transferred to hatchery tanks and may receive a number of feed marks.

Before stocking in the river, approximately 10% of the juveniles receive coded wire tags (CWT). Tags are implanted in the shoulder between the opercle and dorsal fin. A seven day tag retention and mortality study is performed in the hatchery on several batches of these fish.

1994 Strip Spawned American Shad Culture Results

Manning hatchery received 93.5 liters of fertilized eggs from the Hudson River, Delaware River and Connecticut River. The eggs were incubated, hatched and reared to post-larval/pre-juvenile stage (18 days old). These larvae were otolith marked by immersion in tetracycline at days three and seventeen. 2,050,000 larvae were produced by this method. Approximately 1.3 million larvae were stocked in the Susquehanna River at Port Deposit on June 9. The balance of the larvae (400,000-500,000) were stocked in PEPCO ponds on June 30, July 1 and July 2. These fish were grown to sub-adult size and 81,400 juveniles were stocked in the Patuxent River.

1994 Experimental American Shad Culture Results

Manning hatchery received 171 adult American shad from the Conowingo Dam fish lift in four separate trials. Shad from the first trial were used as controls and shad from Trials 2-4 were administered various doses (15.96 to 154.64 micrograms per kilogram body weight) of luteinizing hormone-releasing hormone (LH-RHa). None of the control animals successfully spawned but survival was high. Eleven females were injected in Trial 2 and produced 11 liters of viable eggs. Trial 2 fish experienced a low rate of adult mortality. Fish in Trial 3 produced three liters of eggs and experienced a high rate of adult mortality. None of the Trial 4 fish successfully spawned and this trial also had an unusually high rate of adult mortality.

Approximately 594,000 fertilized natural spawn eggs were incubated and resulted in 400,000 post-larvae. 150,000 larvae were stocked in PEPCO ponds and 250,000 were stocked in a private facility in Queenstown, Maryland. The latter batch of fish were almost a total loss. All larvae were immersion marked in OTC at 3-6 days and received an OTC feed mark before stocking in the river. Approximately 14,000 naturally spawned juveniles were marked with CWT. A total of 23,000 naturally spawned juveniles were stocked in the Patuxent River.

Conclusion

We are encouraged by the results of the experimental natural spawn techniques. Adult fish transported to the hatchery showed excellent survival if they are obtained when water temperatures are still low. Fish successfully spawned when implanted with GnRHa at lower water temperatures. Results indicate that the hatching jar system at Manning Hatchery is successful at rearing American shad eggs to larval size. Survival from egg to larvae is excellent and otolith marking performs flawlessly. CWT retention is also good and tagging mortality with this method is low (Table 1).

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AMERICAN SHAD NATURAL SPAWNING SYSTEM

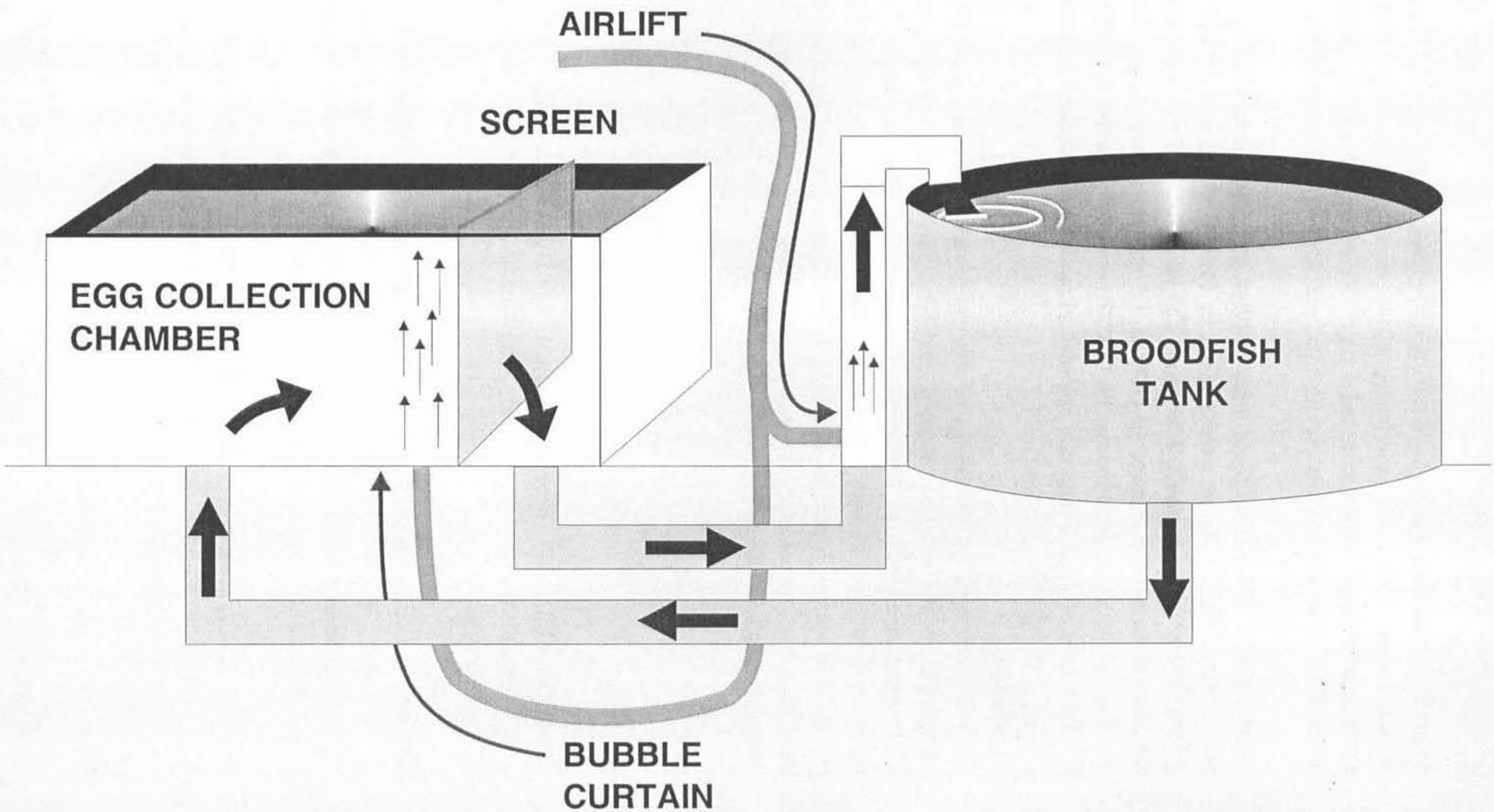

Table 1. Results of ten day tag retention and mortality study in hatchery tanks. Two trials of fish were given four different treatments. Control fish had no treatment. Anesthetic fish were dosed with MS-222. Horizontal tag insertion fish were implanted with coded wire tags (CWT) laterally through the body. Vertical tag insertion fish were implanted with CWTs dorsally through the body. RI = Round I, RII = Round II, NT = no tags were implanted.

Treatment	Control		Anesthetic		Horizontal tag insertion		Vertical tag insertion	
	RI	RII	RI	RII	RI	RII	RI	RII
Number of fish in trial	100	100	100	100	100	100	100	101
Survival percentage	94	99	89	99	85	97	91	100
Tag retention and survival (percent)	NT	NT	NT	NT	80	90	85	96

JOB IV.

EVALUATION OF MOVEMENTS, ABUNDANCE, GROWTH AND STOCK ORIGIN OF JUVENILE AMERICAN SHAD IN THE SUSQUEHANNA RIVER

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INTRODUCTION

Juvenile American shad were collected at several locations in the lower Susquehanna River during the summer and fall of 1994 in an effort to document general abundance, distribution, and timing of outmigration. Otoliths from subsampled shad were analyzed for tetracycline marks to indicate what proportion of the collection was of hatchery origin. Because cultured fish from various shad egg sources and culture sites were distinctively marked, the relative contribution to the nursery and subsequent outmigrant populations could be differentiated for each strain, culture situation, and stocking strategy.

Many individuals were involved in collection and analysis of juvenile shad in 1994. For their contributions to this report, appreciation is extended to Mark Plummer (Wyatt Group), Chris Frese (RMC), Dale Weinrich (Maryland DNR), and Mike Hendricks (PA Fish and Boat Commission). James Nowak and Scott Rhoades (PFBC) processed most of the otoliths.

HATCHERY AND ADULT SHAD STOCKING SUMMARY

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

A total of 28,681 adult American shad was hauled from the Conowingo fish lifts during the period 24 April through 13 June. Most (61%) were stocked above York Haven Dam at Middletown with the remainder being placed at Columbia. Known transport mortalities amounted to 583 fish (2%). Overall sex ratio (SR) in these transfers was about 1.8 to one favoring males. This stocking level compares with about 11,200 live shad delivered in 1993 (SR 1.3:1), 14,500 in 1992 (SR 1:1), and 22,000 in 1991 (SR 1.6:1). With the observed mortalities and sex ratio, the 1994 spawning population above dams amounted to 10,000 females and 18,000 males.

During the 1994 shad production season, PA Fish and Boat Commission biologists reared and released 6.42 million shad fry and 139,500 fingerlings in the Susquehanna watershed above dams. All fry were stocked between 19 May and 13 July in the Juniata River at Thompsontown. Fingerlings reared in Pennsylvania ponds were stocked at Thompsontown between 26 August and 14 October. The 6.42 million shad fry stocked above dams in the Susquehanna in 1994 compares to 6.54 M, 3.04 M, 7.22 M, 5.62 M, and 13.46 M in 1993, 1992, 1991, 1990, and 1989, respectively. Combined fingerling shad releases from PA ponds was almost double the number stocked in 1993 and 1992.

JUVENILE SHAD COLLECTIONS

Juvenile American shad occurrence and outmigration in the river above Conowingo Dam was assessed at numerous locations using several methods during the summer and fall of 1994 as shown below.

Gear	Location	Jul	Aug	Sep	Oct	Nov
Haul seine	Lower river		****************************			
Cast net	York Haven			*************		
Lift net	Holtwood			*******************		
Screens	Peach Bottom				***********	
Strainers	Conowingo					********

Seining was conducted by the Wyatt Group on 25 dates over 15 weeks from 26 July through 3 November. Most sampling occurred in late afternoon and evening and the net used measured 350-ft. x 6 ft. with 3/8" stretch mesh. The area most consistently monitored was Columbia/Wrightsville on 15 occasions. Other sampling areas included Marietta (7 dates), Pequea (5), Three-Mile Island (3), and Amity Hall (2).

At York Haven Dam, shad collections were attempted by Wyatt biologists using a 10-ft. cast net (3/8" mesh) on six dates between 15 September and 3 November. An 8-ft. square lift net with 3/4" mesh body and 1/4" mesh liner was used by RMC Environmental Services at Holtwood's inner forebay (10 lifts/date) during early evening hours twice weekly on 25 dates from 8 September through 5 December.

At Conowingo, RMC checked strainers for impinged shad on 18 occasions (twice weekly) during 3 October to 5 December. RMC also inspected intake screen washes at Peach Bottom Atomic Power Station three times weekly during 6 October through 5 December. As part of their annual juvenile Alosa recruitment survey, Maryland DNR sampled for shad and herring with electrofishing gear in the Susquehanna Flats weekly (14 dates) during August through October.

Samples of shad from most collections were returned to PFBC's Benner Spring Research Station for tetracycline mark and microstructure analysis of otoliths. Most collecting sites used in 1994 are shown in Figures 1 and 6-2.

Seine Survey of Lower River

The principle purpose for seine sampling in the lower river during summer months was to document the occurrence and relative abundance of naturally produced juvenile shad resulting from transplanted adults. As outmigration proceeds in the autumn, the occurrence and relative magnitude of the hatchery component of the juvenile stock becomes increasingly available to this gear. Sampling was concentrated at Columbia and Marietta since these locations proved very effective in past years.

During the summer/fall season, a total of 529 juvenile shad were taken in 168 seine hauls on 25 dates at five locations. Of these, 391 were measured and retained for otolith analysis. Columbia-Wrightsville, Marietta, and/or Pequea were sampled on 22 dates and produced a total of 420 shad in 139 hauls.

Amity Hall in the lower Juniata River was sampled on 9 August and 8 September with 13 hauls producing 27 shad. The purpose was to collect samples of shad for otolith analysis to determine if any natural reproduction occurred in this tributary. Spawning was confirmed, but as expected, most fish analyzed were hatched at Van Dyke. Three collections were made above York Haven Dam at Three Mile Island (8/16 - 9/29) producing 82 juvenile shad in 16 hauls.

Shad catch-per-unit-effort (CPUE) with seines in the river below York Haven in 1994 declined steadily from a high monthly average of 5.9 fish/haul in July to a low of 0.7 in October. Table 1 shows juvenile shad catch and effort by date and location for all seine collections in 1994.

York Haven Dam

Limited cast net collections were made in the York Haven headrace in an effort to document the onset of outmigration from the upper river. Although shad were observed dimpling in the headrace throughout most of September and October, water clarity reduced cast net effectiveness. Only 4 fish were taken with 86 throws of the net, one on 29 October and three on 3 November.

Holtwood Dam

RMC personnel initiated lift netting at Holtwood's inner forebay on 8 September when the first 5 juvenile shad were taken, and continued twice weekly through 5 December. Catch effectiveness here was also hampered by clear water conditions (gear avoidance) throughout much of the season. On 25 sample dates over a 3-month period, total catch amounted to 206 juvenile and 1 blueback herring. By contrast, in 1993, a similar amount of effort at this site produced 1,093 juvenile shad, 173 bluebacks and 24 alewives. Peak catch in 1994 occurred during the 19-day period 3-20 October 172 shad; CPUE = 2.9), and the last fish was taken on 17 November. Daily catch of shad with lift net at Holtwood during autumn 1994 is shown in Table 2.

Peach Bottom APS and Conowingo Dam

With the cooperation of PECO Energy Company, RMC biologists examined intake water travelling screen washes for impinged

American shad at the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pond. Screen sampling occurred three times per week during 6 October through 5 December. Collections for the season amounted to 27 juvenile shad, similar to what was taken here in 1993. Although three shad were taken on the first collecting date, most (17 fish) occurred between 11/21 and 12/2.

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged shad three times each week during 3 October through 5 December. American shad were taken in small numbers (1-4) on eight dates after 23 October. Collections included a total of 19 juvenile American shad, again comparable to the number seen in 1993.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 36 juvenile American shad by electrofisher from the upper Chesapeake Bay during August through October. This compares to 31 shad taken in 1993 and four in 1992. An additional 22 shad were collected in DNR's juvenile striped bass seine collections in the upper Bay. Electrofisher collection results by location and date are provided in Table 6 of Job VI. Otoliths from 54 shad taken in DNR collections were analyzed by PFBC staff.

OTOLITH MARK ANALYSIS

Otoliths from 579 juvenile American shad taken in summer and fall collections by Wyatt Group, RMC Environmental Services, and Maryland DNR were successfully prepared for hatchery mark assessment. Otoliths were surgically removed from the fish, cleaned and mounted on slides, ground and polished to the focus on the sagittal plane on both sides, and viewed under ultraviolet light to detect the presence of fluorescent rings indicative of tetracycline immersion treatments. The marking regime used by the PA Fish and Boat Commission in 1994 is described in Job III.

Amity Hall, TMI and York Haven

Otolith analysis was completed on 89 shad provided from York Haven cast net samples (4 fish on 10/29 and 11/3), seine collections from Amity Hall (26 fish on 8/9 and 9/8), and Three Mile Island (59 fish between 8/16 and 9/29. Of this combined group, 53 (60%) were hatchery produced including 23 of 26 shad examined from Amity Hall. Thirty-three of 63 fish taken at TMI and York Haven (52%) were wild. Based on river of egg origin, 43 (82.7%) of the marked sample were Hudson fish; 2 (3.8%) were Delaware; 2 (3.8%) were Connecticut source, and 5 (9.6%) were from pond-released fingerlings. One fish showed hatchery microstructure but had no visible mark.

Marietta, Columbia, Wrightsville, and Pequea

Seine collections made at these downstream sites during late-July through October provided 290 shad for otolith mark analysis. Overall, 106 of the fish (36.6%) were marked or showed hatchery microstructure and the remaining 184 fish (63.4%) were wild. Hatchery fish appeared in collections as early as 26-28 July at Pequea and Columbia and were available in small numbers (1-14) on all collection dates. Whereas Marietta collections were almost evenly split between hatchery and wild fish, 156 of 240 (65%) of those taken at Columbia-Wrightsville and Pequea were wild. Of the 101 marked hatchery fish in these seine collections, 88 (87.1%) were Hudson River origin; 3 (3.0%) were Delaware source, 1 (1.0%) was Connecticut River, and 8 fish (7.9%) were fingerling releases.

Holtwood and Peach Bottom

Of the 146 shad otoliths processed from Holtwood lift net and Peach Bottom screen collections, 117 (80%) were hatchery origin. Wild fish occurred in most collections, but only in small numbers (1-4). As was the case upstream, Hudson River fish were most abundant in the hatchery-marked component here with 113 fish (97.4%). Delaware River egg source produced the remaining 3 marked fish (2.6%), and one shad was unmarked but showed hatchery microstructure. Unlike 1993 when 20% of marked shad at Holtwood were pond-reared fingerling origin, none were recovered here in 1994.

Upper Chesapeake Bay

Of 54 juvenile shad analyzed from Maryland DNR's electrofisher and seine collections in the upper Chesapeake Bay, 21 (39%) were double marked hatchery fish. These resulted from DNR's release of 1.3 million fry on 9 June at Port Deposit, MD. No hatchery fish of upstream origin were recovered.

Otolith Summary

Otolith analysis of shad samples from all collecting dates and sites above Conowingo Dam is presented in Table 3. The 525 shad analyzed included samples from every week between 26 July and 28 November. Monthly sample sizes for otolith analysis ranged from 197 in August to 23 in November for all sites combined. A total of 276 fish (52.6%) were either TC marked or showed hatchery microstructure and 249 (47.4%) were wild. In 1993, 1992, 1991, and 1990, the wild components of the combined upriver otolith analyses were 58%, 39%, 22%, and 2%, respectively. Holtwood/Peach Bottom samples may be considered as a better indicator of stock composition at outmigration. If this is true, then the naturally produced component of the 1994 year-class was only 20%, compared to 50% at Holtwood in 1993.

Hudson River fry comprised 91.1% of all marked fish in collections above Conowingo Dam (245 of 269). Of the remainder, Delaware River fry made up 3.0% 8 fish), Connecticut fry comprised 1.1% (3 fish), and 4.8% (13 fish) were from fingerling pond releases.

DISCUSSION

In-Stream Movements and Outmigration Timing

Juvenile shad collections at Holtwood in 1994 suggest that outmigration from the river occurred during the month of October as water temperature declined from 18°C to 14°C. Of the 420 juvenile shad collected with seines at Columbia, Wrightsville, Marietta, and Pequea during the 1994 season, 397 were taken prior to October outmigration. Based on analysis of 290 otoliths from these collections, 184 fish (63%) were naturally produced. A sizeable component of the adult transfers in 1994 were stocked at Columbia, and past observations suggest that many fish stocked at Middletown drop below York Haven Dam shortly after release. Therefore, it is likely that a considerable amount of reproduction and summer nursery took place near the seine sites, particularly the free-flowing stretch of river from York Haven to Columbia. The fact that some reproduction occurred upstream from Harrisburg is evidenced by the collection of wild juveniles at Amity Hall and observation of migrating adults in the Juniata River at Thompsontown (Mike Hendricks, personal communication).

Most of the hatchery-marked shad caught in earliest downstream seine collections during 26 July through 19 August (31 of 40 fish) were Hudson River origin stocked at Thompsontown as 7-day old fry (day 5 mark) between 19 May and 9 June. Most of the 61 marked shad in late August through October seine collections were also Hudson origin, 24 with the single-mark and 25 with a triple-mark having been stocked as 14-18-day old fry between 31 May and 21 June. The canal pond at Thompsontown was stocked on 26 August (40,000 fingerlings) and nine of these fish were recaptured between 9/6-10/25 at Columbia and Three Mile Island.

Since single-mark Hudson fish appeared at Pequea as early as 28 July, they made this 65-mile downstream journey in 50-70 days at an average rate of 0.9 to 1.3 miles/day. Movement of later stocked triple-mark Hudson fish was less ambitious. While they dominated the Amity Hall collection on 9 August (16 of 22), their frequency of occurrence in collections at and below Three Mile Island did not peak until late August and September. The earliest pond-release fingerlings in the seine collections migrated from Thompsontown to Columbia in 11 days at a rate of 4.5 miles per day.

River flow in the Susquehanna River during the first three weeks of April was very high causing a delay in trapping operations at Conowingo Dam. Flows subsided quickly and remained modest at 15,000-60,000 cfs throughout the rest of the trapping season. Average daily river flow during August (46,000 cfs) was considerably higher than the long-term mean for this month (12,000 cfs), caused by a major flow event which exceeded 90,000 cfs daily during 19-24 August. Autumn flows were near normal (Figure 2).

Only small numbers of juvenile shad (10 fish) were taken with lift nets at Holtwood in September. Based on catch abundance, peak outmigration appeared to have occurred here during 3-20 October compared to 25 October through 8 November in 1993. The last three shad were collected at Holtwood on 10-17 November. River flows during this period were declining from 30,000 to 10,000 cfs and water temperatures were 15-18°C. Stock composition of marked shad at Holtwood was evenly split between Hudson fish released at 7 days of age (123) and those released at 14-20 days (122 fish). Unlike last year, hatchery fish dominated all Holtwood collections in 1994 (81%), but no pond fish were recovered here.

Although timing of juvenile shad outmigration from the Susquehanna River appears well defined in 1994, unusually clear water conditions lessened effectiveness of the lift net for capturing fish in relation to their true abundance (Chris Frese, personal communication).

<u>Abundance</u>

Comparison of relative abundance of juvenile shad in the Susquehanna River from year to year is difficult due to the opportunistic nature of net sampling and wide variation in river conditions which may influence success. Excluding the Amity Hall samples, a total of 155 seine hauls were made from Three Mile Island to Pequea on 24 dates over 15 weeks in 1994. With a catch of 502 juvenile shad, the overall catch per unit effort (CPUE) was about 3.24. CPUE was highest during the late July through September nursery period (4.1), and declined sharply in October. The table below compares stocking numbers and juvenile recovery data from 1994 with overall shad catch and effort using seines at similar sites in the river during the prior 3-years.

Year	Adult Females	Fry Stocked	Seine Dates	Shad Catch	Number Hauls	Juvenile CPUE
1994	**10,000**	6.42M	7/26-11/03	502	155	**3.24**
1993	4,350	6.54M	7/15-10/20	275	156	1.76
1992	7,275	3.04M	7/17-10/22	304	153	1.99
1991	8,365	7.22M	7/12-10/30	191	193	0.99

Cooling water strainers at Conowingo and intake screens at Peach Bottom are passive samplers. Although catch numbers are small, these collections may provide useful information on relative abundance since they are not influenced by vagaries of net sampling and weather conditions. Juvenile shad CPUE (catch per day) for 1994 at Peach Bottom and Conowingo is compared below with the prior 3 years for those periods encompassing the catch.

Location	Shad Catch Per Unit Effort (Days) 1994	1993	1992	1991
Peach Bottom	**1.13**	1.08	0.03	0.16
Conowingo	**1.58**	0.49	0.18	0.69

Both the seine and strainer/screen collections suggest that juvenile shad abundance in the river and during outmigration in 1994 was somewhat greater than that in earlier years.

The lift net at Holtwood produced 206 juvenile shad in 210 lifts during 8 September through 17 November, 1994. RMC has effectively sampled with this gear for 10 years at Holtwood and the table below compares catch and effort for those periods which encompassed successful collections.

Year	Dates	Effort (lifts)	Shad Catch	CPUE
1994	09/08-11/17	210	206	0.98
1993	09/28-11/22	170	1,093	6.43
1992	09/17-10/29	130	39	0.30
1991	10/14-12/16	210	208	0.99
1990	09/26-11/16	200	3,980	19.90
1989	09/22-10/26	116	556	4.79
1988	10/26-12/07	154	929	6.03
1987	09/10-11/20	358	832	2.32
1986	10/06-12/02	393	2,928	7.45
1985	10/16-12/19	378	3,625	9.59
	Average	**232**	**1,440**	**6.16**

A cursory review of this data shows disagreement with seine, strainer, and screen CPUE's suggesting that stock abundance in 1994 was well below that of 1993 and the long-term average, and similar to that seen in the poorest years (1991-1992). Once again, caution must be used in this evaluation due to gear avoidance noted by RMC biologists during lift netting.

Abundance of wild shad in summer/fall collections was less in 1994 compared to 1993, but higher than in prior years. Based on otoliths analyzed from all collections above Conowingo Dam (except Amity Hall), naturally produced fish comprised 49% compared to 58% in 1993, 39% in 1992, 22% in 1991, and only 2% in 1990. We cannot explain this decrease, particularly since the number of adult shad stocked in 1994 was greater than in any prior year. It is possible that wild fish occupying the lower river nursery were pushed downstream beyond Holtwood during the late August flow event.

The electrofishing collection of 36 juvenile shad from the Susquehanna Flats during August through October 1994, compares to 31 fish in 1993, 4 in 1992, 17 in 1991, and 23 in 1990 with similar effort. About 61% of the shad taken by electrofisher and seine in 1994 were wild compared to 100% in 1993. This was not unexpected since 1.3 million cultured fry were stocked by DNR below Conowingo Dam in 1994 whereas none were placed there in 1993. Outmigration of marked fish from the river above dams probably occurred too late for recovery in the upper Bay.

<u>Growth</u>

Wild juvenile shad collected with seines at Pequea, Marietta and Columbia-Wrightsville averaged 80 mm total length (TL) in late-July (range 55-104) and grew to an average 125 mm (range 112-141 mm) by early October (Figure 3). Growth rate during this period averaged

0.62 mm/day. In 1993, mid-July fish at these sites averaged only 57 mm (range 39-64 mm), perhaps reflecting a later spawning that year due to delayed trapping operations at Conowingo. The three wild fish in the Amity Hall shad sample from 9 August had a mean TL of 84 mm (range 76-97 mm), the same as hatchery fish.

Hatchery fish in downstream seine collections were about the same size as wild fish during the nursery period, improving from 80 mm in late July (range 63-100 mm) to 128 mm in early October (112-146 mm) with an average growth rate of about 0.66 mm/day. These growth rates are smaller than those recorded in past years (1.0 mm/day), and for the first time showed no growth advantage for wild fish.

Although they occurred infrequently in seine collections between Three Mile Island and Columbia during 9/6 through 10/20, recaptured shad stocked as fingerlings at Thompsontown were invariably smaller than those released as fry, averaging 85 mm (range 60-124 mm). Juvenile collections in 1994 produced too few fish of Delaware or Connecticut River origin to allow comparison of growth among the various egg sources stocked as fry at Thompsontown.

Wild juvenile shad in lift net collections at Holtwood from early October through early November displayed no trend in mean fish size. All weekly collections averaged between 123 mm and 129 mm, with individual fish ranging 112-140 mm (n = 21). Hatchery fish from upstream fry stockings in Holtwood samples were slightly larger, but similarly showed no trend. Size of fish in samples averaged between 121-132 mm with a range of 110-150 mm.

<u>Stock Composition and Mark Analysis</u>

Of the 6.42 million shad fry stocked at Thompsontown in 1994, 1.855 million (28.9%) were Connecticut River fish released on 9 dates between July 1-13. Delaware River shad fry comprised 785,200 (12.2%) of the total Juniata River stocking in 1994, with 5 releases between 6 June and 1 July. The remaining 3.78 million fry (58.9%) were Hudson River origin stocked at Thompsontown on 15 dates between 19 May and 22 June. Of these, 996,400 fry were marked on day 5 and stocked at 7 days of age; 779,400 fry were marked on day 18 and stocked at 20 days of age; and the remaining 2,004,200 were marked on days 5, 9, and 13 and stocked at 14-18 days of age.

Unlike 1993 and 1992, Hudson fish comprised the largest percentage of total fry stocked upstream. As expected, they were also the dominant component of tetracycline marked shad in all juvenile collections above Conowingo comprising 91.1% (245 of 269 fish). Delaware source (8 fish) and Connecticut source (3 fish) comprised only 3.0% and 1.1% of marked shad in collections, respectively. Thirteen pond-released fingerlings (4.8% of hatchery total) were recovered in seines between late September and late October.

Survey Area	Collection frequency from various stocked sources Hudson	Delaware	Conn.	Ponds
Above York Haven	84.3%	2.0%	3.9%	9.8%
Marietta-Pequea	88.1%	3.0%	1.0%	7.9%
Holtwood-PB-Cono.	99.1%	0.9%	0.0%	0.0%

Recovery rates (number recovered/number stocked) for the three egg source strains stocked as fry were 0.000065 for Hudson (about 1 in 15,000), 0.000010 for Delaware (1 in 100,000), and 0.000002 for Connecticut (about 1 in 600,000). Relative survival to recovery of Hudson fish exceeded that of Delaware and Connecticut fish by factors of 6.5 and 41.2, respectively.

In 1993, two lots of Connecticut River fry which were stocked in mid-June at only 7 days of age were recovered at a rate over four times that of the remaining Connecticut lots stocked at 22-26 days old. This result and the possibility that hatchery space would be limited due to concurrent egg shipments from the Hudson and Delaware rivers prompted comparative stockings in 1994 of batches of Hudson fry released early (7 days of age with day 5 mark) and late (20 days of age with day 18 mark). All remaining Hudson fry were stocked at 14-18 days of age with triple marks. Stocking numbers, recovery rates and relative survival of these three Hudson releases were:

Hudson Stock	Fry Released Number	%	Recovered Number	%	Recovery Rate	Relative Survival
Day 7	996,400	26.4	123	50.2	0.000123	1.00
Day 18	779,400	20.6	13	5.3	0.000017	0.14
Other	2,004,200	53.0	109	44.5	0.000054	0.44

Results from 1994 and 1993 suggest that there is a definite survival advantage in stocking fry early and this is proposed by PA Fish and Boat Commission for 1995 (see Appendix 4, Job III).

A total of 139,500 specially marked fingerling shad were stocked from Pennsylvania ponds into the Juniata River including an estimated 40,000 Hudson fish from the Thompsontown canal pond on 26 August at 105 days of age, and 99,500 Delaware fish from three Upper Spring Creek ponds during 9 September through 14 October at 112-144 days old. With a total of 13 of these fish taken in downstream collections, their recovery rate from release was 0.000094 (1 in 10,800). However, when this recovery is related to the 429,000 total fry stocked into ponds, rate of return drops to only 0.000030 (1 in 33,000), less than half the value for direct Hudson fry releases. Numbers of shad released and collected, recovery rates, and relative survival from various egg sources stocked in the Susquehanna River during 1988 through 1994 are shown in Table 4.

Based on otolith analysis of 525 shad from all collections above Conowingo Dam in 1994, 47% (249 fish) were naturally produced. This compares to 58% in 1993, 39% in 1992, 21.5% in 1991, and 1-4% each year during 1987-1990. Recovery of juvenile shad at Holtwood may be less biased and more representative of the outmigrant population. Of the 135 otoliths examined from those collections in 1994, only 25 (19%) were wild. This compares to 49% wild fish at Holtwood in 1993.

SUMMARY

The haul seine was effective in taking juvenile shad at several lower river sites during late July through October. Catch per unit effort with this gear of 3.24 shad/haul was higher than that from most past years. Successful reproduction of transplanted adult shad was well documented with the collection of unmarked wild fish at all netting sites throughout the survey.

River flow conditions during the summer of 1994 were somewhat erratic and generally above long-term average values, particularly in August. Outmigration from the river peaked during the first three weeks of October and, based on juvenile shad collections at Holtwood, the outmigrant population was weaker than in 1993.

Hatchery released fry grew well, reaching an average size of about 125 mm within 4-months of release. Too few Connecticut and

Delaware River source shad appeared in collections to evaluate their growth rates with that of dominant Hudson River recoveries. Wild shad grew at about the same rate as hatchery fish and maintained similar average sizes in combined monthly collections.

Relative to their abundance at stocking, Hudson River source juvenile shad were recaptured at 6.5 to 41 times greater frequency than Delaware and Connecticut River fish, respectively. Pond-reared fingerlings were not well represented in late season collections as compared with Hudson fry releases. Same source fish stocked at 7 days of age outperformed those released at 14-20 days of age by a factor of three.

Table 1. Summary of Juvenile American Shad Collected with Seines in the Susquehanna River, July-October, 1994.

Date	Location	No. Hauls	No. Shad
7/26	Columbia	2	75
	Marietta	4	0
7/28	Pequea	9	13
8/02	Columbia	4	60
	Marietta	3	1
8/05	Pequea	6	0
8/09	Amity Hall	5	26
8/11	Wrightsville	2	5
	Columbia	9	24
8/16	Three Mile Isl.	6	20
	Columbia	3	13
8/18	Pequea	1	1
8/19	Marietta	2	20
8/24	Marietta	4	37
8/25	Three Mile Isl.	5	13
8/29	Col/Wrights.	8	46
9/01	Pequea	7	3
9/06	Col/Wrights.	9	15
9/08	Amity Hall	8	1
9/13	Col/Wrights.	7	35
9/20	Marietta	3	1
	Col/Wrights.	5	25
9/22	Pequea	5	9
9/27	Col/Wrights.	9	14
9/29	Three Mile Isl.	5	49
10/04	Col/Wrights.	8	5
10/13	Marietta	3	0
	Col/Wrights.	6	5
10/20	Col/Wrights.	7	2
10/25	Marietta	1	1
	Col/Wrights.	6	10
11/03	Col/Wrights.	6	
	Totals	168	529

Table 2. Summary of Juvenile Fish Collections with Lift Net in the Holtwood Hydroelectric Station Forebay during Autumn 1994. Effort was 10 lifts per event.

Date	Water Temp.(C)	American Shad	All Other*
9/08	20.0	5	15
9/12	20.5	2	10
9/15	22.0	0	0
9/19	22.0	0	0
9/22	21.5	0	0
9/26	21.5	0	1
9/29	21.5	3	3
10/3	16.5	55	5
10/6	15.0	31	5
10/10	18.0	57	1
10/13	18.0	14	4
10/17	16.0	4	1
10/20	17.0	11	2
10/24	17.5	0	0
10/27	17.5	7	2
10/31	16.0	0	2
11/03	14.0	2	1
11/07	15.0	12	3
11/10	14.0	1	2
11/14	14.0	1	3
11/17	11.5	1	1
11/21	13.0	0	0
11/23	11.0	0	2
11/28	8.0	0	3
12/05	6.0	0	0
	Totals	206	66

* Includes 22 gizzard shad, 21 walleye, and 23 others representing nine species.

Table 3. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1994.

Collection Site	Coll. Date	Immersion marks: Day 5	Day 18	Days 5,9,13	Days 3,13,17	Days 5,9,13, 17,21	Days 3,17	Feed marks: Canal Pond	USC Pond 1	USC Pond 2	USC Pond 3	Hatchery Micro-structure Not Marked	Total Hatchery	Wild Micro-structure Not Marked	Total
Amity Hall	8/9/94	4	1	16	1								22	3	25
	9/8/94			1									1		1
Three Mile Island	8/16/94	4		1									5	15	20
	8/25/94	2	1	1								1	5	8	13
	9/29/94	2	2	7		2		4			1		18	8	26
York Haven	10/29/94												0	1	1
	11/3/94	1			1								2	1	3
Marrietta	8/2/94	1											1		1
	8/19/94	4										1	5	14	19
	8/24/94	4		9		1							14	14	28
	9/20/94								1				1		1
	10/25/94				1								1		1
Columbia/ Wrightsville	7/26/94	6		2									8	20	28
	8/2/94	7		2									9	16	25
	8/11/94	5		3								1	9	18	27
	8/16/94	3		2									5	8	13
	8/29/94	2		3								1	6	19	25
	9/6/94	1		2				1					4	10	14
	9/13/94	5		1								2	8	17	25
	9/20/94	6		4									10	15	25
	9/27/94	2	1	1									4	10	14
	10/4/94	1		1									2	3	5
	10/13/94			2	1			1					4	1	5
	10/20/94									2			2		2
	10/25/94	2			1			3					6	2	8

Table 3. (continued).

Collection Site	Coll. Date	Immersion marks: Day 5	Day 18	Days 5,9,13	Days 3,13,17	Days 5,9,13, 17,21	Days 3,17	Feed marks: Canal Pond	USC Pond 1	USC Pond 2	USC Pond 3	Hatchery Micro-structure Not Marked	Total Hatchery	Wild Micro-structure Not Marked	Total
Pequea	7/28/94	4											4	9	13
	8/18/94	1											1		1
	9/11/94			2									2	1	3
	9/20/94												0	7	7
Holtwood	9/8/94	4											4	1	5
	9/12/94			1									1	1	2
	9/29/94	1		2									3		3
	10/3/94	14	2	5									21	4	25
	10/6/94	10	1	10									21	4	25
	10/10/94	9	1	11								1	22	3	25
	10/13/94	7	2	2	1								12	1	13
	10/17/94	1		3									4		4
	10/20/94	3		6									9	2	11
	10/27/94	1		2									3	4	7
	11/3/94			1									1	1	2
	11/7/94	2	1	4									7	2	9
	11/10/94			1									1		1
	11/14/94												0	1	1
	11/17/94												0	1	1
	11/28/94	1											1		1
Peach Bottom	10/6–11/30/94	3	1	1	2								7	4	11
Total (above Con.)		123	13	109	8	3	0	9	1	2	1	7	276	249	525
Percent		23%	2%	21%	2%	1%	0%	2%	0%	0%	0%	1%	53%	47%	
Holtwood Only		53	7	48	1	0	0	0	0	0	0	1	110	25	135
Percent		39%	5%	36%	1%	0%	0%	0%	0%	0%	0%	1%	81%	19%	

Table 3. (continued).

Collection Site	Coll. Date	Immersion marks: Day 5	Day 18	Days 5,9,13	Days 3,13,17	Days 5,9,13, 17,21	Days 3,17	Feed marks: Canal Pond	USC Pond 1	USC Pond 2	USC Pond 3	Hatchery Micro-structure Not Marked	Total Hatchery	Wild Micro-structure Not Marked	Total
Below	7/18/94												0	1	1
Cono-	7/20/94						7						7	5	12
wingo	8/4/94												0	3	3
	8/10/94						2						2	5	7
	8/17/94						1						1	2	3
	9/7/94						3						3	5	8
	9/12/94												0	1	1
	9/14/94						2						2	1	3
	9/21/94						1						1		1
	9/28/94												0	4	4
	9/30/94												0	1	1
	10/5/94						2						2		2
	10/11/94						1						1		1
	10/19/94						1						1	3	4
	10/26/94						1						1	2	3
Total (below Con.)		0	0	0	0	0	21	0	0	0	0	0	21	33	54
Percent		0%	0%	0%	0%	0%	39%	0%	0%	0%	0%	0%	39%	61%	

Key to immersion marks:
Day 5– stocked at 7d of age, Juniata River.
Day 18– stocked at 20d of age, Juniata River.
Days 5,9,13– Hudson River egg source, stocked in Juniata River.
Days 3,13,17– Delaware River egg source, stocked in Juniata River.
Days 5,9,13,17,21– Connecticut River egg source, stocked in Juniata River.
Days 3,17– Reared at Manning, stocked below Conowingo Dam.

Table 4. Relative survival of American shad fry from various egg source rivers, stocked in the Susquehanna River, 1988–1994.

Year	Egg Source	Release Dates	Fry Released Number	Fry Released %	Juveniles Recovered Number	Juveniles Recovered %	Recovery Rate	Relative Survival
1988	Va.	5/13–5/31	682,685	11	111	40	0.000163	1.00
	Del.	6/1–6/10	495,670	8	69	25	0.000139	0.85
	Col.	7/5–7/25	5,272,330	82	99	36	0.000019	0.12
1989	Va.	5/30–6/1	477,320	4	67	26	0.000140	1.00
	Hud.	6/5–6/28	2,864,720	21	94	37	0.000033	0.23
	Del.	6/16–7/7	1,644,630	12	11	4	0.000007	0.05
	Col.	6/30–7/11	8,477,980	63	80	32	0.000009	0.07
1990	Va.	5/22	178,300	3	4	1	0.000022	0.12
	Del.	5/26–6/8	1,622,800	29	19	3	0.000012	0.06
	Hud.	6/6–7/2	3,817,900	68	714	97	0.000187	1.00
1991	Del.	5/31–6/9	1,085,000	15	61	13	0.000056	0.83
	Hud.	5/30–6/18	6,098,000	84	415	87	0.000068	1.00
	Conn.	6/28	35,000	<1	0	0	0.000000	0.00
1992	Del.	6/4–6/18	798,700	26	41	17	0.000051	0.19
	Hud.	6/5–6/16	568,700	19	152	64	0.000267	1.00
	Conn.	6/29–7/6	1,672,000	55	43	18	0.000026	0.10

Table 4. (continued).

Year	Egg Source	Release Dates	Fry Released Number	%	Juveniles Recovered Number	%	Recovery Rate	Relative Survival
1993	Del. (H21)	6/22	227,700	3	3	1	0.000013	0.11
	Del. (other)	6/11–7/2	2,271,700	35	83	35	0.000037	0.32
	Del. (total)	6/11–7/2	2,499,400	38	86	37	0.000034	0.30
	Hud.	6/3–6/18	1,104,200	17	128	55	0.000116	1.00
	Conn. (I21)	6/25	243,800	4	2	1	0.000008	0.07
	Conn. (J11,J21)	6/13–6/14	891,700	14	12	5	0.000013	0.12
	Conn. (other)	6/22–7/13	1,802,400	28	6	3	0.000003	0.03
	Conn. (total)	6/13–7/13	2,937,900	45	20	9	0.000007	0.06
1994	Hud. (d7)	5/19–6/9	996,400	15	123	46	0.000123	1.00
	Hud. (d20)	6/12–6/22	779,400	11	13	5	0.000017	0.14
	Hud. (other)	5/31–6/21	2,004,200	29	109	41	0.000054	0.44
	Delaware	6/6–7/1	785,200	11	8	3	0.000010	0.08
	Connecticut	7/1–7/13	1,854,900	27	3	1	0.000002	0.01
	Canal Pond	8/26	150,000	2	9	3	0.000113	0.89 *
	USCP1	9/12	93,000	1	1	0	0.000029	0.19 *
	USCP2	10/13–10/14	93,000	1	2	1	0.000249	0.45 *
	USCP3	9/19–9/20	93,000	1	1	0	0.000031	0.99 *
1994 Holtwood Only								
	Hud. (d7)	5/19–6/9	996,400	15	53	20	0.000053	1.00
	Hud. (d20)	6/12–6/22	779,400	11	7	3	0.000009	0.17
	Hud. (other)	5/31–6/21	2,004,200	29	48	18	0.000024	0.45
	Delaware	6/6–7/1	785,200	11	1	0	0.000001	0.02
	Connecticut	7/1–7/13	1,854,900	27	0	0	0.000000	0.00

*Corected to include only fish collected 7 days after pond stocking.

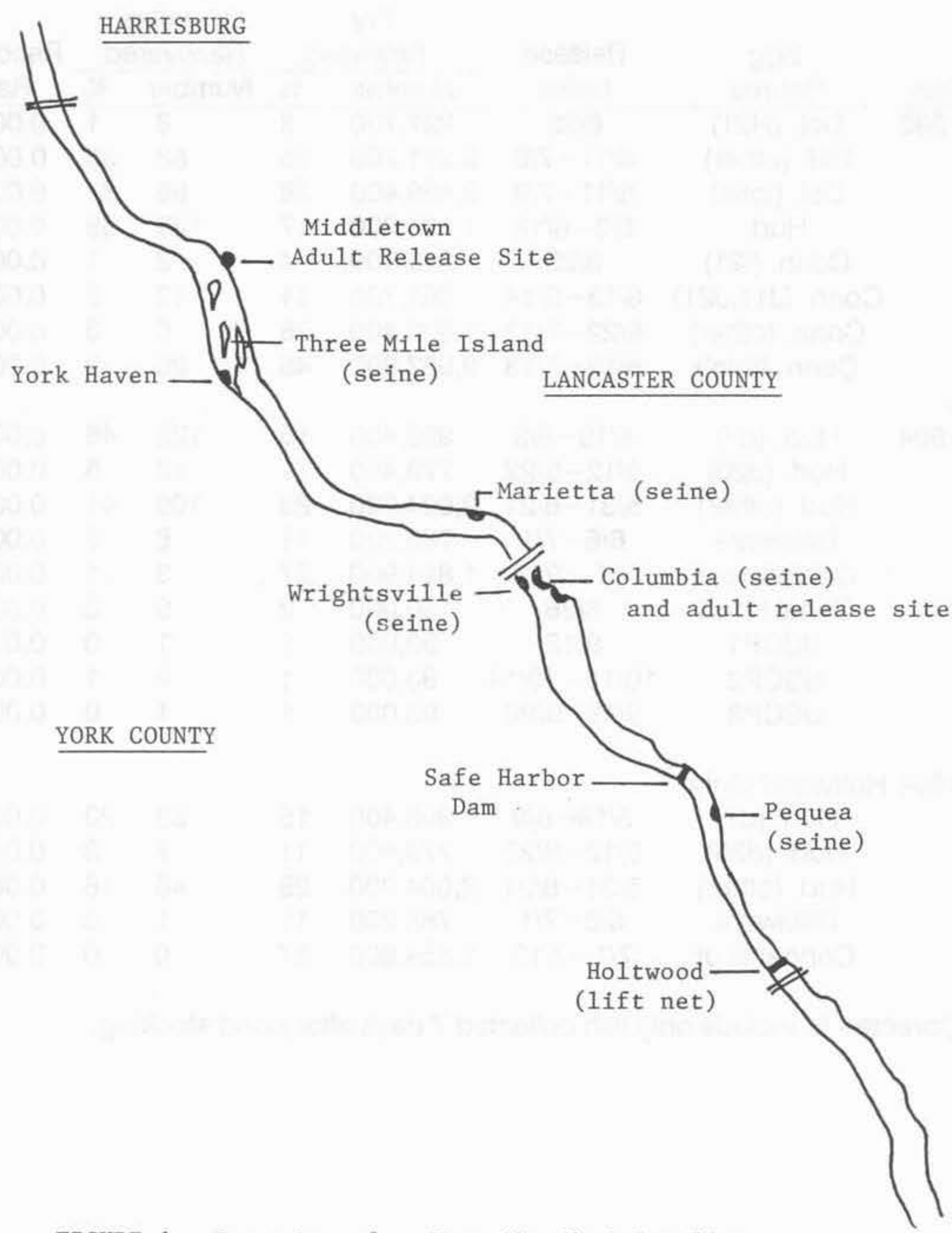


FIGURE 1. Locations for Juvenile Shad Sampling During July - October, 1994.

Figure. 2. Comparison of River Flow during June-November, 1994 with Long-Term Monthly Mean Flow.

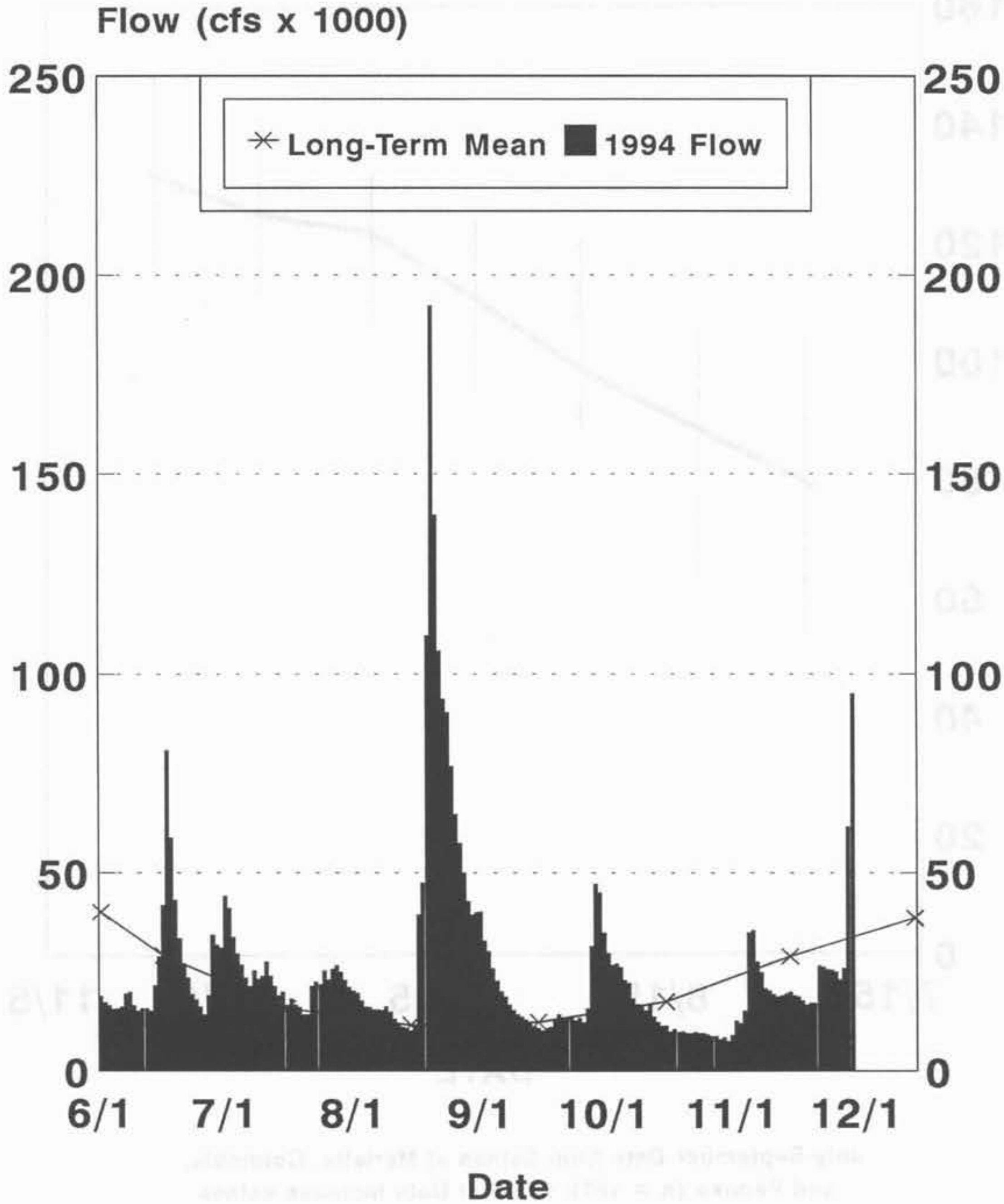
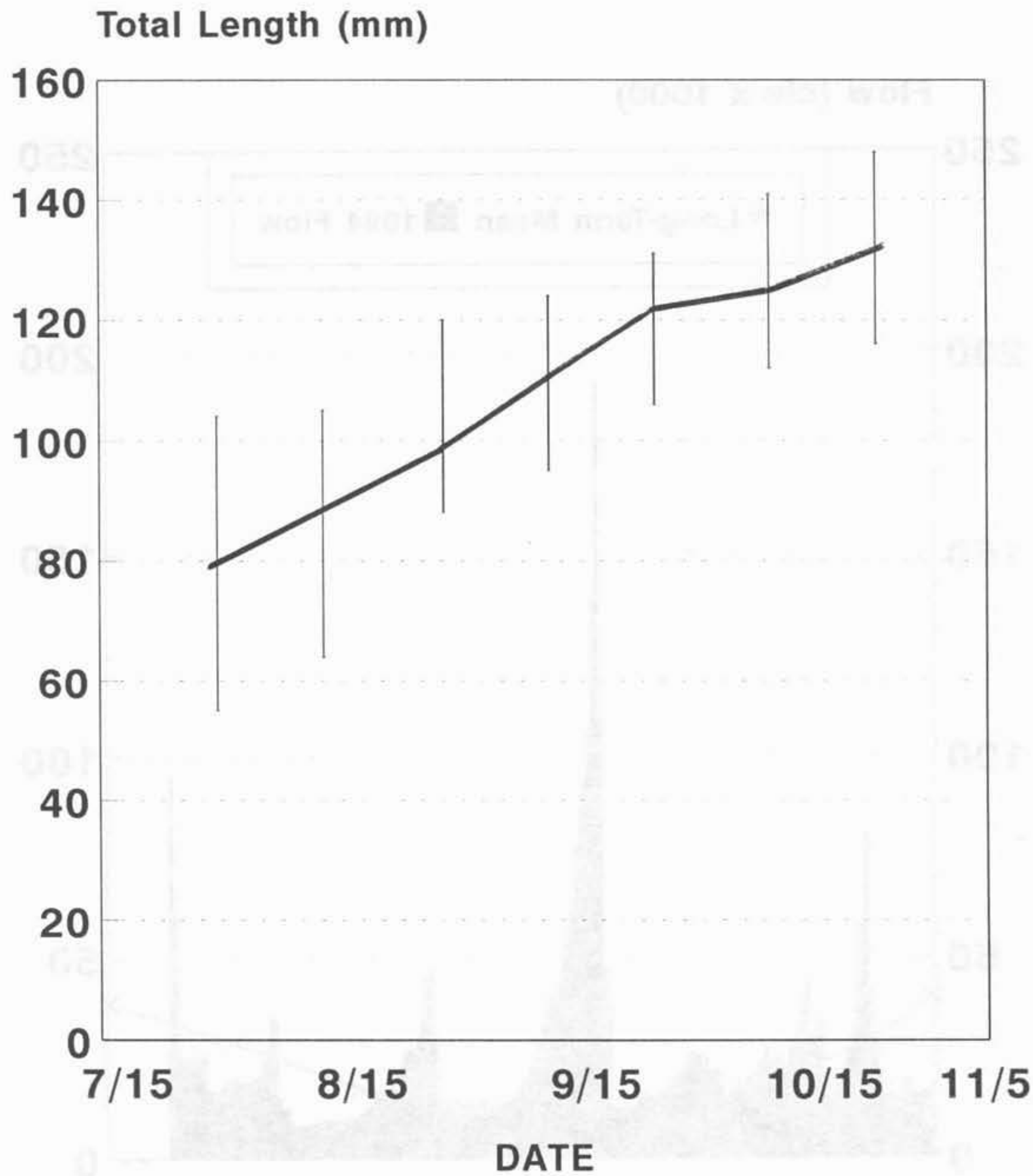


Figure. 3. Growth of Wild Juvenile Shad in the Susquehanna River in 1994.



July-September Data from Seines at Marietta, Columbia, and Pequea (n = 167); October Data includes seines at Columbia and Holtwood Lift Net (n = 27).

JOB V - TASK 1

ASSESSMENT OF DROPBACK OF ADULT AMERICAN SHAD USING THE CONOWINGO EAST FISH PASSAGE FACILITY

Prepared for:

Susquehanna River Anadromous Fish Restoration Committee

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JOB V. TASK I. ASSESSMENT OF DROPBACK OF ADULT AMERICAN SHAD USING THE CONOWINGO EAST FISH PASSAGE FACILITY

5.1 INTRODUCTION

The upstream Licensees (Pennsylvania Power & Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company), members of the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) expressed concern relative to the high rate of dropback of American shad (*Alosa sapidissima*) after release in the outer forebay during a preliminary study at Safe Harbor Hydroelectric Station in 1993. Although the sample size was small (N=46) data indicated that 36% of shad in the outer forebay dropped back (RMC 1993a). The potential impact of dropback on shad restoration efforts in the Susquehanna River prompted SRAFRC and Susquehanna Electric Company to contract with RMC Environmental Services (RMC) to examine dropback of shad that exit the Conowingo East Fish Passage Facility (East lift). A work plan was submitted (RMC 1993b). Following input and consensus of all committee members a revised study plan was developed to investigate this issue at Conowingo. The study objective was to examine turbine discharge effects on fallback under two 12 hour test conditions (Unit 11 on and Unit 11 off). Additionally, information on fallback was obtained during the 48 hour period following the start of each release.

5.2 METHODS AND MATERIALS

5.2.1 Handling, Tagging, and Transport

Migrating adult American shad were taken from the East lift and radio tagged. Fish were held overnight and tagged the next morning. Fish were tagged after capture by netting them from a holding tank and held immobile in a water filled tagging cooler with a piece of fine mesh netting to reduce stress. A transmitter was inserted orally through the esophagus into the stomach, its trailing whip antenna was left to run along the specimen's body from its mouth. Fish were sexed and placed into one of two water filled circular tubs, each 20" in diameter x 15.5" in height. Up to five shad were placed in each tub. The tubs were then lifted to the elevation of the trough using a two ton hoist. Fish were netted into the trough and held overnight.

Release groups consisted of 50 fish per release; 20 radio tagged and 30 untagged. Tagging, lifting, and release of shad into the trough was limited to 15 minutes to minimize effects of handling stress on specimens. On release days, the exit door in the trough was opened at 0700 hr to allow shad to swim freely into Conowingo Pond. The door was closed at 1900 hr the day of each release. Flows into and within the trough were maintained as if the East lift was being operated in an upstream passage mode. Floating debris was removed at least daily or on an as needed basis throughout the study period.

5.2.2 Radio Telemetry Equipment

5.2.2.1 Radio Transmitters

Pulsed radio transmitters supplied by Lotek Engineering Company Inc., were utilized for this study. Transmitters were 36 mm in length x 10 mm in diameter with a 290 mm flexible whip antenna. Transmitters propagated signals at a rate of 102 to 140 beats per minute on frequencies ranging from 148.006 to 148.645 MHz.

5.2.2.2 Radio Receivers

Lotek SRX_400 telemetry receivers installed with version 3.1x W18 or W9 software were utilized to monitor shad movement. Prior to release of fish, station noise floor levels were determined and receivers were configured to exclude background noise by utilizing specific features within the receiver's software. Receivers were set to scan each frequency for a specific time period, depending on location. When a signal was received, the scan program temporarily suspended and the validity of the signal was verified and logged or rejected. Data were stored in the SRX-400 as either a single event or a period of multiple events. If a fish was detected in and remained in the predetermined reception area for a period of up to five minutes or more, it was recorded as a continuous event. Single events or events occurring greater than five minute apart were recorded individually. Data stored for each event were: start date, start time, frequency, average pulse rate, average signal strength, interval standard deviation, number of events, number of suspect events, end date, and end time.

5.2.2.3 Receiver/Antenna Layout and Strategy

Three receivers were installed to monitor movement of radio tagged American shad exiting the trough and determine subsequent dropback of shad through the turbines (Figure 5.1). Receiver 20, connected to a 4-element Yagi antenna (Cushcraft model P150-4), monitored the west side of the tailrace (small units; discharge 5,000 cfs per unit) and was located at the West Fish Lift. Receiver 20's antenna was oriented slightly downriver due to its spatial orientation to the trough. Receiver 21, connected to a 4-element Yagi antenna, monitored the east side of the tailrace (large units; discharge 10,000 cfs per unit) and was located at the East lift. Receiver 21's antenna was positioned to encompass the discharge from the large units. Receiver 22, connected to a copper wire antenna, was located beside the trough. The copper wire antenna was suspended over the trough and the system continuously scanned tagged shad in the trough. The last time a shad was detected in the trough was considered the fish's exit time.

5.2.3 Release Scenarios

Four test releases were made during the peak of the shad run under pre-specified station discharges. As specified in the study plan, test releases one and three were made with turbine

Unit 11 on from 0700 to 1900 hours; water temperatures and river flows ranged from 15.7 to 16.1°C and 44,600 to 51,700 cfs, respectively. Releases two and four were made with turbine Unit 11 off from 0700 to 1900 hours; water temperatures and river flows ranged from 16.0 to 17.0°C and 50,400 to 59,000 cfs, respectively (Figure 5.2).

5.2.4 Data Retrieval

Data were off-loaded daily from the receivers with a portable computer and stored on 3½" diskettes. Backup diskettes of all data were made and stored in a fireproof vault. Organization and editing of files was accomplished using Statistical Analysis System (SAS v6.04) software. Data were critically analyzed to determine the validity of records. Those events deemed not credible due to suspect power level, deviation, or site/time relationship were discarded.

5.3 RESULTS AND DISCUSSION

Tagged shad were monitored for 48 hours starting at 0700 h during each of the four releases from the East lift between 4 and 14 May. This time period corresponded with an early season catch of 4,951 shad at the East lift (Figure 5.2).

A total of 80 shad was tagged. Forty-five shad exited the trough within the 12 hour time frame, 31 remained in the trough and the status of four (including a tag failure) was unknown (Table 5.1). Five tagged shad that exited the trough dropped back through the turbines within 12 hours. A total of 13 shad dropped back passing downstream in 48 hours.

A total of four shad dropped back within the 48 hour monitoring period during both releases when turbine Unit 11 was on (Table 5.1). Two shad that dropped back on 4 May passed during the 12 hour pre-arranged generation scenario (Table 5.2). The remaining two shad that exited the trough during the release on 9 May dropped back approximately 13.5 and 33.5 hours after the generation scenario was terminated at 1900 hours (Table 5.3). These shad were detected on the receiver which monitored dropback through the large units.

Nine shad dropped back within the 48 hour monitoring period during both releases when Unit 11 was off (Table 5.1). However, only three of nine shad dropped back during the two 12 hour periods when Unit 11 was off (Tables 5.4 and 5.5). Three of four shad dropped back on 6 May. These shad dropped back within five hours of exiting the trough. All shad (5) that left the trough on 11 May dropped back on 12 May within 21.3 to 31.5 hours after they exited the trough (Table 5.5). Seven of nine shad that passed through the turbines were detected on the receiver which monitored dropback through the large units. The other two dropped back through the small units during minimum flow.

Only 45 (56.2%) of the test fish exited the trough. Since the number of test fish was considerably smaller than expected, reliability of results is low. Based on a Fisher's Exact Test

(SAS v6.04) no statistical difference ($P > 0.05$) in dropback rates for the first 12 hour period between any of the four releases was detected. Additionally, no significant difference in dropback rates were evident based on the operational status of Unit 11 (on versus off).

In summary, 9% (2) and 13% (3) of the shad dropped back during pre-arranged station generation scenarios with Unit 11 on and off, respectively (Figure 5.3). Eleven of 13 shad dropped back between 0700 and 1900 hours and they passed through anyone of the large turbines at station discharges of 50,000 to 65,000 cfs. Five of the 11 shad dropped back when Unit 11 was off.

The 29% dropback rate observed in the 48 hour monitoring period was similar to that observed (36% and 30% to 44%) at Safe Harbor (RMC 1994). Although some dropback is expected it may be lower during routine operation of the East Lift because shad would not have to contend with the effects of stress imposed by handling, holding, and tagging. Tagged American shad are known to move downstream (Legget 1976).

In general, procedures established and protocols utilized were effective to monitor dropback of adult American shad that exited the East lift. Data were limited therefore applicability of the observed dropback rate may be questionable. If further study of dropback rate is warranted special effort should be expended to ensure telemetered fish are exposed to the same level of handling. In addition, it should incorporate procedures utilized in this study for collecting, tagging, transporting, and monitoring adult shad.

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Table 5.1

Summary of four releases of adult radio tagged American shad into the Conowingo East Fish Lift trough, spring 1994.

			Number of						
Release Group	Generation Scenario Tested	Release Date	Untagged shad placed in trough	Tagged shad placed in trough	Tagged shad remaining in trough after 12 h	Shad of unknown status after 12 h	Tagged shad that exited trough in 12 h	Number (%) tagged shad that dropped back in 12 h after exiting trough	Number (%) tagged shad that dropped back 48 h after exiting trough
I	Unit No. 11 on	4 May	30	20	7	3	10	2 (20)	2 (20)
II	Unit No. 11 off	6 May	30	20	8	0	12	3 (25)	4 (33)
III	Unit No. 11 on	9 May	30	20	8	0	12	0 (0)	2 (17)
IV	Unit No. 11 off	11 May	30	20	8	1	11	0 (0)	5 (45)
TOTAL			120	80	31	4	45	5 (11)	13 (29)

Table 5.2

Results of radio tagged adult American shad released 4 May (Group I) into the Conowingo East Fish Lift trough (Unit No. 11 on).

Frequency	Flume exit Date	Flume exit Time	Last located	Elapsed time until dropback
148.445			Trough	
148.455	4 May	1659	Upstream	
148.466	4 May	1028	Upstream	
148.477A	4 May	0757	Upstream	
148.477B	*			
148.486A	*			
148.506	4 May	0959	Upstream	
148.516			Trough	
148.525	4 May	1354	Upstream	
148.536	**			
148.546	4 May	1234	4 May 1757 East tailrace	5 h 23 min
148.557	4 May	0738	Upstream	
148.577			Trough	
148.586			Trough	
148.607			Trough	
148.615	4 May	1352	Upstream	
148.626	4 May	1545	Upstream	
148.636			Trough	
148.645			Trough	
148.486B	Exit time unknown		4 May 0716 East tailrace	Unknown

* No data.

** Radio tag failed; no data

Table 5.3

Results of radio tagged adult American shad released 9 May (Group III) into the Conowingo East Fish Lift trough (Unit No. 11 on).

Frequency	Flume exit Date	Time	Last located	Elapsed time until dropback
148.227			Trough	
148.237	9 May	1037	Upstream	
148.246			Trough	
148.256	9 May	0841	Upstream	
148.265	9 May	2001	Upstream	
148.274	9 May	0704	11 May 0433 East tailrace	1 d 21 h 29 min
148.286	9 May	1041	Upstream	
148.296			Trough	
148.307	9 May	0757	Upstream	
148.316			Trough	
148.327	9 May	1015	Upstream	
148.337	9 May	1022	10 May 0832 East tailrace	22 h 10 min
148.355			Trough	
148.367	9 May	1356	Upstream	
148.376	9 May	0831	Upstream	
148.387			Trough	
148.397			Trough	
148.406			Trough	
148.415	9 May	0758	Upstream	
148.426	9 May	1100	Upstream	

Table 5.4

Results of radio tagged adult American shad released 6 May (Group II) into the Conowingo East Fish Lift trough (Unit No. 11 off).

Frequency	Flume exit Date	Flume exit Time	Last located	Elapsed time until dropback
148.006	6 May	0833	Upstream	
148.017	6 May	0953	Upstream	
148.027			Trough	
148.036	6 May	0740	Upstream	
148.057	6 May	0740	6 May 1210 East tailrace	4 h 30 min
148.066	6 May	0732	Upstream	
148.077	6 May	0953	Upstream	
148.097	6 May	0818	Upstream	
148.107	6 May	1408	7 May 0444 East tailrace	14 h 36 min
148.117			Trough	
148.127	6 May	1050	6 May 1227 East tailrace	1 h 37 min
148.137	6 May	1720	Upstream	
148.146	6 May	1329	Upstream	
148.157	6 May	1051	6 May 1322 East tailrace	2 h 31 min
148.166			Trough	
148.177			Trough	
148.187			Trough	
148.196			Trough	
148.206			Trough	
148.217			Trough	

Table 5.5

Results of radio tagged adult American shad released 11 May (Group IV) into the Conowingo East Fish Lift trough (Unit No. 11 off).

Frequency	Flume exit Date	Time	Last located	Elapsed time until dropback
148.246	11 May	1003	Upstream	
148.257	11 May	1303	12 May 1021 East tailrace	21 h 18 min
148.265	11 May	0927	12 May 1702 West tailrace	1 d 7 h 35 min
148.276	11 May	0911	Upstream	
148.285	11 May	1041	Upstream	
148.296	11 May	0723	Upstream	
148.306	11 May	1048	12 May 1610 East tailrace	1 d 5 h 22 min
148.316			Trough	
148.326	11 May	1041	Upstream	
148.337	*			
148.347	11 May	1303	12 May 1732 East tailrace	1 d 4 h 29 min
148.356	11 May	1624	12 May 1706 West tailrace	1d 42 min
148.367			Trough	
148.377			Trough	
148.386			Trough	
148.396			Trough	
148.406			Trough	
148.416			Trough	
148.425			Trough	
148.435	11 May	0733	Upstream	

* No data.

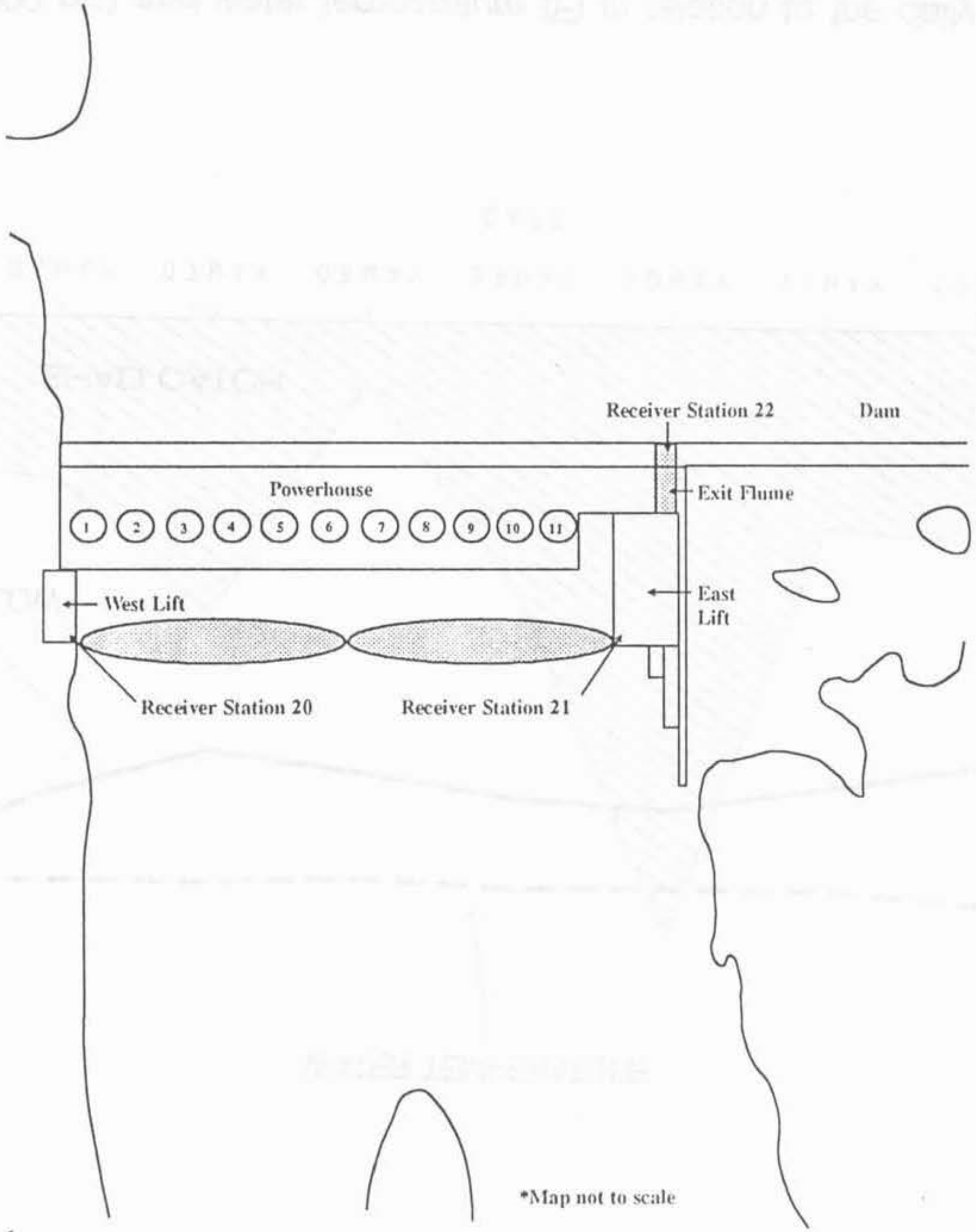

Figure 5.1

Trough release location and reception areas at Conowingo Hydroelectric Station, spring 1994.

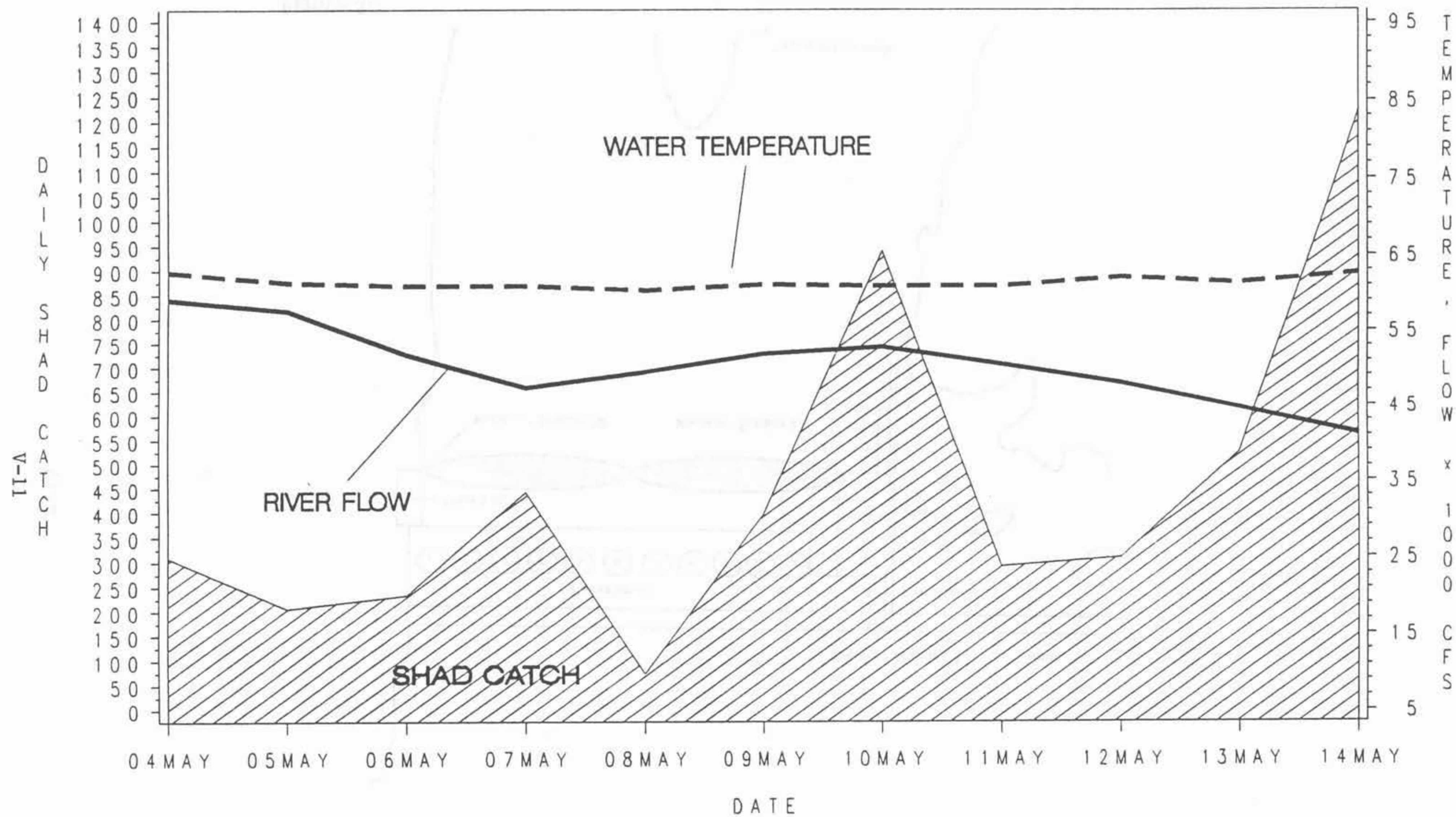

FIGURE 5.2

A plot of river flow (x 1000 cfs) and water temperature (F) in relation to the daily American shad catch at the Conowingo East Lift, May 4 to May 14 1994.

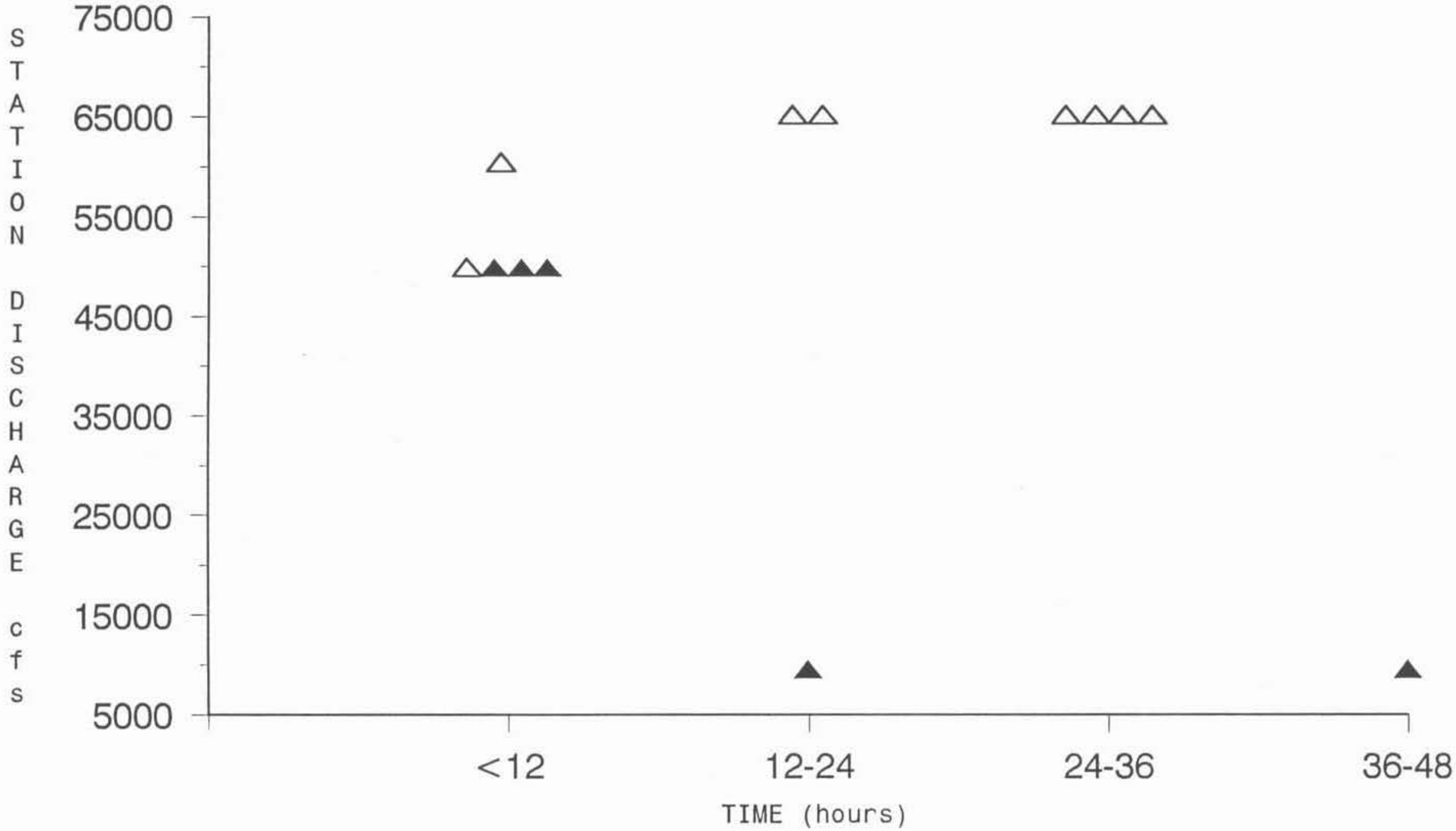

Figure 5.3

Number of shad entrained by time, station discharge, and operational status of turbine Unit 11 (on △ and off ▲) for four releases into the Conowingo East Fish Lift trough, spring 1994.

Job V., Task 2. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1994

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Abstract

A total of 322 adult American shad were sacrificed for otolith analysis at the Conowingo Dam fish lifts in 1994. Based on tetracycline marking and otolith microstructure, 10% of the 287 readable otoliths were identified as wild and 90% hatchery. Ninety-three percent of the otoliths with hatchery microstructure also exhibited tetracycline marks. Estimates of hatchery contribution to the population of adults entering the lifts ranged from 67% in 1990 to 89% in 1994.

Wild fish represented a significantly higher proportion of the catch in samples collected in Upper Chesapeake Bay pound nets (44%) than that found in Conowingo Fish Lift collections (10%).

During 1989-1992, double marked fish (releases below Conowingo Dam) represented only 5% of the marked fish in the Conowingo Lift samples. In 1993, double marked fish represented 21% of the marked fish in the Conowingo Lift samples and 25% of the marked fish in the pound net samples. In 1994, double marked fish represented 9% of the marked fish in the Conowingo Lift samples and 54% of the marked fish in the pound net samples.

Introduction

Efforts to restore American shad to the Susquehanna River have been conducted by the Susquehanna River Anadromous Fish Restoration Committee (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.

Tetracycline mark retention to adulthood has not been determined due to our inability to rear American shad to adulthood. In addition, since mark retention did not approach 100% until 1987, adult hatchery shad over the age of seven may not exhibit marks. Marking rates can therefore be used only to determine minimum contribution of hatchery-reared fish.

In Spring 1987, it was observed that otoliths of "wild" Susquehanna River juvenile American shad (as determined by the absence of a tetracycline mark) appeared to have different microstructural characteristics than hatchery-reared shad. Specifically, the increments formed during the first 20 days appeared to be wider and more distinct in wild juveniles than in hatchery-reared fish. In addition, hatchery-reared fish exhibited an increase in increment width and definition somewhere around increment 20-25, possibly as a result of increased growth rate after stocking. Hendricks, et al. (1994) developed a method to distinguish between wild and hatchery-reared American shad based solely on otolith microstructure. This report represents a continuation of that work, focusing on evaluation of otoliths from adult American shad collected in 1994.

Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 100th shad to enter each lift. Each sampled fish was sexed, measured and the otoliths were extracted on site by RMC personnel.

Adult American shad collected in pound nets at Cara Cove and Cherry Tree (Upper Chesapeake Bay) were also sacrificed for otolith analysis. Net mortalities and weak looking fish were used for this analysis.

Otoliths (sagittae) were delivered to Benner Spring, mounted on microscope slides and ground on both sides to produce a thin sagittal section. Under white light, each otolith specimen was classified hatchery or wild based upon subjective visual microstructural characteristics. The classifications were done by two experienced researchers. If visual microstructural classification was questionable, increment measurements were performed using a Biosonics Optical Pattern Recognition System (OPRS). Hendricks et al. (1994) found that increments 6-13 constituted a homogeneous set with a mean width of 2.99 microns for hatchery-reared fish and 5.97 microns for wild fish. A cutoff point was established at 3.86 microns, 1.02 standard deviations from both means. Otoliths with mean increment widths (increments 6-13) of less than 3.86 were classified hatchery while those with mean increment widths of more than 3.86 were classified wild. If the visual and width classifications disagreed, characteristics were discussed to attempt to reach consensus. If consensus was not reached, the otolith was classified as "microstructure unknown."

After microstructure classification, the white light was turned off and the specimen examined under UV light for the presence of a tetracycline mark.

It was possible to estimate hatchery and wild contributions to the population of adult shad entering the lifts by applying a correction factor based on the error rates achieved in blind classification trials (Hendricks et al., 1994):

$$P_w=100\ (n_w - n_w E_h + n_h E_w)\ /T$$

$$\text{and } P_h=100\ (n_h - n_h E_w + n_w E_h)\ /T$$

where P_w was the percentage of the population estimated as wild, P_h equals the percentage of the unmarked population estimated as hatchery, n_w equals the number of specimens in the sample classified as wild, n_h equals the number of specimens in the sample classified as hatchery which did not exhibit a tetracycline mark, E_w and E_h equal the proportions of wild and hatchery fish which were misclassified in the blind trials, and T equals the total number of specimens classified in the sample.

The blind trials (Hendricks et al., 1994), included a group of Delaware River fish for comparison. If we exclude Delaware River fish, which would not be expected to enter the trap, a total of 2.4% of the hatchery fish were classified incorrectly (E_h = 0.0240) while 17.7% of the wild fish were classified incorrectly. If we include the 1.3% of the wild fish on which we disagreed, the error rate for wild fish is 19.0% (E_w =0.190).

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

Results and Discussion

A total of 322 shad was sacrificed from the lift catch at Conowingo Dam in 1994. For 35 of those, otoliths were broken, not extracted, or had unreadable grinds, leaving 287 readable otoliths (Table 1). A total of 28 (10%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 90% of the specimens were identified as hatchery in origin. Seventeen otoliths (6%) had hatchery microstructure and no tetracycline mark. Two-hundred and forty-two otoliths (84%) exhibited tetracycline marks including single, double, triple and quadruple immersion marks. Three specimens (1%) exhibited feed marks, applied as pond-reared fingerlings. One of the specimens exhibited a triple immersion mark (days 5, 9, 13) and single feed mark indicative of Canal Pond culture. The two other feed marked specimens exhibited triple immersion marks (days 3, 13, 17) and a single feed mark indicative of culture in Upper Spring Creek Pond 1.

Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. Estimates of hatchery contribution to the adult population entering the Conowingo Dam fish lifts during 1989-1994 ranged from 67% to 89% (Table 2, Figure 1). The percentage of fish with hatchery microstructure which also exhibited tetracycline marks was 28% in 1989, 54% in 1990, 66% in 1991, 90% in 1992, 97% in 1993, and 93% in 1994. All unmarked fish with hatchery microstructure collected in 1994 exhibited autofluorescence which may have obscured the TC mark.

Random samples of adult American shad collected at the Conowingo Dam Fish Lifts have been sacrificed for otolith analysis since 1989. The contribution of wild fish to this population is surprisingly low, considering the closure of the Maryland shad fishery since 1980. Analysis of otoliths of adult American shad collected in Upper Chesapeake Bay pound nets during 1993 and 1994 (Table 1) suggests that the pound nets and fish lifts are sampling different populations. Wild fish constituted 52% of the pound net catch in 1993 and 44% of the pound net catch in 1994. The lift catch included only 17% wild fish in 1993 and only 10 % wild fish in 1994 (Table 1). Based on a Chi-square Test of Independence, we concluded that the proportion of wild and hatchery fish was <u>dependent</u> upon the collection site (Chi-square = 43.7, df =1) and therefore the populations at those two sites have different constituencies. Similar results were obtained in 1993. 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.

Another surprising feature of the results prior to 1993, was the low return of hatchery fish released below Conowingo Dam (double tetracycline mark). In 1993 and 1994, recovery of double marked shad improved dramatically. In 1993, twenty double marked fish were recovered in the Lift sample, representing 16% of the total and 21% of the marked fish. Three double marked fish were recovered in the pound net samples representing 6% of the total and 25% of the marked fish. In 1994, twenty-two double marked fish were recovered in the Lift sample, representing 8% of the total and 11% of the marked fish (Table 1). Fourteen double marked fish were recovered in the pound net samples representing 24% of the total and 54% of the marked fish.

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Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1994.

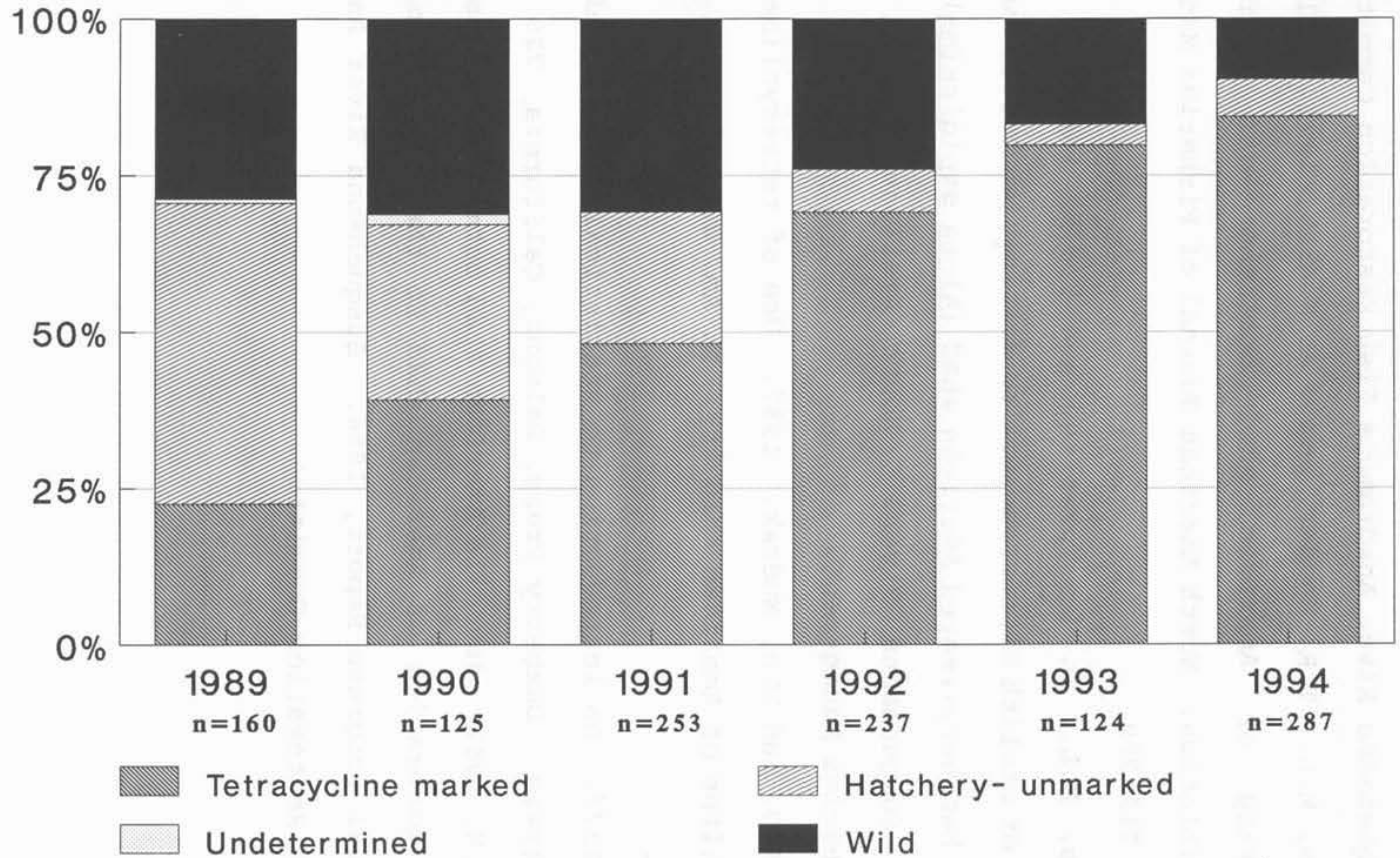

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts and Susquehanna Flats pound nets, 1994. One of every 100 fish collected in each lift was sacrificed.

			Conowingo Dam		Susq. Flats	
			N	%	N	%
Wild Microstructure, No TC Mark			28	10%	26	44%
Hatchery Microstructure	No TC Mark*		17	6%	7	12%
	Single TC Mark	Day 5	19	7%	1	2%
		Day 18 or 19	3	1%	1	2%
	Double TC Mark	Days 5,9	22	8%	14	24%
	Triple TC Mark	Days 5,9,13	155	54%	9	15%
		Days 3,13,17	26	9%	0	0%
	Quadruple TC Mark	Days 5,9,13,17	14	5%	1	2%
	Feed Marks	Days 5,9,13 + single feed mark	1	0%	0	0%
		Days 3,13,17 + single feed mark	2	1%	0	0%
		Total Hatchery	259	90%	33	56%
		Total readable otoliths	287		59	
		Unreadable Otoliths**	35		14	
		Total	322		73	

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

Table 2. Composition of the catch of adult American shad at Conowingo dam fish lifts, based on microstructure classification and tetracycline marking, 1989–1994. Estimates of population proportions were derived from sample classifications corrected based on error rates from a blind classification trial.

	1989			1990			1991			1992			1993			1994		
	Sample n		Population	Sample n		Population	Sample n		Population	Sample n		Population	Sample n		Population	Sample n		Population
Wild Microstructure:	29	18%	29%	32	26%	31%	68	27%	31%	54	23%	24%	21	17%	17%	28	10%	11%
Microstructure unknown	1	1%	1%	2	2%	2%	0	0%	0%	0	0%	0%	0	0%	0%	0	0%	0%
Hatchery Microstructure No Tetracycline mark:	94	59%	48%	42	34%	28%	63	25%	21%	19	8%	7%	4	3%	3%	17	6%	5%
Tetracycline marked	36	23%	23%	49	39%	39%	122	48%	48%	164	69%	69%	99	80%	80%	242	84%	84%
Total Hatchery	130	81%	71%	91	73%	67%	185	73%	69%	183	77%	76%	103	83%	83%	259	90%	89%
Total	160			125			253			237			124			287		

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 has been closed to sport and commercial fishing since 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 concerning this stock. The adult sampling is followed by a juvenile recruitment survey designed to assess reproductive success. The information obtained through these activities is provided to SRAFRC to aid in restoration of American shad to the Susquehanna River.

Methods and Materials

Collection procedures for adult American shad in 1994 were identical to those in 1993. Two commercial pound nets were sampled, one at Cherry Tree Point and the other at Cara Cove (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.

Juvenile production in 1994 was again monitored by project personnel with the Smith-Root electrofisher. The Susquehanna Flats shoreline area was gridded off into 21 separate cells approximately 2,000 feet long (Figure 2). Based on juvenile American shad abundance over the previous five years, mean catch-per-unit-effort (CPUE) for each of these 21 cells was calculated and each cell was assigned to either a high or low density strata. Each strata was then weighted and, based on the method of optimal allocation, six high density and three low density cells were randomly selected and sampled weekly. Sampling results from the Department's Juvenile Seine Survey were also utilized in analysis of the reproductive success of American shad in the upper Bay during 1994.

Results

Pound net tagging for 1994 began on 4 April and continued until 19 May, while hook and line effort commenced on 26 April and ended 9 June. Of the 844 adult American shad captured, 639 (75.7%) were tagged and 153 (18.1%) subsequently recaptured (Table 1). Of these 153 recaptures, one occurred outside the upper Bay system in the Delaware River. The 153 total also does not reflect the 39 multiple recaptures, two unverifiable tag numbers, and two fish tagged prior to 1994 collected by RMC from the two fish lifts. Recapture data for the 1994 season is summarized as follows:

a. 153 fish recaptured by the Conowingo Fish Lifts (does not include 39 multiple recaptures, 2 pre-1994 tagged fish, and 2 fish with unverifiable tag numbers)

0 fish recaptured by pound net

0 fish recaptured by hook and line from the tailrace

1 fish recaptured outside the system

b. 144 fish recaptured originally caught by hook and line

9 fish recaptured originally caught by pound net

c. 144 fish recaptured in the same area as initially tagged

9 fish recaptured upstream of their initial tagging site (includes 1 recapture from the Delaware River)

0 fish recaptured downstream of its initial tagging site

d. shortest period at large: 1 day

longest period at large: 37 days (1994 fish only)

mean number days at large: 11.2

e. number of pre-1994 tagged fish recaptured: 2

number of pre-1994 multiple recaptures: 2

The 1994 adult American shad Petersen population estimate for the upper Chesapeake Bay was 129,482 (Table 2), and has been increasing exponentially since 1980 (r^2=0.75, $P \leq 0.0003$). Since one recapture occurred outside the upper Bay system, an emigration factor was calculated in order to adjust the number of fish marked (M) in the Petersen statistic, but lost and unavailable for later recapture. The Conowingo tailrace population estimate was 94,770 (Table 3), and has also been increasing exponentially since 1984 (r^2=0.77, $P \leq 0.0004$).

Effort, catch, and catch-per-unit-effort (CPUE) by gear type for adult American shad in the upper Bay during 1994 and comparison with previous years is presented in Table 4. Pound net and hook and line CPUE increased in 1994; however, no significant linear trends over time were evident (Pound net: r^2=0.11, $P \leq 0.29$; Hook and line: r^2=0.31, $P \leq 0.12$).

A total of 727 adult American shad (303 pound net, 424 hook and line) were examined for physical characteristics by DNR biologists in 1994 (Table 5). The 1989 year-class (age 5, sexes combined) was the most abundant year-class sampled in the upper Bay by pound net and hook and line, accounting for 44.2% and 48.4%, respectively, of the total catch (Table 5). Age frequency modes for males and females occurred at age 5 for both pound net and hook and line catches. Both sexes (gears combined) were present in age groups 4-7; there were no age 3 females and only one age 8 male. Males were more abundant at ages 3-5, and females were more abundant at ages 6-7. The overall incidence of repeat spawning in male American shad decreased from 14.4% in 1993 to 12.1% in 1994. Similarly, female American shad repeat spawning decreased from 26.1% in 1993 to 12.8% in 1994.

Juvenile *Alosa* sampling in the upper Bay during 1994 again produced large numbers of American shad. A total of 36 juvenile American shad were collected by electrofisher in 1994. Supplemental haul seine sampling by the Department's Juvenile Seine Survey in 1994 captured another 21 juvenile American shad. Table 6 provides a breakdown by cell and date of the juvenile American shad collected by electrofishing from the upper Chesapeake Bay during 1994.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, April-June 1994.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	320	183
	Cara Cove	26	14
	Total	346	197
Hook and Line	Conowingo Tailrace Susquehanna River	498	442
Fish Lift	Conowingo Tailrace Susquehanna River	32,330	
	TOTALS	33,174	639

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1994 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1994 survey -

C = 33,072
R = 152
M = 598*

Therefore -

$$N = \frac{(33,072 + 1)\ (598 + 1)}{(152 + 1)}$$

= **129,482**

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

Using Chapman (1951):

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

where: R^t = tabular value (Ricker p343)

$$\text{Upper } N^* = \frac{(33,072 + 1)\ (598 + 1)}{129.68 + 1} = 151,597$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(33,072 + 1)\ (598 + 1)}{178.16 + 1} = 110,576$$ @ .95 confidence limits

* M adjusted for emigration and 3% tag loss

Table 3. Population estimate of adult American shad in the Conowingo tailrace during 1994 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1994 survey -

C = 31,736
R = 143
M = 429*

Therefore -

$$N = \frac{(31,736 + 1)\ (429 + 1)}{(143 + 1)}$$

$$= \mathbf{94,770}$$

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

Using Chapman (1951):

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

where: R^{t} = tabular value (Ricker p343)

$$\text{Upper } N^* = \frac{(31,736 + 1)\ (429 + 1)}{168.44 + 1} = 80,541$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(31,736 + 1)\ (429 + 1)}{121.40 + 1} = 111,494$$ @ .95 confidence limits

* M adjusted 3% tag loss

Table 4. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad by pound net and hook and line during the 1980-1994 tagging program in the upper Chesapeake Bay.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POPLN. EST.
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 Tree	41	75	1.83	
	Romney Creek	41	8	0.20	
	1988 Total	115	170	1.48	38,386
1989	Rocky Pt.	32	91	2.84	
	Cherry Tree	62	295	4.76	
	Beaver Dam	11	14	1.27	
	1989 Total	105	400	3.81	75,820
1990	Rocky Pt.	38	221	5.82	
	Cherry Tree	71	178	2.50	
	1990 Total	109	399	3.66	123,830
1991	Rocky Pt.	38	251	6.61	
	Cherry Tree	56	594	10.61	
	Bohemia River	54	209	3.87	
	1991 Total	148	1054	7.12	141,049
1992	Cherry Tree	56	147	2.63	
	Bohemia River	47	43	0.87	
	1992 Total	103	190	1.80	105,255
1993	Cherry Tree	48	255	5.31	
	Cara Cove	45	26	0.58	
	1993 Total	93	281	3.02	47,563
1994	Cherry Tree	48	320	6.67	
	Cara Cove	46	26	0.57	
	1994 Total	94	346	3.68	129,482

Table 4, continued.

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPAH*	CPUE HTC**	POPLN. EST.
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	141,049
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

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

Table 5. Catch (N), age composition (%), number and percent of repeat spawners, and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1994 upper Chesapeake Bay spring tagging operation.

	MALE				FEMALE			
AGE GROUP	N(%)	RPTS.	MEAN	RANGE	N(%)	RPTS.	MEAN	RANGE
Pound Net								
III	22(7)	0	348	305-380	0	0	-	-
IV	63(21)	1	383	345-410	21(7)	2	410	350-440
V	66(22)	16	416	380-470	68(22)	5	437	390-490
VI	14(5)	6	444	425-470	35(12)	5	469	435-505
VII	1	0	505	-	12(4)	5	490	440-545
VIII	1	0	540	-	0	0	-	-
% Repeat Spawners		13.8				12.5		
Hook and Line								
III	15(4)	0	354	333-375	0	0	-	-
IV	120(28)	3	381	340-410	22(5)	0	412	388-433
V	122(29)	23	405	318-456	83(19)	11	430	390-465
VI	13(3)	4	454	435-483	41(10)	6	471	418-510
VII	0	0	-	-	8(2)	3	475	435-495
% Repeat Spawners		11.1				13.0		
All gears combined								
III	37(5)	0	351	305-380	0	0	-	-
IV	183(25)	4	381	340-410	43(6)	2	411	350-440
V	188(26)	39	409	318-470	151(21)	16	433	390-490
VI	27(4)	10	449	425-483	76(10)	11	470	418-510
VII	1	0	505	-	20(3)	8	484	435-545
VIII	1	0	540	-	0	0	-	-
% Repeat Spawners		12.1				12.8		

Table 6. Juvenile American shad captured by date and cell and associated catch-per-unit-effort (American shad caught per shock hour) during the 1994 upper Chesapeake Bay electrofishing survey. No sampling at a particular date and cell is represented by a blank space.

CELL	AUGUST					SEPTEMBER				OCTOBER				NOV		SHOCK	
NO.	4	10	17	24	30	7	14	21	28	5	11	19	26	3	CATCH	TIME (SEC)	CPUE
1		X			X	X	X			X	X	X	X	X	0	4500	0.0
2	3	1		X		3	X		1			X		X	8	4000	7.2
3	X	1		X	X	X		X		X	X		X		1	4500	0.8
4				X				X	X			X	X		0	2500	0.0
5				X	X							X			0	1500	0.0
6		X					X	X							0	1500	0.0
7	X								2	X	X				2	2000	3.6
8											X			X	0	1000	0.0
9	X			X	X			X	X	X	X		X	X	0	4500	0.0
10				X		X				X					0	1500	0.0
11		X					X						X		0	1500	0.0
12	X			X			X	1	X	X	1	X	X	X	2	5000	1.4
13	X													X	1	1500	2.4
14					X								X	X	0	1500	0.0
15								X		X					0	1500	0.0
16		X	X			X		X	X	X	X		X	X	0	4500	0.0
17						X					X	X			0	1500	0.0
18		X				2	X								2	1500	4.8
19			X	X	X	3	X	1	X	2	X	3	3		12	4500	9.6
20		3		X	1		X	X				1		X	5	3000	6.0
21		2	X		X	1	X		X			X			3	3500	3.1
TOT	3	7	0	0	1	9	0	2	4	2	1	4	3	0	**36**	57000	2.27

Figure 1. Gear and locations utilized in capturing adult American shad in the upper Chesapeake Bay in 1994.

Capture Locations:

■ Hook and Line
● Pound Net

1. Cara Cove
2. Cherry Tree

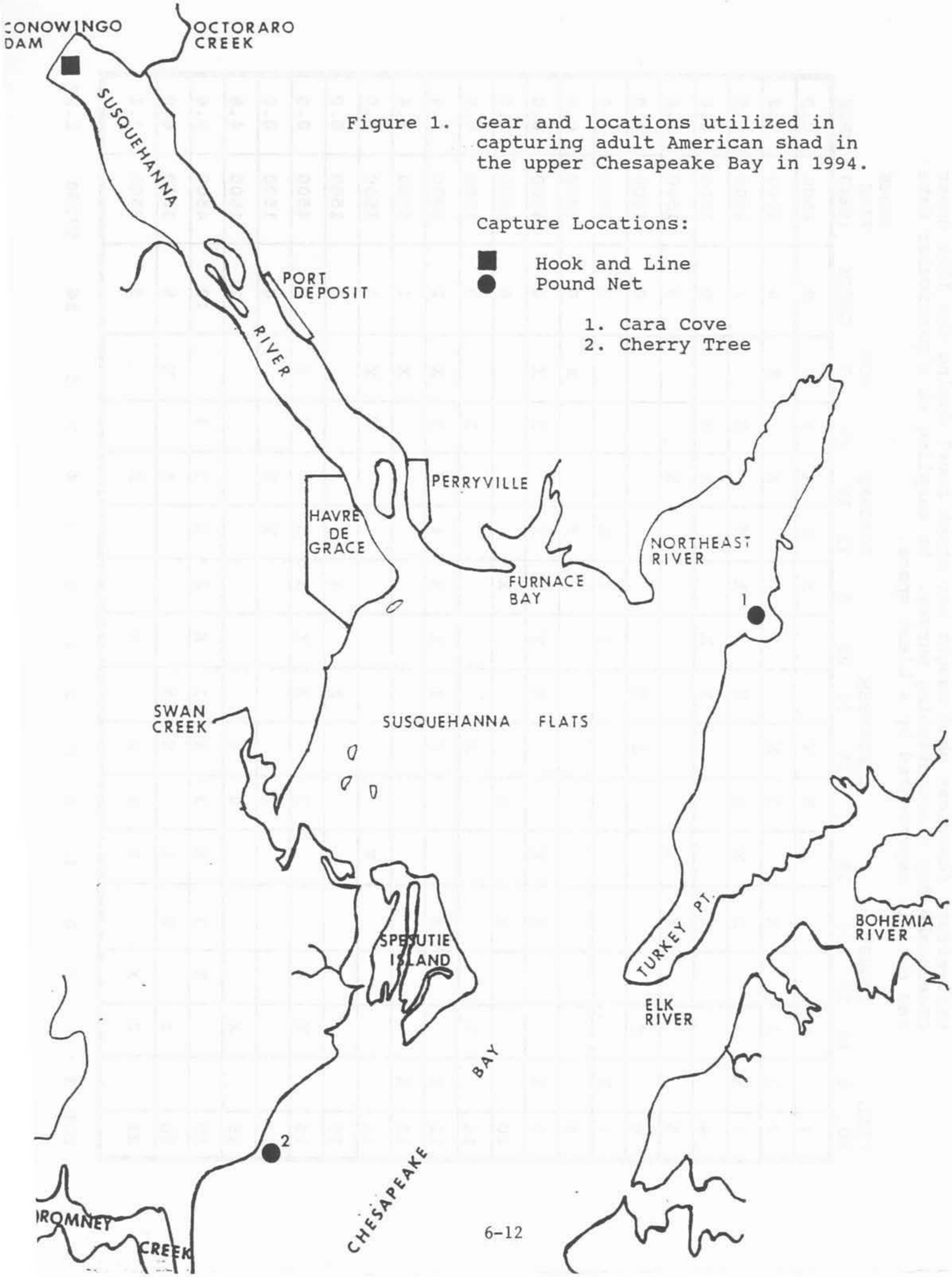


Figure 2. Upper Chesapeake Bay electrofishing cells sampled during the 1994 juvenile *Alosa* survey.

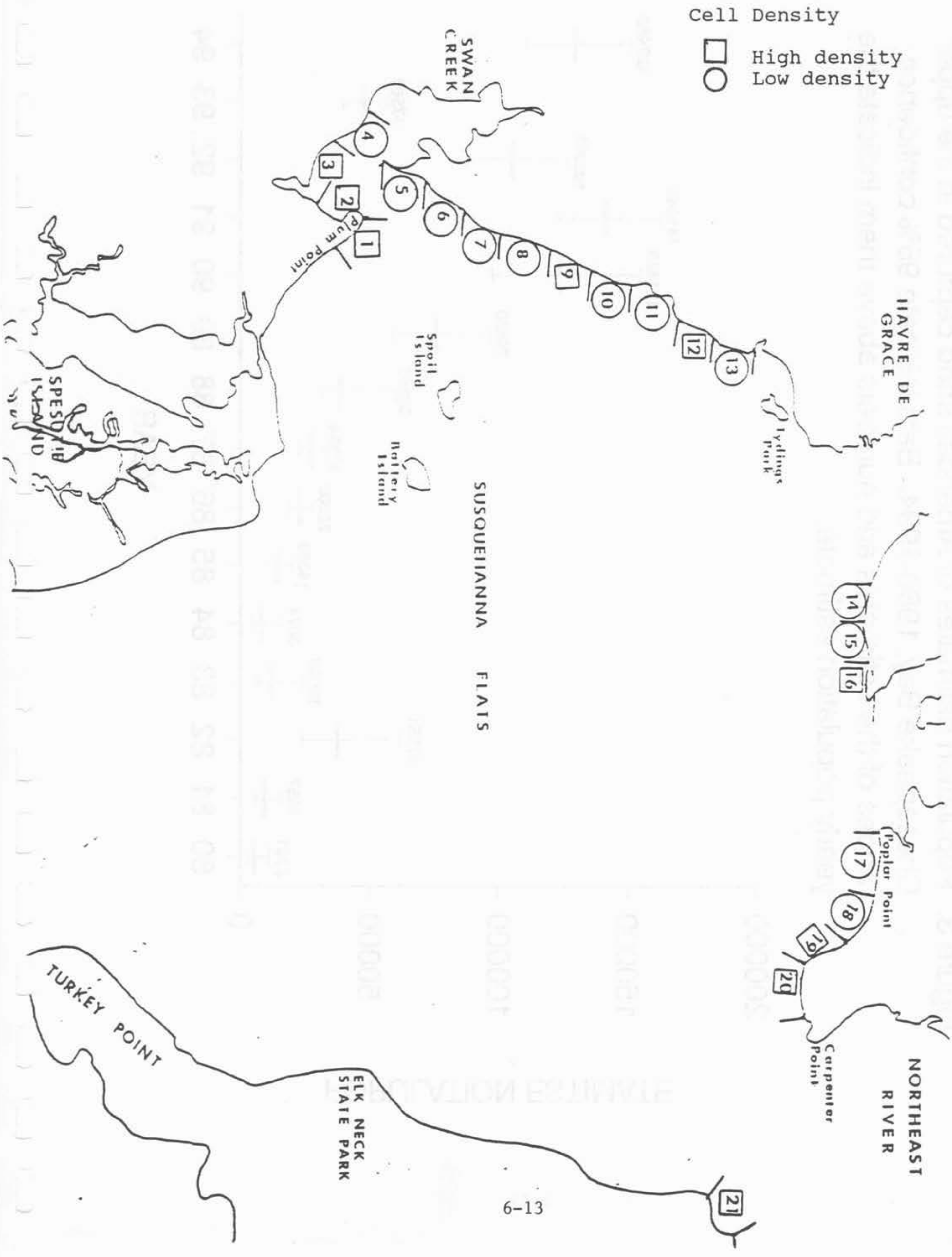


Figure 3. Population estimates of American shad captured in the upper Chesapeake Bay, 1980-1994. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.

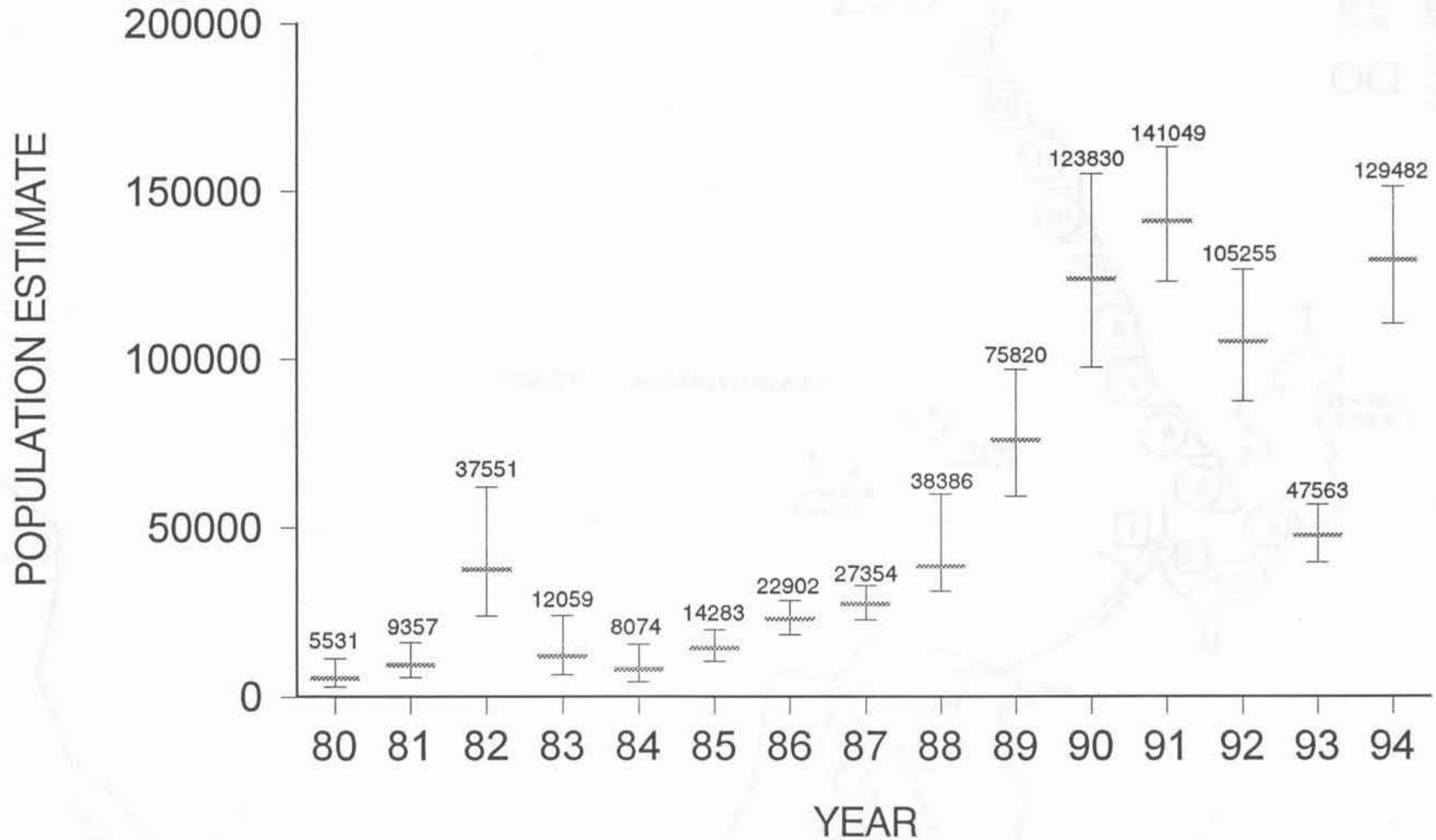
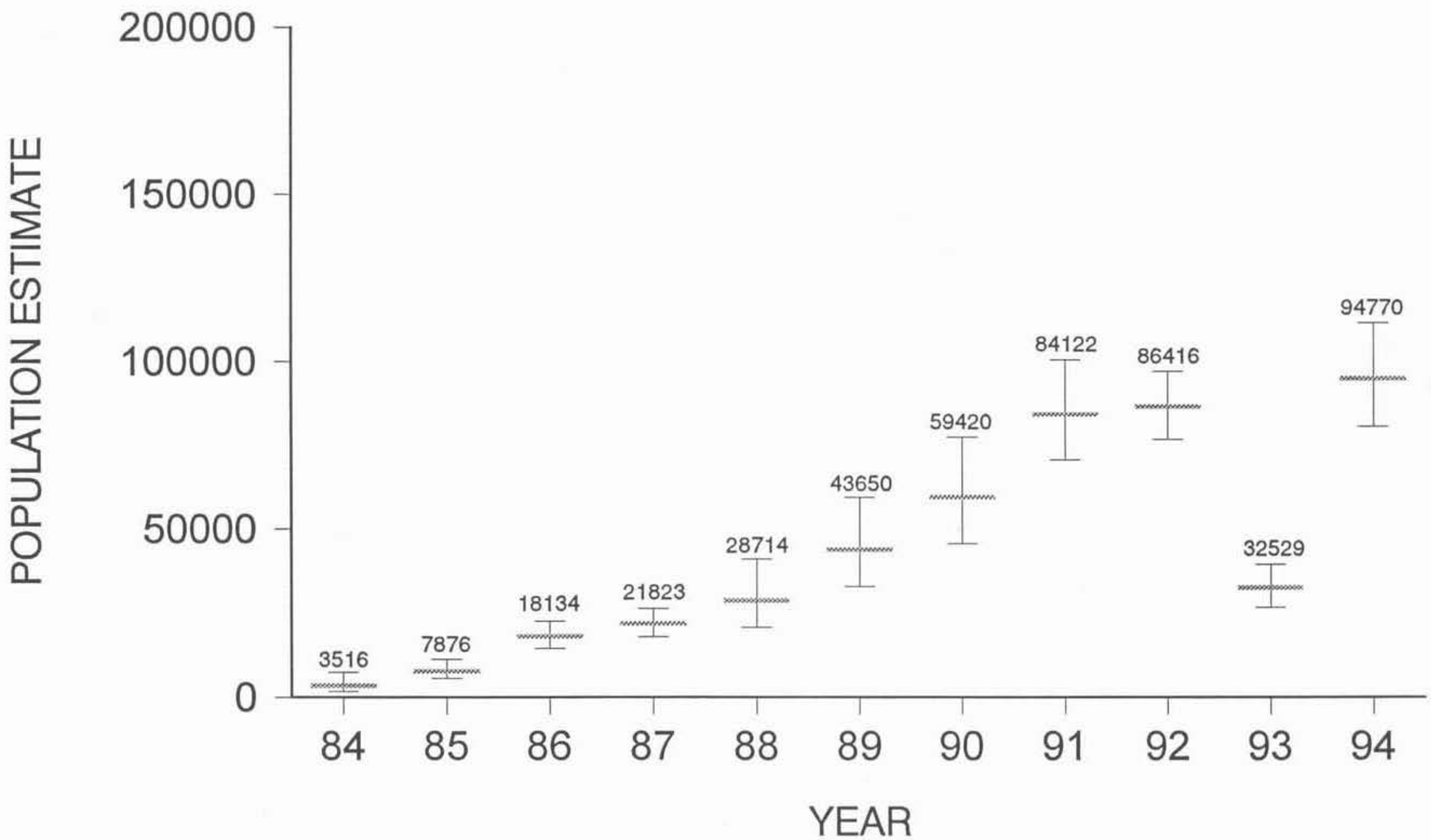


Figure 4. Population estimates of American shad captured in the Conowingo Dam tailrace, 1984-1994. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.



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