Restoration of American Shad to the Susquehanna River

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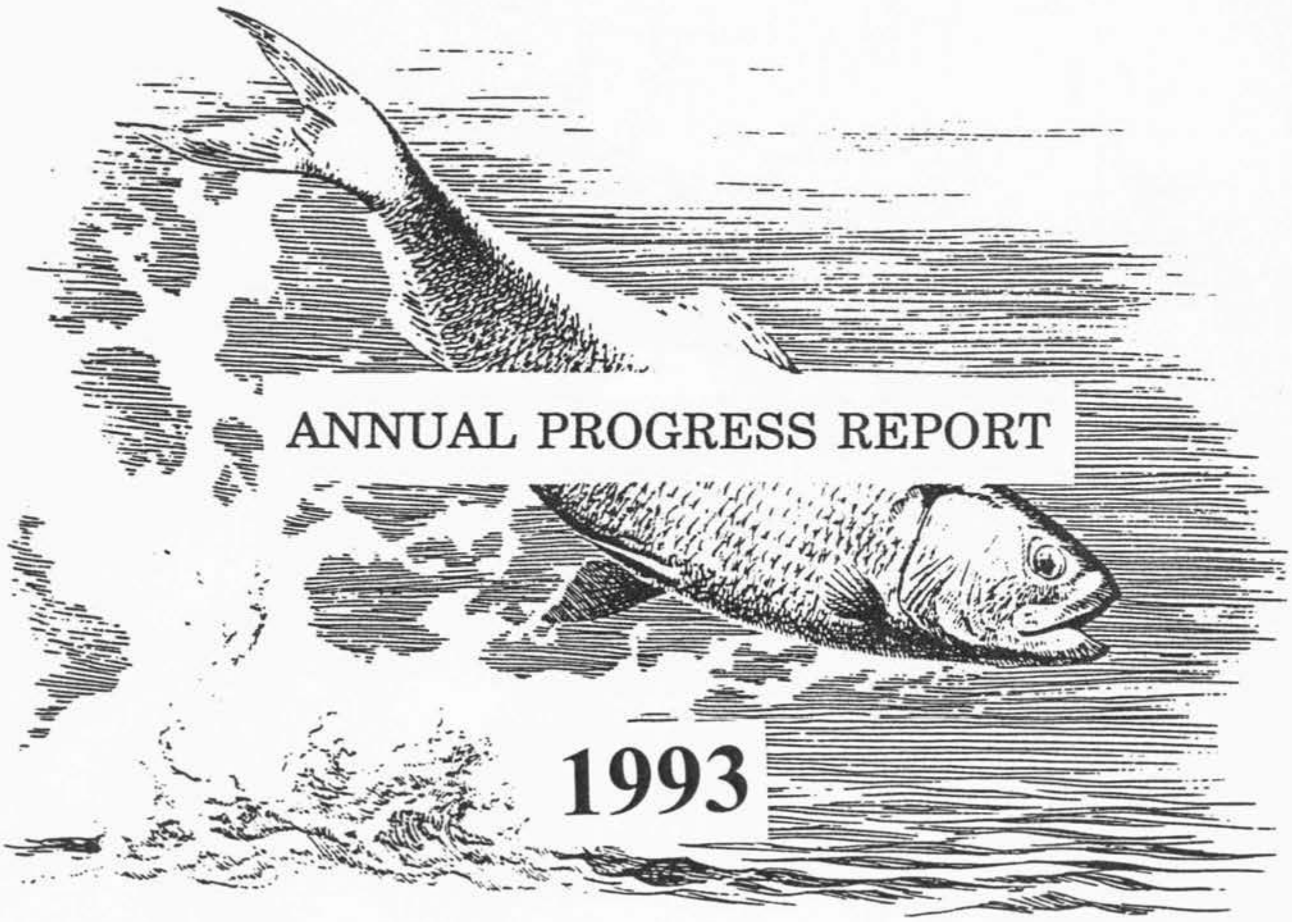
RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



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 AND LIGHT COMPANY
SAFE HARBOR WATER POWER CORPORATION
SUSQUEHANNA RIVER BASIN COMMISSION
PHILADELPHIA ELECTRIC COMPANY
YORK HAVEN POWER COMPANY

FEBRUARY 1994

EXECUTIVE SUMMARY

The 1993 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 ninth year of a 10-year program 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. Considerable efforts this year were dedicated to evaluating juvenile shad passage at several hydroelectric dams and assessment of downstream migration from the river. 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 1993 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 47,563 fish (Petersen Index). This was based on recapture of 117 shad from a tagged population of 400 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 1993 was 55% less than in 1992 and continued a 2-year decline from 1991's record estimate of 141,000. The apparently reduced stock is partially explained by record river flows in April which delayed trap operation start-up by one month. However, most shad stocks along the Atlantic Coast experienced similar declines in 1993, perhaps related to unusual climatological events.

Several improvements were made to trap and transfer operations in 1993 including development of new holding facilities at the East lift. Both fish lifts at Conowingo Dam began operations on 4 May and continued daily through mid-June. A total of 1.243 million fish representing 37 taxa was handled, down from almost 4 million fish in 1992. Gizzard shad comprised 94% of the total catch. Alosa species included 13,546 American shad, 8,626 blueback herring, and 572 alewives. No hickory shad were taken.

American shad catch in 1993 was 12,175 (47%) fewer than in 1992. Blueback and alewife numbers were down 75% and 84%, respectively, and the last year in which hickory shad failed to appear was in 1979. The West lift accounted for 5,343 American shad, 4,052 bluebacks, and all alewives. The East lift took 8,203 American shad and 4,574 bluebacks. Catch per fishing hour for American shad at both lifts was 16.2, slightly lower than the 20.8 recorded in 1992.

Overall sex ratio of shad in lift collections was 1.3 to 1 favoring males. Males ranged in age from III to VI (86% @ IV-V), and females were IV to VII (87% @ V-VI). Based on scale analysis of 230 shad, 26 (11.3%) were repeat spawners of which 4 fish had two spawning checks.

Otoliths were successfully examined from 124 adult shad sacrificed at the fish lifts. Of these, 21 (17%) showed wild microstructure and no tetracycline tags. All remaining samples had hatchery microstructure and 99 of 103 also exhibited TC marks including single, double, triple, and quadruple immersion treatments. Two otoliths displayed feed tags. Since 1989, the corrected hatchery component of the return population at Conowingo has ranged from 67% to 1993's high of 83%. Frequency of unmarked otoliths with hatchery microstructure has declined, as expected, from 48% to 4%. A second otolith sample from 48 shad taken in pound nets in the Upper Chesapeake Bay were 52% wild and 48% hatchery, indicating that a substantial portion of the shad population in the upper Bay are probably not imprinted to return to the Susquehanna River to spawn.

A total of 11,171 American shad was transported to potential upstream spawning areas with less than 6% observed transport mortality. Most shad were stocked at the Tri-County Boat Club above York Haven Dam, with smaller numbers being released at Swatara Creek and Columbia. A total of 1,333 river herring was stocked at Middletown and 2,302 were provided to Maryland DNR for release into the Patapsco River which is undergoing restoration.

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 10 May to 15 June, 19.72 million shad eggs were delivered to Van Dyke from the Delaware River (9.30 M), the Hudson River (2.97 M), and the Connecticut River (7.45 M). Overall viability of these eggs was 61%, and production for the Susquehanna amounted to 6.54 million fry and 79,400 fingerlings. Additionally, Van Dyke reared 538,800 Pamunkey River fry for Virginia Game and Inland Fisheries for stocking the James River, and 789,600 Delaware source fry were stocked into the Lehigh River.

Shad fry produced at Van Dyke were distinctively marked with one to five separate immersions in 200 ppm tetracycline (TC). Pond-reared fingerlings also received feed tags. All fish produced by PFBC for the Susquehanna program in 1993 were stocked in the Juniata River at Thompsontown.

Maryland DNR supported pond production of about 100,000 fingerling shad (mixed with bluebacks) at Elkton, MD. These resulted from a fry stocking of about 185,000 shad from Van Dyke. DNR's Joseph Manning Hatchery successfully reared shad fry from Connecticut River eggs and from natural spawning of adults taken from the West lift at Conowingo. Researchers at Manning hatchery were successful in applying coded wire tags to juvenile shad and stocked about 1,000 of these specially marked fish into the Patuxent River. Manning also provided about 300,000+ shad fry to Potomac Electric Power Company for pond and tank culture at their Chalk Point aquaculture facility. About 92,000 tetracycline-marked phase II fingerling shad were stocked into the Patuxent River at three locations between late October and mid-November.

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 1993, shad were sampled with seines at several sites above and below York Haven Dam; with cast nets and a sluice net sampler at York Haven Dam; with lift nets at Holtwood; from cooling water intake strainers and screens at Safe Harbor, Conowingo and Peach Bottom; and by electrofishing in the upper Chesapeake Bay.

River flows during summer and fall months were generally stable and below average. Good numbers of shad were collected with seines at Marietta, Columbia and Pequea during mid-July through mid-October and most (84%) were naturally produced. Outmigration from the river occurred during the period 25 October through 16 November and otolith analysis of lower river sluice, seine, lift net and strainer/screen shad samples noted the shift in abundance to hatchery fish as this component passed.

Both wild and hatchery shad grew well in the Susquehanna (1 mm/day) with wild fish showing slightly larger mean sizes. Catch per effort (CPUE) of juvenile shad with seines in 1993 was comparable to that in 1992. However, CPUE in all other lower river collections was many times greater than that recorded last year. Maryland DNR collected 67 juvenile shad in the upper Chesapeake Bay by electrofisher (31) and seines (36). This compares to only 4 taken shad in 1992.

Over 600 shad from collections at Amity Hall, Three Mile Island, York Haven, Marietta, Columbia, Holtwood, Peach Bottom and Conowingo were returned to Benner Spring for tetracycline mark analysis. Otoliths from 356 fish (58%) were unmarked and displayed wild microstructure. This compares to 39% wild fish in 1992, 21.5% in 1991 and only 1-4% in earlier years. All fish examined from upper Bay collections were wild.

Rate of recovery of Hudson, Connecticut, and Delaware River fish was disproportionate to their stocking numbers. Hudson fish comprised only 17% of total fry stocked but 49% of all marked recoveries. Connecticut River fry made up 45% of the total release at Thompsontown but only 8% of juvenile returns. Delaware source fry showed an intermediate recovery rate relative to stocking numbers. Pond-reared fingerlings released at Thompsontown were well represented in late season catches and made up 10% of all marked recoveries.

Under direction of the Susquehanna River Technical Committee, a juvenile American shad turbine survival study was completed at Conowingo Dam. Using a combination of radiotags and the balloon tag technique developed by RMC Environmental Services, 108 shad were passed through a newly installed mixed-flow Kaplan turbine (Unit 8) during 28 October through 6 November. An equal number of shad were tagged and released as controls into the tailrace. Recapture rates for the test and control groups were 88% and 93%, respectively. Estimates for immediate and 48-hour delayed survival through the turbine were 95% and 93%, respectively.

Underwater strobe lights and high frequency sound generators were used independently and in combination to direct outmigrating juvenile shad to the open trash sluice and to minimize turbine entrainment at the York Haven project. Strobe lights and sound generators were effective in repelling shad. In independent tests of the devices however, both failed to appreciably keep fish from passing through turbine units closest to the sluiceway. This was partially explained by unusual hydraulic conditions in the headrace caused by Unit 2 outage and Unit 1 operations at only 50% load. The combined strobe/sound tests appeared to be most effective in avoiding turbine entrainment.

American shad egg collections, hatchery culture and marking, juvenile recovery, adult and juvenile shad mark analysis, and new equipment purchases were funded from the 1985 settlement agreement with upstream utilities. This funding source provided $353,836 in 1993. Upstream licensees cooperated with Susquehanna Electric Company (SECO) in separately covering costs associated with lift operations, collection, sorting and trucking of shad from Conowingo Dam.

SECO paid for strainer and screen checks for juvenile shad at Conowingo Dam and Peach Bottom and the turbine survival study at Conowingo. Metropolitan Edison Company paid for the strobe/sound studies at York Haven dam, and staff at the Safe Harbor project sampled their cooling water stainers for juvenile shad. Maryland DNR funded the adult shad population assessment, juvenile shad electrofishing and seining in the upper Chesapeake Bay, and shad culture at their Manning hatchery.

On June 1, 1993, upstream licensees and interveners met in Harrisburg and signed an agreement to design, construct, and evaluate performance of permanent fish passage facilities at Holtwood, Safe Harbor, and York Haven dams. State-of-the-art lift facilities will be operational at the lower two projects no later than April 1, 1997, and at York Haven within 3 years thereafter. Fish passage technical advisory committees were established for each project. Licensees further agreed to continue trap and transfer of adult shad from Conowingo until passage facilities are operational at Holtwood and Safe Harbor, and to maintain sufficient funding for shad egg collection and hatchery operations until all three devices are on-line.

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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INTRODUCTION

Philadelphia Electric Company (PECO) 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 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 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 to construct an east side fish 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, Susquehanna Electric Company (SECO), a subsidiary of PECO, had responsibility for funding the trap and transport operations. Completion of the East Lift shifted funding responsibility for trap and transport operations to the Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company (collectively termed Upstream Licensees). However, funding for the 1993 operation and maintenance of the East and West Lifts remained with SECO.

Objectives of 1993 operation were to: (1) continue to assess the operation of the East Fish Passage Facility, (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 agreement between PECO 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 1993 Susquehanna River Technical Committee Work Plan.

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

At the end of each day, after biologists completed recording lift, holding, transport, and pertinent biological data using the Scriptwriter pad, the data was transformed into ASCII files and uploaded to the PC. The ASCII files were read into PC-SAS to produce a quality assurance listing that was reviewed the following day. Noted corrections were made to the ASCII files using the data editing system. Following the quality assurance check, a daily summary was produced. The ASCII files were appended to a master ASCII file that contained previous days' data. Thus, the master file was kept correct and current at all times. From this file, daily, weekly, and annual reports were generated. Generally, the data entry and reporting system, developed and implemented, improved efficiency and performed well.

1.1 East and West Lift Operation

Lift operation was delayed until early May due to a long period of sustained high natural river flow that resulted in a 39 day period of spill which began on 25 March and continued through April. Daily lift operation (0700 to 1900h) at both facilities commenced on 4 May one day after spill had stopped and continued through 12 June. Half-day operation (0700 to 1300h) occurred on 13 and 14 June at the East fish lift and from 13 to 17 June at the West fish lift. Lift operations were terminated at the East and West lifts on 14 and 17 June, respectively.

Work stoppages due to mechanical/electrical failures or maintenance occurred infrequently. The lifts were operated in the most efficient manner possible around each problem to minimize outage time and maximize the catch. At the East Lift minor outages occurred on 19 and 20 May due to problems with the hopper hose assembly. On 4 June spill gate B and the downstream weir gate controls malfunctioned and rendered this equipment inoperable for the remainder of the season. A minor outage occurred at the West Lift on 4 June that involved a control problem with the crowder that prevented it from traveling forward. However, this was quickly resolved and lift operation continued until June 17.

The mechanical aspects of West lift operation in 1993 was similar to that described in RMC (1983), while the 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), which reduced the mechanical delays associated with normal operation was employed during periods of high fish density. Second, the weir gate settings were adjusted and operation in the "Fast Fish" mode was continued until the fish density was reduced. Normal lift operation was 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 1993. Matrix charts developed during 1991 and 1992 were expanded upon and used during 1993. The matrix charts contain pond and tailrace elevations, turbine unit operation, fish abundance, 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.

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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.

Water velocities at the entrances and within the crowder channel at the East lift were established to maximize the American shad catch. 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 velocity and flow at the West lift were similar to those maintained since 1982 (RMC 1983). Hydraulic conditions 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 gates and house service unit settings 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 17 June, respectively. Generally, Units 5 and 6 were used to meet minimum flow releases in May. Unit 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 that died in handling and transport. Per the 1993 SRTC Work Plan, every 100th shad collected per each Lift was sacrificed to obtain otoliths for stock identification study by the Pennsylvania Fish and Boat Commission (PFBC). In addition, muscle and liver 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 the 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. PFBC access areas at Swatara Creek and Falmouth were utilized on a discretionary basis to minimize delays in stocking fish pending each transport crew's assessment of conditions at Tri-County. The PFBC access at Columbia was utilized late in the season to reduce transport time and stress on fish. Several additional stocking locations were utilized to release radio tagged American shad for assisting in the fishway siting studies conducted for each of the Upstream Licensees.

Several improvements were made to enhance transport survival from the East Lift. A holding facility was constructed prior to the start of the season. This involved the relocation of steps to the sorting tank, platform construction, purchase and installation of two 1,000 gallon circular tanks, installation of chutes from the sorting tank to each holding tank and installation of an aeration system that utilized bottled oxygen. Other improvements included the installation of large gas tanks to each circulating water pump on all transport trailers and the installation of an additional 4 ft steel plate between the stop-log crane rails at the East Lift.

To increase the efficiency of the transport program at both lifts, American shad and river herring were held until sufficient numbers were collected to warrant transport. Holding facilities at each lift consisted of black circular tanks (two 1,000 gallon capacity tanks at the East Lift; 4

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. Although improvements were made to enhance East Lift handling, holding and transport, the basic procedures employed at both lifts in 1993 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 facility in 1993 is presented in Table 1. Fewer fish were collected at both fish lifts as compared to 1992. Sustained high river flow in April delayed operation of the lifts until 4 May, resulting in fewer fishing days in 1993 and was in part responsible for the reduced catch. No new species were collected in 1993 as compared to previous years of operation (RMC 1992).

A combined total of 1,242,748 fish was collected (Table 1). The East lift accounted for 529,594 fish of 29 taxa while the West lift collected 713,155 fish of 37 taxa. A total of 13,546 American shad (East=8,203; West=5,343) was captured. Alosids (American shad, blueback herring, and alewife) comprised 1.8% of the total catch. No hickory shad were captured at either lift, while alewife were only captured at the West lift. Gizzard shad dominated the catch and comprised 94% of the total. Although carp comprised only 1.2% of the total combined catch, they were a nuisance problem at both lifts during the latter part of the season and interfered with efficient sorting of alosids.

2.2 American Shad Catch (East and West Lift)

In 42 days of operation at the East lift, a total of 8,203 American shad was captured

(Table 2). The West lift operated a total of 45 days and captured 5,343 American shad (Table 3). Approximately 82% of the total shad captured were transported. A total of 2,352 shad was released back to the tailrace due to advanced maturation of fish and hooking injury. The remainder consisted of shad transported in combined loads, MD DNR recaptures, holding and lift mortalities, and those sacrificed.

American shad were collected at both lifts on 4 May (first day of operation). Nearly 62% (8,356 shad) of the shad were collected between 9 and 22 May. The peak day occurred on 16 May when 1,061 shad were captured at the East lift and the West lift collected 1,191 shad. During the period 23 May to 5 June, 3,365 shad were caught and accounted for nearly 25% of the total catch.

American shad were collected at water temperatures of 60.5 to 76.7 F and at natural river flows of 12,500 to 76,000 cfs (Figures 3 and 4). Over 90% of the shad were collected at water temperatures >65 F (Table 4) due in part to the lack of lift operation during April when water temperatures are generally < 65 F.

The catch per effort (CPE) of American shad at the East lift varied by station generation, weekend or week day, and time of day (Tables 5, 6, and 7). The overall CPE was lower on weekdays (14.6) than on weekends (31.7). Generally, during both periods, catches were greatest between 1500 and 1900 h although some relatively high catch rates were observed prior to 1100 h for both periods. Catch rates were independent of turbine units 10 and 11 operation at station discharge of 10,000-65,000 cfs (Table 7). However, the catch rate was highest (54.8 fish per hour) when Unit 11 was off and Unit 10 was varying in generation.

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. 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 5,892 shad was sexed. The sex ratios are provided in Table 8. The combined male/female ratio observed in 1993 was 1.3:1. Males comprised nearly 61% of the total catch in May while females comprised 56% of the catch in June.

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

Scale samples of 230 shad were aged (Table 9). Males were III to VI years old while females were IV to VII years old. Almost all the males were IV to VI years old, with age group V dominating. Almost all the females were V and VI years old. Most males and females were virgins. Of the 118 males, 15 (12.7%) were single repeat spawners and 1 (0.8%) was a double repeat spawn. Seven (6.3%) females were single repeat spawners and 3 (2.7%) were double repeat spawners. The overall repeat spawners were 11.3%, slightly lower than the repeaters in 1992 (15%).

Females were larger than males in the sampled population (Table 9). The smallest male measured 312 mm fork length, the smallest female was 380 mm. The average length of males and females were 402 and 457 mm, respectively.

2.5 Maryland Tag-Recapture (East and West Lifts)

Including multiple recaptures, 226 MD DNR tagged American shad were recaptured in 1993; 124 at the East lift and 102 at the West lift (Table 10). Of the 226 shad recovered, 7 were tagged by MD DNR in the tailrace in 1992 and 1 in a pound net in 1991. The MD DNR tagged 412 shad in 1993; 159 from pound nets in the upper Chesapeake Bay and 253 by hook and line in the Conowingo tailrace. Of the 117 first time MD DNR recaptures, 98 were tagged in the tailrace and 19 in the pound nets. The 19 shad from pound nets averaged 16.1 days free before capture, while those in the tailrace averaged 8.5 days free.

2.6 Other Alosids (East and West Lifts)

A total of 8,626 blueback herring was collected (Tables 2 and 3). Blueback herring were first collected on 4 May at the East lift. Blueback herring were common from 6 to 17 May at water temperatures ranging from 61.9 to 69.7°F.

A total of 572 alewife was collected, exclusively from the West lift (Tables 2 and 3). Alewife were captured only during the first 8 days of West lift operation when water temperatures ranged from 60.5 to 68.8°F. Nearly 61% of the alewife were captured on 5 May.

The combined catch of river herring (blueback herring and alewife) from both lifts was 9,198. It was lower than the total catch observed in recent years (RMC 1992). No hickory shad were captured at either lift in 1993.

2.7 Transport of American Shad (East and West Lifts)

Pre-spawned American shad were transported from 5 May through 16 June. Over 82% of the American shad catch was transported to upstream spawning areas with an overall observed stocking survival of 94.3% (Table 11). A total of 11,171 shad were transported; 6,983 from the East lift, 3,973 from the West lift, and 215 in combined transports. Some 8,479 shad were stocked directly to the Susquehanna River at Tri-County Marina. Additionally, 1,884 shad were released at the PFBC Columbia access and 228 shad were stocked at the PFBC Swatara Creek access. Smaller schools of shad totalling 580 fish were released at other upstream locations as part of a radio telemetry study funded by the Upstream Licensees.

Transportation of shad occurred on 25 and 29 days from the East and West lifts, respectively (Table 11). The number of transport trips per day at the East Lift ranged from 1 to 7, while West Lift transports ranged from 1 to 4 per day. East transport load size varied from 49 to 179 shad per trip. The load size of transports originating from the West lift ranged from 10 to 293 shad per trip. Transport survival ranged from 65 to 100% from the East lift while West lift transport survival ranged from 94.9 to 100%. Shad were transported at water temperatures of

62.6 to 78.8°F.

Holding facilities at both lifts were utilized to reduce stress, maximize transport operations, and release larger schools of fish. A total of 873 shad was held over at the East lift with no holding mortalities, while 983 shad were held over at the West facility with a total of 13 holding mortalities.

A total of 215 shad were transported upstream in combined transports. The average transport survival for the three trips was 94%; load size ranged from 27 to 124 shad per trip. All shad from these combined transports were released at Tri-County Marina.

2.8 River Herring Transport

During 1993, a total of 1,333 river herring (14.5% of total catch) was transported upstream and released at Tri-County Marina (Table 12). The transports included 203 alewife and 1,130 blueback herring. Herring were transported between 6 May and 30 May with 100% survival.

A total of 2,302 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 1993. 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 24 days beginning 8 May and continued until transport ceased from both fish lifts. These efforts resulted in the recovery of 194 dead shad (1.7%) of the total shad transported. In 1992 delayed transport mortalities were estimated at 5%.

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 vs. reduced generation), natural river flow, and water temperature.

The sustained high natural river flow (> 150,000 cfs) in early spring, particularly in April, delayed fish lift operations until 4 May. Based on previous years' data and experience, it is estimated that 264 hours of lift operation per facility was potentially lost due to the late start. It appears that the reduced American shad catch of 13,546 was at least in part due to the inability to operate the lifts in April. However, most clupeid runs along the East coast in 1993 have experienced noticeable declines compared to past years. The reasons for this decline are unknown at present.

Although fewer American shad and river herring were trapped and transported in 1993, improvements were made in the trap and transport operation. SECO overhauled the West lift and made modifications to the East lift which reduced down time due to mechanical and electrical breakdowns. The installation of a two-tank holding facility at the East lift coupled with other facility/equipment modifications were undertaken and helped reduce stress and improve transport survival of fish.

Most transport mortalities (62%) occurred during the first seven days of lift operation. A higher velocity within the transport tank and larger load size may have caused these mortalities, particularly at the East Lift. Thus, velocity in each transport unit was checked and maintained at the desired level of 1 fps prior to loading of American shad and herring. Additionally, load size of fish transported was reduced to prevent undue stress due to crowding. Finally, on very hot days or when large numbers of shad were being captured, the transported fish were released at the PFBC Columbia access which shortened the trip by approximately one hour. These steps appeared to improve transport survival and will be incorporated as part of standard transport operating procedures.

4.0 RECOMMENDATIONS

1. To maximize transport survival in trailer mounted transport units, seal the seam of each unit's tank with fiberglass to minimize disruption of flow conditions that result from leakage. (NOTE: the seam in the tank of the transport trailer unit received during the 1993 season was sealed prior to placing the unit in service).

2. Investigate and change the surge brake system on each trailer mounted transport unit to a vacuum brake system based on findings of a feasibility study to maximize personnel and public safety.

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Table 1. Catch of fishes at the Conowingo Dam Fish Lifts, 1993.

LOCATION	EAST	WEST
NO. OF DAYS	42	45
NO. OF LIFTS	848	1032
OPERATING TIME (HRS)	463.5	505.4
FISHING TIME	421.2	416.7
NO. OF TAXA	29	37
AMERICAN SHAD	8203	5343
BLUEBACK HERRING	4574	4052
ALEWIFE	-	572
GIZZARD SHAD	504116	666010
COMMON CARP	6649	8488
STRIPED BASS	327	1595
American eel	49	1487
Rainbow trout	5	4
Brown trout	53	98
Muskellunge	9	9
Comely shiner	3563	7358
Quillback	540	746
White sucker	82	59
Shorthead redhorse	184	858
Yellow bullhead	2	19
Brown bullhead	1	73
Channel catfish	534	10841
White perch	215	3892
Rock bass	10	90
Redbreast sunfish	34	170
Green sunfish	1	10
Pumpkinseed	2	22
Bluegill	58	200
Smallmouth bass	185	227
Largemouth bass	12	84
Yellow perch	46	318
Walleye	71	217
Sea lamprey	4	5
Striped bass x white bass	64	112
Tiger muskie	1	2
Spotfin shiner	-	10
White catfish	-	97
Margined madtom	-	12
White crappie	-	62
Black crappie	-	7
Brook trout x lake trout	-	5
Sunfish hybrids	-	1
TOTAL	529594	713155

Note: No Hickory shad were collected at either fish lift in 1993.

Table 2. Daily summary of fishes collected at the Conowingo Dam East Lift, 4 May through 14 June, 1993. Note that no Hickory shad were collected in 1993.

DATE	04MAY	05MAY	06MAY	07MAY	08MAY	09MAY	10MAY	11MAY	12MAY	13MAY
NO OF LIFTS	17	15	23	21	23	21	22	21	21	25
FIRST LIFT	7:30	7:27	7:16	7:12	7:10	7:06	7:03	7:09	7:13	8:35
LAST LIFT	18:30	18:56	18:37	18:43	18:42	18:51	18:36	18:40	18:30	18:20
OPERATING TIME (HRS)	11.0	11.5	11.4	11.5	11.5	11.8	11.6	11.5	11.3	9.8
FISHING TIME (HRS)	10.0	10.8	10.1	10.5	10.5	10.8	10.8	10.3	10.3	8.9
AVG WATER TEMP (F)	61.5	62.4	63.1	64.4	64.9	66.7	68.4	69.1	70.5	70.5
BLUEBACK HERRING	1									1
ALEWIFE										
AMERICAN SHAD	165	354	133	176	394	384	455	383	134	387
GIZZARD SHAD	16115	8229	14553	16852	15507	12761	15520	19165	31437	43600
COMMMON CARP	33	12	11	15	13	13	74	17	65	45
STRIPED BASS									1	
OTHER SPP	67	63	103	102	196	128	217	101	196	134
TOTAL	16381	8658	14800	17145	16110	13286	16266	19666	31833	44167

DATE	14MAY	15MAY	16MAY	17MAY	18MAY	19MAY	20MAY	21MAY	22MAY	23MAY
NO OF LIFTS	22	19	23	19	23	11	20	17	22	22
FIRST LIFT	7:21	7:18	7:06	8:10	7:09	7:20	7:19	7:25	7:13	7:13
LAST LIFT	18:52	18:39	18:26	18:57	18:40	13:09	18:40	18:30	18:48	18:49
OPERATING TIME (HRS)	11.5	11.4	11.3	10.8	11.5	5.8	11.4	11.1	11.6	11.6
FISHING TIME (HRS)	10.6	10.1	10.1	9.9	10.6	5.3	10.4	8.2	10.5	10.6
AVG WATER TEMP (F)	70.7	69.8	70.5	71.6	71.8	69.3	69.8	68.7	68.5	69.1
BLUEBACK HERRING	1	48	3265	16	73	6	7	2	173	339
ALEWIFE										
AMERICAN SHAD	141	772	1061	163	480	219	13	230	496	184
GIZZARD SHAD	7530	4030	18727	7960	13289	10925	8030	14875	14309	1307[illegible]
COMMMON CARP	9	2	7	143	26	1	5	6	4	
STRIPED BASS			1	2	1		13	2	3	6
OTHER SPP	63	72	225	66	55	26	93	1008	10	1[illegible]
TOTAL	7744	4924	23286	8350	13924	11177	8161	16123	14995	1361[illegible]

DATE	24MAY	25MAY	26MAY	27MAY	28MAY	29MAY	30MAY	31MAY	01JUN	02JUN
NO OF LIFTS	22	22	22	20	23	22	20	20	20	20
FIRST LIFT	7:11	7:03	7:03	6:59	7:11	7:01	7:12	7:15	7:10	7:09
LAST LIFT	18:52	18:40	18:43	18:48	18:53	18:40	17:40	18:42	18:45	18:40
OPERATING TIME (HRS)	11.7	11.6	11.7	11.8	11.7	11.7	10.5	11.5	11.6	11.5
FISHING TIME (HRS)	10.7	10.4	10.6	10.9	10.7	10.7	9.5	10.5	10.6	10.5
AVG WATER TEMP (F)	69.1	68.9	68.5	69.3	69.3	70.3	69.8	71.6	71.6	72.0
BLUEBACK HERRING	47		14	27	21	273	18	15	1	
ALEWIFE										
AMERICAN SHAD	101	71	195	175	119	433	48	153	3	42
GIZZARD SHAD	16805	25002	10397	10223	12939	6304	6895	15668	13745	9598
COMMMON CARP	42	17	107	71	56	15	1434	102	4	6
STRIPED BASS	4	1	4	2	6	3	4	6	3	5
OTHER SPP	17	12	5	3	17	20	8	23	18	25
TOTAL	17016	25103	10722	10501	13158	7048	8407	15967	13774	9678

Table 2. Continued.

DATE	03JUN	04JUN	05JUN	06JUN	07JUN	08JUN	09JUN	10JUN	11JUN	12JUN
NO OF LIFTS	18	22	21	22	23	21	22	22	22	22
FIRST LIFT	7:13	7:06	7:18	7:06	7:02	7:16	7:07	7:01	7:05	7:02
LAST LIFT	18:40	18:30	18:45	18:33	19:00	18:45	18:43	18:34	18:43	18:45
OPERATING TIME (HRS)	11.5	11.4	11.5	11.5	12.0	11.5	11.6	11.6	11.6	11.7
FISHING TIME (HRS)	10.5	10.3	10.5	10.5	10.9	10.5	10.5	10.5	10.6	10.7
AVG WATER TEMP (F)	71.6	72.5	71.6	71.4	72.1	72.1	72.1	74.3	74.7	75.6
BLUEBACK HERRING	76	8	58		73	1	6	4		
ALEWIFE										
AMERICAN SHAD	42	54	14	14	3		2	3		5
GIZZARD SHAD	8013	9907	11665	7660	5000	4563	6141	7699	3470	2560
COMMMON CARP	2	93	128	658	159	104	703	1191	1118	8
STRIPED BASS	6	23	7	29	34	34	24	19	43	13
OTHER SPP	8	42	15	1184	26	670	210	367	65	31
TOTAL	8147	10127	11887	9545	5295	5372	7086	9283	4696	2617

DATE	13JUN	14JUN	TOTALS
NO OF LIFTS	8	7	848
FIRST LIFT	7:02	7:01	.
LAST LIFT	13:00	13:00	.
OPERATING TIME (HRS)	6.0	6.0	463.5
FISHING TIME (HRS)	5.7	5.7	421.2
AVG WATER TEMP (F)	75.2	75.7	.
BLUEBACK HERRING			4574
ALEWIFE			0
AMERICAN SHAD		2	8203
GIZZARD SHAD	464	2913	504116
COMMMON CARP	25	105	6649
STRIPED BASS	11	17	327
OTHER SPP	15	8	5725
TOTAL	515	3045	529594

Table 3. Daily summary of fishes collected at the Conowingo Dam West Lift, 4 May through 17 June, 1993. Note that no Hickory shad were collected in 1993.

DATE	04MAY	05MAY	06MAY	07MAY	08MAY	09MAY	10MAY	11MAY	12MAY	13MAY
NO OF LIFTS	17	19	25	27	28	32	25	29	23	26
FIRST LIFT	11:07	10:27	7:47	7:26	7:00	7:04	7:00	7:00	7:01	7:05
LAST LIFT	16:28	18:18	18:07	18:46	18:58	18:45	18:57	18:56	18:45	19:00
OPERATING TIME (HRS)	5.3	7.8	10.3	11.3	12.0	11.7	12.0	11.9	11.7	11.9
FISHING TIME (HRS)	5.4	6.2	7.1	8.0	9.4	9.1	9.2	9.7	9.3	9.9
AVG WATER TEMP (F)	60.4	62.1	61.9	63.9	64.7	67.1	68.0	68.7	70.2	70.2
BLUEBACK HERRING			435	281	236	55	126	52	56	285
ALEWIFE	15	348		178		30		1		
AMERICAN SHAD	1	9	5	50	19	36	159	135	74	89
GIZZARD SHAD	41600	45200	60344	56403	67300	24260	16250	29520	14275	22880
COMMMON CARP	102	125	148	331	468	227	68	118	157	229
STRIPED BASS			2	6	6	40	7	9	13	18
OTHER SPP	56	288	472	586	699	1747	1171	685	1164	1037
TOTAL	41774	45970	61406	57835	68728	26395	17781	30520	15739	24538

DATE	14MAY	15MAY	16MAY	17MAY	18MAY	19MAY	20MAY	21MAY	22MAY	23MAY
NO OF LIFTS	23	22	20	25	24	24	26	24	25	25
FIRST LIFT	7:07	7:14	7:05	7:07	7:01	7:00	7:02	7:09	7:07	7:03
LAST LIFT	18:54	18:45	18:35	18:52	18:40	19:25	18:57	18:58	18:56	18:55
OPERATING TIME (HRS)	11.6	11.5	11.5	11.8	11.7	12.4	11.9	11.8	11.8	11.9
FISHING TIME (HRS)	6.7	8.8	10.4	9.5	9.1	10.5	9.8	10.1	10.3	10.6
AVG WATER TEMP (F)	70.2	69.6	69.8	69.6	69.3	69.8	68.0	67.6	68.0	67.6
BLUEBACK HERRING	59[illegible]	492	319	651	4	2	37	39	161	78
HICKORY SHAD										
ALEWIFE										
AMERICAN SHAD	95	282	1191	194	66	50	207	122	338	439
GIZZARD SHAD	18960	15150	6190	19865	9520	5632	15685	9036	8780	12410
COMMMON CARP	366	12	8	47	182	33	24	28	18	13
STRIPED BASS	6	5	14	49	43	71	50	40	41	56
OTHER SPP	1239	2613	630	616	219	424	618	422	330	126
TOTAL	[illegible]	18554	8352	21424	10034	6212	16621	9687	9668	13122

DATE	24MAY	25MAY	26MAY	27MAY	28MAY	29MAY	30MAY	31MAY	01JUN	02JUN
NO OF LIFTS	27	27	25	27	23	26	26	22	22	25
FIRST LIFT	7:04	7:00	7:02	7:06	7:00	7:03	7:00	7:00	7:00	7:00
LAST LIFT	18:55	18:55	18:55	18:53	18:50	18:49	18:54	18:45	18:55	18:50
OPERATING TIME (HRS)	11.9	11.9	11.6	11.8	11.8	11.8	11.9	11.6	11.9	11.8
FISHING TIME (HRS)	9.6	9.0	9.9	9.6	9.9	9.9	10.2	10.0	9.8	9.4
AVG WATER TEMP (F)	68.5	68.4	70.7	68.9	69.8	70.5	70.3	69.8	71.2	71.1
BLUEBACK HERRING	6	2	9	3	4	30	34	8		2
ALEWIFE										
AMERICAN SHAD	65	183	145	85	145	196	148	69	28	57
GIZZARD SHAD	18835	17215	12355	18305	10140	6590	7160	4310	5702	11250
COMMMON CARP	123	109	57	92	164	168	44	153	324	156
STRIPED BASS	46	36	55	72	54	34	29	31	93	55
OTHER SPP	221	129	889	286	724	1114	112	366	344	337
TOTAL	19296	17774	13510	18843	11231	8132	7527	4937	6491	11857

Table 3. Continued.

DATE	03JUN	04JUN	05JUN	06JUN	07JUN	08JUN	09JUN	10JUN	11JUN	12JUN
NO OF LIFTS	24	16	23	25	23	22	22	22	22	19
FIRST LIFT	7:00	7:00	7:03	7:02	7:00	7:02	7:00	7:02	7:02	7:04
LAST LIFT	18:55	19:00	18:55	18:30	18:58	18:55	18:50	18:45	18:55	18:52
OPERATING TIME (HRS)	11.9	12.0	11.9	11.5	12.0	11.9	11.8	11.7	11.9	11.8
FISHING TIME (HRS)	10.0	6.7	10.1	8.9	10.5	10.2	10.2	10.3	10.2	10.7
AVG WATER TEMP (F)	69.4	70.3	70.2	71.2	71.1	71.1	72.1	74.5	74.8	74.7
BLUEBACK HERRING		3	1	37	9		1		1	1
ALEWIFE										
AMERICAN SHAD	18	20	133	114	51	25	42	19	59	2
GIZZARD SHAD	14743	3772	5761	8723	5598	1128	3270	3320	1970	1040
COMMMON CARP	270	104	60	2245	458	67	50	105	189	116
STRIPED BASS	54	16	17	44	88	49	50	35	48	38
OTHER SPP	313	183	73	1453	219	214	619	807	282	91
TOTAL	15398	4098	6045	12616	6423	1483	4032	4286	2549	1288

DATE	13JUN	14JUN	15JUN	16JUN	17JUN	TOTALS
NO OF LIFTS	19	18	16	12	10	1032
FIRST LIFT	7:01	7:01	7:01	7:10	7:01	.
LAST LIFT	18:55	17:30	16:12	14:16	13:00	.
OPERATING TIME (HRS)	11.9	10.5	9.2	7.1	6.0	505.4
FISHING TIME (HRS)	11.2	9.3	8.2	6.4	5.4	416.7
AVG WATER TEMP (F)	74.8	75.4	75.6	76.3	76.6	.
BLUEBACK HERRING			1			4052
ALEWIFE						572
AMERICAN SHAD	54	48	19	48	9	5343
GIZZARD SHAD	1115	2115	823	760	650	666010
COMMMON CARP	568	124	5	12	20	8486
STRIPED BASS	23	34	45	42	31	1595
OTHER SPP	753	421	953	466	493	27095
TOTAL	2513	2742	1846	1328	1203	713155

Table 4. Catch of American shad by water temperature at the Conowingo Dam Fish Lifts (East and West), 1993. Cleanout lifts excluded.

WATER TEMP. (F)	HOURS FISHING	CATCH NUMBER	CATCH CATCH/ EFFORT	CATCH PERCENT
< 65	73.1	1284	17.6	9.5
> 65	759.4	12242	16.1	90.5
TOTAL	832.5	13526	16.2	100.0

TABLE 5. Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam East Fish Lift, 1993.

DATE		WEIR GATES				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
04MAY	# Shad			83	82	165
	Hrs Fishing			4.7	5.3	10.0
	Catch / Hr Fishing			17.7	15.4	16.5
05MAY	# Shad			283	71	354
	Hrs Fishing			7.1	3.6	10.8
	Catch / Hr Fishing			39.6	19.6	32.9
06MAY	# Shad			109	24	133
	Hrs Fishing			7.6	2.5	10.1
	Catch / Hr Fishing			14.3	9.6	13.2
07MAY	# Shad			127	49	176
	Hrs Fishing			6.5	3.9	10.5
	Catch / Hr Fishing			19.4	12.5	16.8
08MAY	# Shad			347	47	394
	Hrs Fishing			8.8	1.7	10.5
	Catch / Hr Fishing			39.5	27.9	37.6
09MAY	# Shad			323	61	384
	Hrs Fishing			9.5	1.3	10.8
	Catch / Hr Fishing			34.1	45.7	35.6
10MAY	# Shad			307	148	455
	Hrs Fishing			8.4	2.4	10.8
	Catch / Hr Fishing			36.7	62.1	42.3
11MAY	# Shad			313	70	383
	Hrs Fishing			6.7	3.7	10.4
	Catch / Hr Fishing			47.0	19.0	37.0
12MAY	# Shad			113	21	134
	Hrs Fishing			7.5	2.8	10.3
	Catch / Hr Fishing			15.0	7.6	13.1
13MAY	# Shad			324	62	386
	Hrs Fishing			7.6	1.4	8.9
	Catch / Hr Fishing			42.8	45.9	43.3
14MAY	# Shad			112	29	141
	Hrs Fishing			10.1	0.5	10.6
	Catch / Hr Fishing			11.1	58.0	13.3
15MAY	# Shad	401		101	270	772
	Hrs Fishing	6.3		1.7	2.2	10.1
	Catch / Hr Fishing	64.0		59.4	124.6	76.2
16MAY	# Shad	968		26	67	1061
	Hrs Fishing	7.6		0.6	1.9	10.0
	Catch / Hr Fishing	127.4		45.9	35.6	105.6
17MAY	# Shad	78		38	47	163
	Hrs Fishing	2.4		5.2	2.4	9.9
	Catch / Hr Fishing	32.3		7.4	19.9	16.4

TABLE 5. Continued.

DATE		WEIR GATES				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
18MAY	# Shad	96		336	48	480
	Hrs Fishing	1.4		7.8	1.4	10.6
	Catch / Hr Fishing	69.4		43.4	33.9	45.5
19MAY	# Shad	17		146	56	219
	Hrs Fishing	0.5		3.7	1.2	5.3
	Catch / Hr Fishing	34.0		39.8	48.0	41.1
20MAY	# Shad	-		7	6	13
	Hrs Fishing	0.9		7.3	2.2	10.4
	Catch / Hr Fishing	-		1.0	2.7	1.2
21MAY	# Shad	149		13	68	230
	Hrs Fishing	0.8		3.8	3.6	8.2
	Catch / Hr Fishing	190.2		3.4	19.1	28.1
22MAY	# Shad	324		22	150	496
	Hrs Fishing	4.9		2.0	3.7	10.5
	Catch / Hr Fishing	66.8		11.0	40.9	47.2
23MAY	# Shad	144			40	184
	Hrs Fishing	8.2			2.4	10.6
	Catch / Hr Fishing	17.6			16.6	17.4
24MAY	# Shad	51		35	15	101
	Hrs Fishing	3.0		5.7	2.0	10.7
	Catch / Hr Fishing	17.0		6.1	7.7	9.5
25MAY	# Shad	10		46	15	71
	Hrs Fishing	1.0		6.7	2.7	10.4
	Catch / Hr Fishing	10.0		6.8	5.6	6.8
26MAY	# Shad	99		43	53	195
	Hrs Fishing	5.3		2.0	3.2	10.6
	Catch / Hr Fishing	18.6		21.5	16.3	18.4
27MAY	# Shad	115		20	40	175
	Hrs Fishing	3.6		4.1	3.2	10.9
	Catch / Hr Fishing	32.1		4.9	12.6	16.1
28MAY	# Shad	67		21	31	119
	Hrs Fishing	5.8		2.4	2.4	10.7
	Catch / Hr Fishing	11.5		8.7	12.8	11.2
29MAY	# Shad	345			88	433
	Hrs Fishing	7.8			2.9	10.7
	Catch / Hr Fishing	44.4			30.2	40.5
30MAY	# Shad	39			9	48
	Hrs Fishing	6.8			2.7	9.5
	Catch / Hr Fishing	5.7			3.4	5.0
31MAY	# Shad	147			6	153
	Hrs Fishing	10.0			0.5	10.5
	Catch / Hr Fishing	14.7			12.0	14.5
01JUN	# Shad	-		2	1	3
	Hrs Fishing	2.3		4.4	4.0	10.6
	Catch / Hr Fishing	-		0.5	0.3	0.3

TABLE 5. Continued.

DATE		WEIR GATES				
		A Only Open	B Only Open	Down Only Open	Changing	TOTAL
02JUN	# Shad	23		-	19	42
	Hrs Fishing	3.6		2.3	4.7	10.6
	Catch / Hr Fishing	6.4		-	4.1	4.0
03JUN	# Shad	32		2	8	42
	Hrs Fishing	6.0		1.7	2.8	10.5
	Catch / Hr Fishing	5.3		1.2	2.8	4.0
04JUN	# Shad	39		11	4	54
	Hrs Fishing	5.0		2.2	3.1	10.3
	Catch / Hr Fishing	7.8		4.9	1.3	5.2
05JUN	# Shad	10			4	14
	Hrs Fishing	7.6			2.9	10.5
	Catch / Hr Fishing	1.3			1.4	1.3
06JUN	# Shad	13			1	14
	Hrs Fishing	9.5			1.0	10.5
	Catch / Hr Fishing	1.4			1.0	1.3
07JUN	# Shad	3			-	3
	Hrs Fishing	8.4			2.5	10.9
	Catch / Hr Fishing	0.4			-	0.3
08JUN	# Shad	-	-		-	-
	Hrs Fishing	6.1	1.0		3.4	10.5
	Catch / Hr Fishing	-	-		-	-
09JUN	# Shad	-	-		2	2
	Hrs Fishing	4.6	2.5		3.5	10.6
	Catch / Hr Fishing	-	-		0.6	0.2
10JUN	# Shad	2	-		1	3
	Hrs Fishing	5.6	2.4		2.5	10.5
	Catch / Hr Fishing	0.4	-		0.4	0.3
11JUN	# Shad	-	-		-	-
	Hrs Fishing	3.5	4.6		2.5	10.6
	Catch / Hr Fishing	-	-		-	-
12JUN	# Shad	4			1	5
	Hrs Fishing	9.2			1.5	10.7
	Catch / Hr Fishing	0.4			0.7	0.5
13JUN	# Shad	-				-
	Hrs Fishing	5.7				5.7
	Catch / Hr Fishing	-				-
14JUN	# Shad	2	-		-	2
	Hrs Fishing	2.6	1.0		2.1	5.7
	Catch / Hr Fishing	0.8	-		-	0.3
TOTAL *	# Shad	3178	-	3310	1714	8202
	Hrs Fishing	155.7	11.5	148.1	105.9	421.2
	Catch / Hr Fishing	20.4	-	22.3	16.2	19.5

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

Table 6. Comparison of catch per effort (hr) of American shad on weekdays vs. weekend days by generation (cfs) at the Conowingo Dam East Fish Lift, 4 May through 14 June, 1993.

	LIFT TIME	5,000 CFS CATCH/HOUR	6-10,000 CFS CATCH/HOUR	11-20,000 CFS CATCH/HOUR	21-40,000 CFS CATCH/HOUR	> 40,000 CFS CATCH/HOUR	VARYING CFS CATCH/HOUR	TOTAL CATCH/HOUR
WEEKDAYS	05:00-09:00	2.7	17.3	8.2	8.0	17.2	14.0	10.6
WEEKDAYS	09:01-11:00	0.2	25.8	16.7	19.6	17.4	2.5	14.3
WEEKDAYS	11:01-15:00	1.0	7.6	5.2	5.6	14.2	3.8	10.4
WEEKDAYS	15:01-19:00	0.8	21.1	3.6	9.0	30.0	15.0	22.3
WEEKDAYS MEAN		1.7	18.8	8.9	8.8	19.8	9.5	14.6
WEEKEND	05:00-09:00	0.9	56.4	38.0	-	25.7	37.5	31.5
WEEKEND	09:01-11:00	0.8	53.7	49.5	8.0	14.2	141.6	28.7
WEEKEND	11:01-15:00	1.0	36.3	15.7	17.4	35.3	61.0	27.4
WEEKEND	15:01-19:00	1.3	57.7	22.0	-	62.0	13.1	39.1
WEEKEND MEAN		1.0	48.9	26.8	13.2	37.4	53.3	31.7
TOTAL		1.4	35.7	13.9	9.4	22.3	16.7	19.5

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, 4 May through 14 June, 1993.

TOTAL DISCHARGE (X 1000 cfs)	UNIT 11	UNIT 10	NUMBER OF LIFTS	TIME (hours)	TOTAL SHAD	SHAD/HOUR
5-10	OFF	OFF	95	56.4	77	1.4
5-10 TOTAL			95	56.4	77	1.4
10-65	CHG	CHG	-	1.2	2	1.7
10-65	CHG	OFF	-	0.8	2	2.7
10-65	CHG	ON	-	0.9	3	3.4
10-65	OFF	CHG	-	3.3	16	4.8
10-65	OFF	OFF	376	129.0	3468	26.9
10-65	OFF	ON	-	9.2	96	10.4
10-65	ON	CHG	-	1.1	8	7.4
10-65	ON	OFF	29	12.2	63	5.2
10-65	ON	ON	284	171.0	3859	22.6
10-65 TOTAL			689	328.6	7517	22.9
VARYING	CHG	CHG	22	10.9	146	13.4
VARYING	CHG	OFF	-	1.0	36	36.0
VARYING	CHG	ON	-	0.5	-	-
VARYING	OFF	CHG	-	2.5	138	54.8
VARYING	OFF	OFF	20	15.8	212	13.5
VARYING	ON	CHG	22	4.2	45	10.7
VARYING	ON	OFF	-	0.6	16	27.4
VARYING	ON	ON	-	0.9	15	16.7
VARYING TOTAL			64	36.3	608	16.7
TOTAL			848	421.2	8202	19.5

Table 8. Daily sex ratio of American shad at the Conowingo Dam Fish Lifts for 1993.

Date	Daily Catch	SEXED	No. of Males	No. of Females	Ratio (M/F)
04MAY	166	106	80	26	3.1 to 1
05MAY	363	110	84	26	3.2 to 1
06MAY	138	105	59	46	1.3 to 1
07MAY	226	161	112	49	2.3 to 1
08MAY	413	123	93	30	3.1 to 1
09MAY	420	138	85	53	1.6 to 1
10MAY	614	223	159	64	2.5 to 1
11MAY	518	208	141	67	2.1 to 1
12MAY	208	134	90	44	2.0 to 1
13MAY	476	192	120	72	1.7 to 1
14MAY	236	195	120	75	1.6 to 1
15MAY	1054	248	172	76	2.3 to 1
16MAY	2252	219	120	99	1.2 to 1
17MAY	357	223	129	94	1.4 to 1
18MAY	546	179	102	77	1.3 to 1
19MAY	269	157	102	55	1.9 to 1
20MAY	220	120	75	45	1.7 to 1
21MAY	352	238	147	91	1.6 to 1
22MAY	834	216	115	101	1.1 to 1
23MAY	623	218	112	106	1.1 to 1
24MAY	166	166	86	80	1.1 to 1
25MAY	254	180	114	66	1.7 to 1
26MAY	340	210	158	52	3.0 to 1
27MAY	260	201	94	107	0.9 to 1
28MAY	264	201	105	96	1.1 to 1
29MAY	629	210	120	90	1.3 to 1
30MAY	196	151	72	79	0.9 to 1
31MAY	222	175	71	104	0.7 to 1
01JUN	31	31	23	8	2.9 to 1
02JUN	99	99	54	45	1.2 to 1
03JUN	60	60	27	33	0.8 to 1
04JUN	74	74	45	29	1.6 to 1
05JUN	147	116	47	69	0.7 to 1
06JUN	128	114	48	66	0.7 to 1
07JUN	54	54	19	35	0.5 to 1
08JUN	25	25	8	17	0.5 to 1
09JUN	44	44	18	26	0.7 to 1
10JUN	22	22	10	12	0.8 to 1
11JUN	59	59	26	33	0.8 to 1
12JUN	7	7	3	4	0.8 to 1
13JUN	54	54	18	36	0.5 to 1
14JUN	50	50	16	34	0.5 to 1
15JUN	19	19	10	9	1.1 to 1
16JUN	48	48	15	33	0.5 to 1
17JUN	9	9	3	6	0.5 to 1
TOTAL	13546	5892	3427	2465	1.3 to 1

Table 9. Age and spawning history of American shad collected at the Conowingo Dam Fish Lifts in 1993.

Sex	Age	Spawning History				Fork Length		
		N	Virgins	Repeats Once	Repeats Twice	Mean	Min	Max
MALE	III	1	1	-	-	327	327	327
	IV	34	34	-	-	369	312	453
	V	67	57	9	1	414	341	457
	VI	16	10	6	-	428	352	455
	Total for males	118	102	15	1	402	312	457
FEMALE	IV	6	6	-	-	400	380	434
	V	41	38	3	-	442	391	495
	VI	56	49	4	3	466	418	505
	VII	9	9	-	-	502	468	538
	Total for females	112	102	7	3	457	380	538
Grand Total		230	204	22	4	429	312	538

Table 10. Daily capture of tagged Maryland DNR American shad at the Conowingo Fish Lifts, 1993.

	DAILY CATCH		NO. OF MD DNR RECAPTURES	
DATE	EAST	WEST	EAST	WEST
04MAY93	165	1	-	-
05MAY93	354	9	-	-
06MAY93	133	5	2	-
07MAY93	176	50	-	-
08MAY93	394	19	4	-
09MAY93	384	36	5	-
10MAY93	455	159	6	-
11MAY93	383	135	1	2
12MAY93	134	74	-	2
13MAY93	387	89	4	1
14MAY93	141	95	2	1
15MAY93	772	282	5	5
16MAY93	1061	1191	23	16
17MAY93	163	194	2	5
18MAY93	480	66	8	1
19MAY93	219	50	6	-
20MAY93	13	207	1	4
21MAY93	230	122	6	3
22MAY93	496	338	10	9
23MAY93	184	439	4	8
24MAY93	101	65	2	1
25MAY93	71	183	2	5
26MAY93	195	145	6	5
27MAY93	175	85	4	2
28MAY93	119	145	1	4
29MAY93	433	196	12	3
30MAY93	48	148	-	3
31MAY93	153	69	4	1
01JUN93	3	28	-	4
02JUN93	42	57	2	4
03JUN93	42	18	2	1
04JUN93	54	20	-	1
05JUN93	14	133	-	3
06JUN93	14	114	-	4
07JUN93	3	51	-	1
08JUN93	-	25	-	-
09JUN93	2	42	-	-
10JUN93	3	19	-	-
11JUN93	0	59	-	1
12JUN93	5	2	-	-
13JUN93	0	54	-	1
14JUN93	2	48	-	1
15JUN93	-	19	-	-
16JUN93	-	48	-	-
17JUN93	-	9	-	-
TOTALS	8203	5343	124	102

Table 11. Summary of transports of American shad from the Conowingo Dam Fish Lifts, 1993.

COMBINED TRANSPORTS

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
26MAY	-	72.0	124	Tri-County Marina	11	91.1	9.5	11.3	68.9
02JUN	-	72.9	64	Tri-County Marina	2	96.9	7.6	10.0	72.9
06JUN	-	73.0	27	Tri-County Marina	0	100.0	8.1	9.0	73.0
TOTALS			215		13				

TRANSPORTED FROM EAST LIFT

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
05MAY	354	61.7	105	Tri-County Marina	0	100.0	11.6	10.4	62.6
		63.5	179	Tri-County Marina	55	69.3	11.3	11.4	64.4
		62.6	154	Tri-County Marina	7	95.5	12.0	12.0	66.2
06MAY	133	63.5	79	Tri-County Marina	0	100.0	12.8	13.2	64.4
		65.8	121	Tri-County Marina	70	42.1	13.2	11.6	59.0
07MAY	176	64.4	132	Tri-County Marina	11	91.7	9.0	11.9	65.3
08MAY	394	67.6	139	Tri-County Marina	6	95.7	8.8	10.0	66.2
		68.0	151	Tri-County Marina	6	96.0	9.0	10.8	68.0
		67.6	94	Tri-County Marina	0	100.0	13.5	10.8	64.0
09MAY	384	70.7	134	Tri-County Marina	36	73.1	11.5	12.2	71.6
		69.8	137	Tri-County Marina	21	84.7	12.0	11.9	70.7
10MAY	455	68.0	123	Tri-County Marina	0	100.0	11.0	10.0	66.2
		72.5	111	Tri-County Marina	12	89.2	12.8	10.4	70.2
		71.6	128	Tri-County Marina	44	65.6	9.1	11.0	72.5
11MAY	383	7'.4	139	Tri-County Marina	2	98.6	13.4	13.6	72.'
		74.5	136	Tri-County Marina	49	64.0	11.0	12.4	74.3
		74.5	128	Tri-County Marina	82	35.9	12.0	9.8	70.2
13MAY	387	70.7	148	Tri-County Marina	6	95.9	9.2	11.5	71.6
		71.2	117	Tri-County Marina	0	100.0	12.2	10.4	66.2
		70.7	120	Tri-County Marina	5	95.8	12.1	12.5	71.6
14MAY	141	71.6	121	Tri-County Marina	0	100.0	11.6	10.3	66.7
15MAY	772	72.5	130	Tri-County Marina	0	100.0	9.3	11.5	72.5
		71.6	125	Columbia PFC	0	100.0	10.0	8.0	71.6
		71.8	128	Columbia PFC	3	97.7	11.2	11.0	73.4
		73.4	128	Tri-County Marina	0	100.0	10.0	10.1	74.3
		71.6	125	Tri-County Marina	4	96.8	11.4	11.7	72.5
16MAY	1061	71.6	135	Columbia PFC	2	98.5	11.0	11.2	71.6
		72.3	125	Columbia PFC	3	97.6	10.6	13.0	73.2
		73.4	125	Columbia PFC	1	99.2	9.8	10.9	74.3
		73.4	125	Columbia PFC	8	93.6	12.4	12.2	73.4
		75.2	124	Columbia PFC	6	95.2	7.6	11.0	75.2
		73.4	122	Tri-County Marina	5	95.9	12.9	8.8	64.4
		23.2	129	Columbia PFC	7	94.6	13.0	12.6	73.8
17MAY	163	73.4	105	Columbia PFC	10	90.5	10.0	10.6	73.4
		74.7	124	Tri-County Marina	4	96.8	10.0	11.0	75.2
18MAY	480	74.8	130	Tri-County Marina	1	99.2	9.2	11.2	71.6
		71.6	116	Tri-County Marina	7	94.0	11.0	12.0	72.3
		70.9	127	Tri-County Marina	5	96.1	10.0	10.6	70.9
19MAY	219	69.8	135	Falmouth PFC	1	99.3	10.6	9.0	62.6
		69.8	99	Tri-County Marina	3	97.0	11.8	10.6	70.7
21MAY	230	68.0	130	Tri-County Marina	3	97.7	8.6	11.2	68.0

Table 11. Continued.

TRANSPORTED FROM EAST LIFT

(continued)

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
21MAY	230	68.2	71	Tri-County Marina	1	98.6	9.4	10.4	68.4
22MAY	496	69.8	125	Columbia PFC	0	100.0	10.0	9.6	66.2
		69.8	128	Columbia PFC	3	97.7	9.2	9.9	66.2
		69.8	111	Tri-County Marina	0	100.0	12.2	10.2	68.9
		69.6	83	Tri-County Marina	1	98.8	12.7	11.4	69.8
23MAY	184	70.7	111	Tri-County Marina	0	100.0	10.0	10.8	71.6
24MAY	101	70.7	133	Tri-County Marina	9	93.2	8.6	10.0	70.2
25MAY	71	71.8	56	Tri-County Marina	0	100.0	12.0	11.0	72.0
26MAY	195	71.6	108	Tri-County Marina	1	99.1	10.0	14.2	72.0
27MAY	175	71.8	131	Tri-County Marina	4	96.9	10.0	10.5	72.9
28MAY	119	72.9	106	Tri-County Marina	0	100.0	10.5	14.0	75.2
29MAY	433	72.7	116	Columbia PFC	0	100.0	9.6	10.0	73.4
		74.8	105	Columbia PFC	0	100.0	8.8	9.7	73.0
		70.2	106	Tri-County Marina	13	87.7	11.0	14.2	71.2
		72.5	85	Tri-County Marina	0	100.0	10.0	10.0	69.8
31MAY	153	73.4	122	Tri-County Marina	0	100.0	8.2	9.7	73.6
		72.0	49	Columbia PFC	0	100.0	10.6	10.8	72.3
04JUN	54	74.3	54	Tri-County Marina	1	98.1	9.0	13.0	74.8
TOTALS			6983		518				

Table 11. Continued.

TRANSPORTED FROM WEST LIFT

DATE	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
06MAY	5	66.2	11	Tri-County Marina	0	100.0	14.1	5.0	66.2
08MAY	19	66.2	58	Tri-County Marina	0	100.0	10.4	10.6	68.0
10MAY	159	69.8	27	Pequea Cr. launch	0	100.0	12.6	11.4	69.8
		69.8	29	Bainbridge	0	100.0	10.8	10.4	68.5
		69.8	117	Tri-County Marina	3	97.4	10.4	10.6	69.8
11MAY	135	71.6	27	Peters Cr boat ramp	0	100.0	10.4	11.2	71.6
		71.6	90	Tri-County Marina	0	100.0	10.0	9.4	71.6
12MAY	74	71.2	28	Safe Harbor Forebay	0	100.0	12.0	13.3	71.6
13MAY	89	71.6	104	Tri-County Marina	1	99.0	12.0	11.2	71.6
15MAY	282	22.5	201	Columbia PFC	3	98.5	11.2	10.8	73.4
16MAY	1191	72.5	293	Tri-County Marina	31	89.4	11.5	10.5	66.2
		71.6	204	Tri-County Marina	5	97.5	12.0	10.6	64.4
		72.0	204	Tri-County Marina	3	98.5	11.2	9.9	65.3
		72.0	215	Tri-County Marina	4	98.1	9.4	8.8	64.4
17MAY	194	73.4	25	Bainbridge	0	100.0	10.2	11.0	73.4
		73.4	196	Tri-County Marina	18	90.8	10.9	11.3	73.4
19MAY	50	70.7	25	Peters Cr boat ramp	0	100.0	10.5	10.8	71.6
20MAY	207	68.9	35	York Haven Forebay	0	100.0	9.6	10.4	69.4
		68.4	164	Tri-County Marina	3	98.2	10.6	10.0	68.4
22MAY	338	69.8	195	Tri-County Marina	5	97.4	10.6	10.2	69.8
		68.9	142	Tri-County Marina	2	98.6	10.2	11.0	70.7
23MAY	439	69.8	140	Swatara Cr. PFC	3	97.9	10.4	10.7	70.7
		69.8	151	Tri-County Marina	0	100.0	11.0	10.6	70.7
24MAY	65	68.9	28	Bainbridge	0	100.0	10.2	10.3	69.8
		68.0	30	Pequea Cr. launch	0	100.0	9.0	11.0	68.0
		69.8	83	Tri-County Marina	6	90.4	10.6	11.4	69.8
25MAY	183	71.6	100	Tri-County Marina	1	99.0	11.8	11.0	71.6
26MAY	145	71.6	37	Holtwood Forebay	0	100.0	11.8	10.0	71.6
27MAY	85	71.6	30	Peters Cr boat ramp	1	96.7	10.2	11.8	71.6
28MAY	145	65.3	130	Tri-County Marina	4	96.9	10.1	9.8	66.2
		73.0	18	Safe Harbor Forebay	0	100.0	11.4	8.2	73.0
29MAY	196	66.2	10	Safe Harbor Forebay	0	100.0	8.0	9.1	66.2
		73.4	173	Tri-County Marina	5	97.1	9.8	10.0	73.4
30MAY	148	73.4	109	Tri-County Marina	3	97.2	10.2	11.0	73.4
31MAY	69	72.5	25	City Island	1	96.0	9.8	9.8	72.5
01JUN	28	72.5	30	City Island	0	100.0	8.0	8.4	72.5
		72.5	24	Bainbridge	1	95.8	9.3	9.8	72.5
02JUN	57	71.6	17	Bainbridge	0	100.0	9.7	8.8	71.6
05JUN	133	73.4	118	Tri-County Marina	6	94.9	8.4	9.2	73.4
06JUN	114	69.8	88	Swatara Cr. PFC	0	100.0	7.8	9.0	69.8
09JUN	42	73.8	70	Tri-County Marina	0	100.0	10.0	8.6	74.3
11JUN	59	77.0	53	Tri-County Marina	1	98.1	8.4	8.6	77.0
14JUN	48	77.0	80	Tri-County Marina	0	100.0	8.8	9.2	77.0
16JUN	48	78.8	39	Columbia PFC	0	100.0	7.6	7.4	78.8
TOTALS			3973		112				
TOTALS FOR SEASON			11171		643				

Table 12. Summary of transports of river herring from the Conowingo Dam Fish Lifts, 1993.

TRANSPORTED FROM WEST LIFT										
DATE	SPECIES	NO. COLLECTED	WATER TEMP (F)	NO. TRANSPORTED	LOCATION	OBSERVED MORTALITY	PERCENT SURVIVAL	DO (PPM) START	DO (PPM) FINISH	WATER TEMP (F) AT STOCKING LOCATION
06MAY	BLUEBACK HERRING	435	66.2	662	Tri-County Marina	0	100.0	14.1	5.0	66.2
08MAY	BLUEBACK HERRING	236	66.2	323	Tri-County Marina	0	100.0	10.4	10.6	68.0
	ALEWIFE	-	66.2	161	Tri-County Marina	0	100.0	10.4	1C.6	68.0
10MAY	BLUEBACK HERRING	126	69.8	100	Tri-County Marina	0	100.0	10.4	10.6	21.0
	ALEWIFE	-	69.8	42	Tri-County Marina	0	100.0	10.4	10.6	69.8
13MAY	BLUEBACK HERRING	285	71.6	9	Tri-County Marina	0	100.0	12.0	11.2	71.6
24MAY	BLUEBACK HERRING	6	69.8	6	Tri-County Marina	0	100.0	10.6	11.4	69.8
25MAY	BLUEBACK HERRING	2	71.6	1	Tri-County Marina	0	100.0	11.8	11.0	71.6
29MAY	BLUEBACK HERRING	30	73.4	1	Tri-County Marina	0	100.0	9.8	10.0	73.4
30MAY	BLUEBACK HERRING	34	73.4	28	Tri-County Marina	0	100.0	10.2	11.0	73.4
TOTALS FOR SEASONS				1333		0				

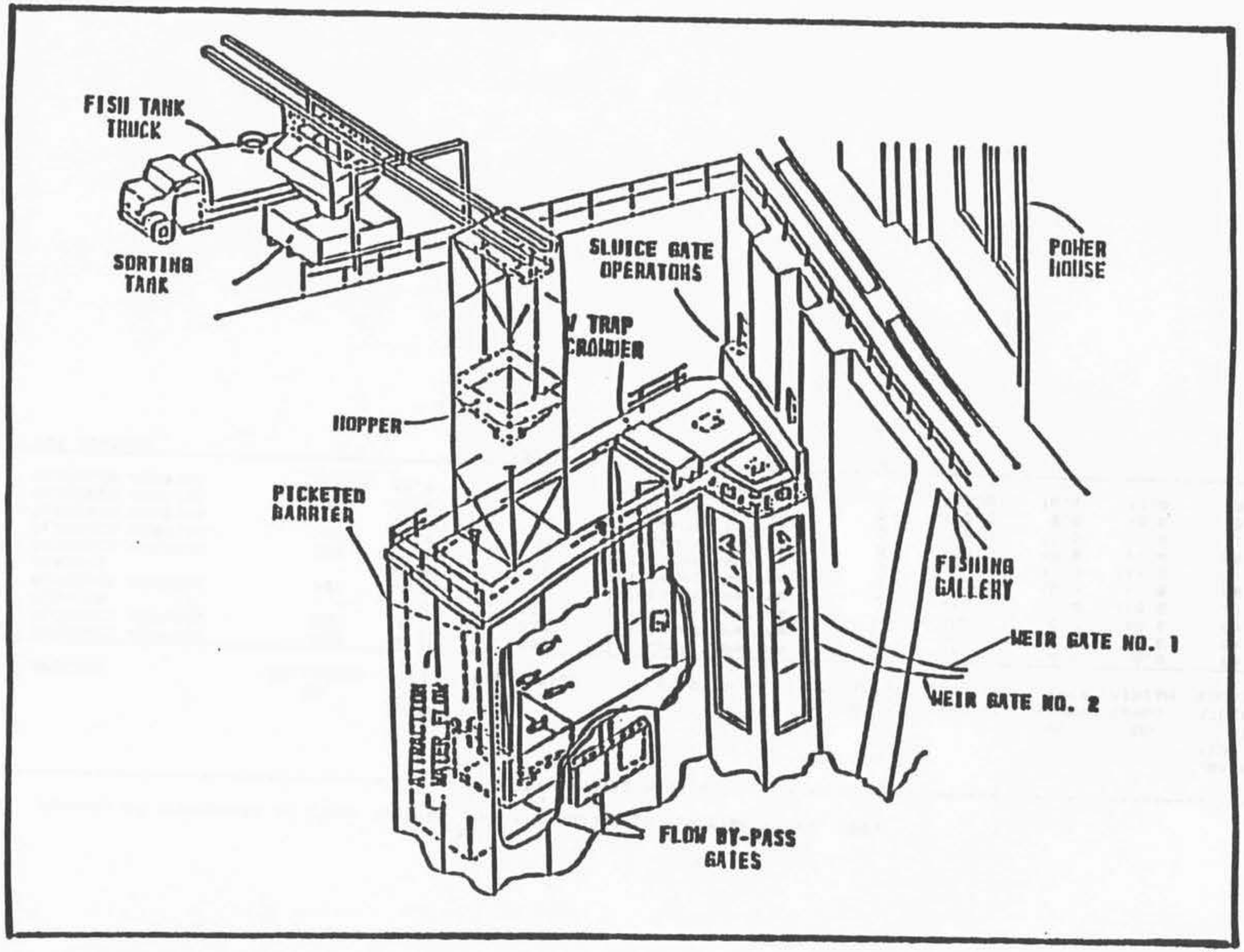

Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

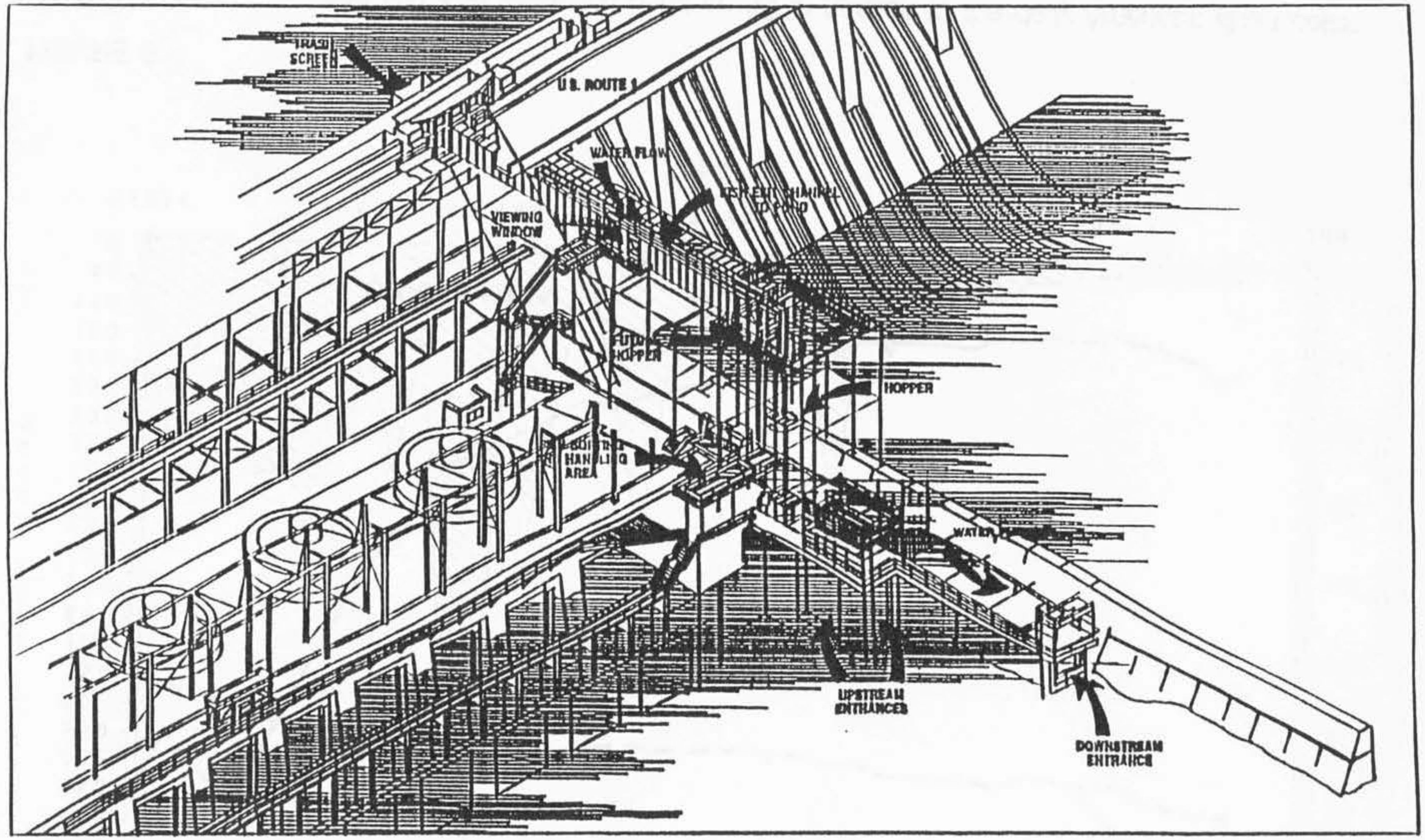

Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

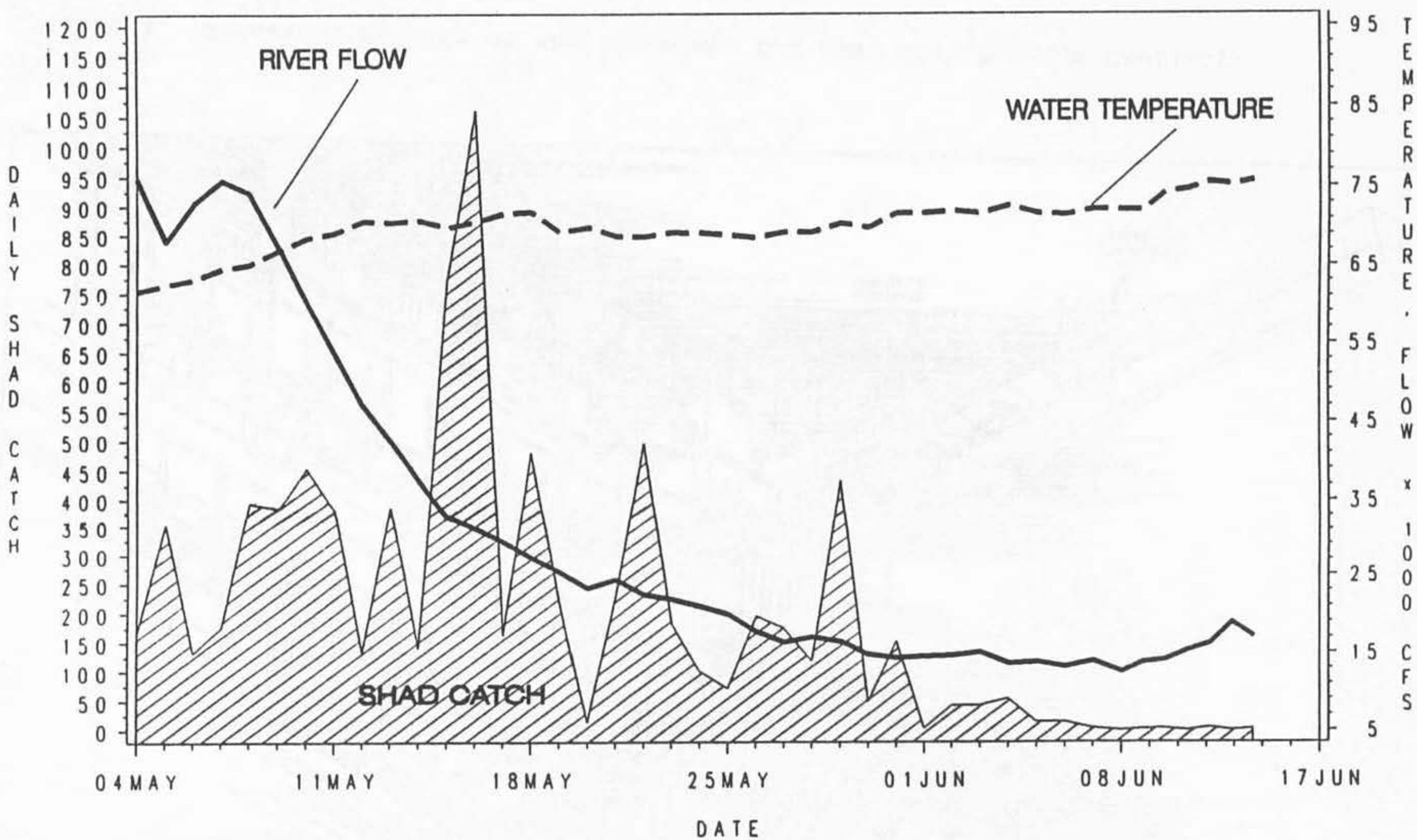

FIGURE 3

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, 1993.

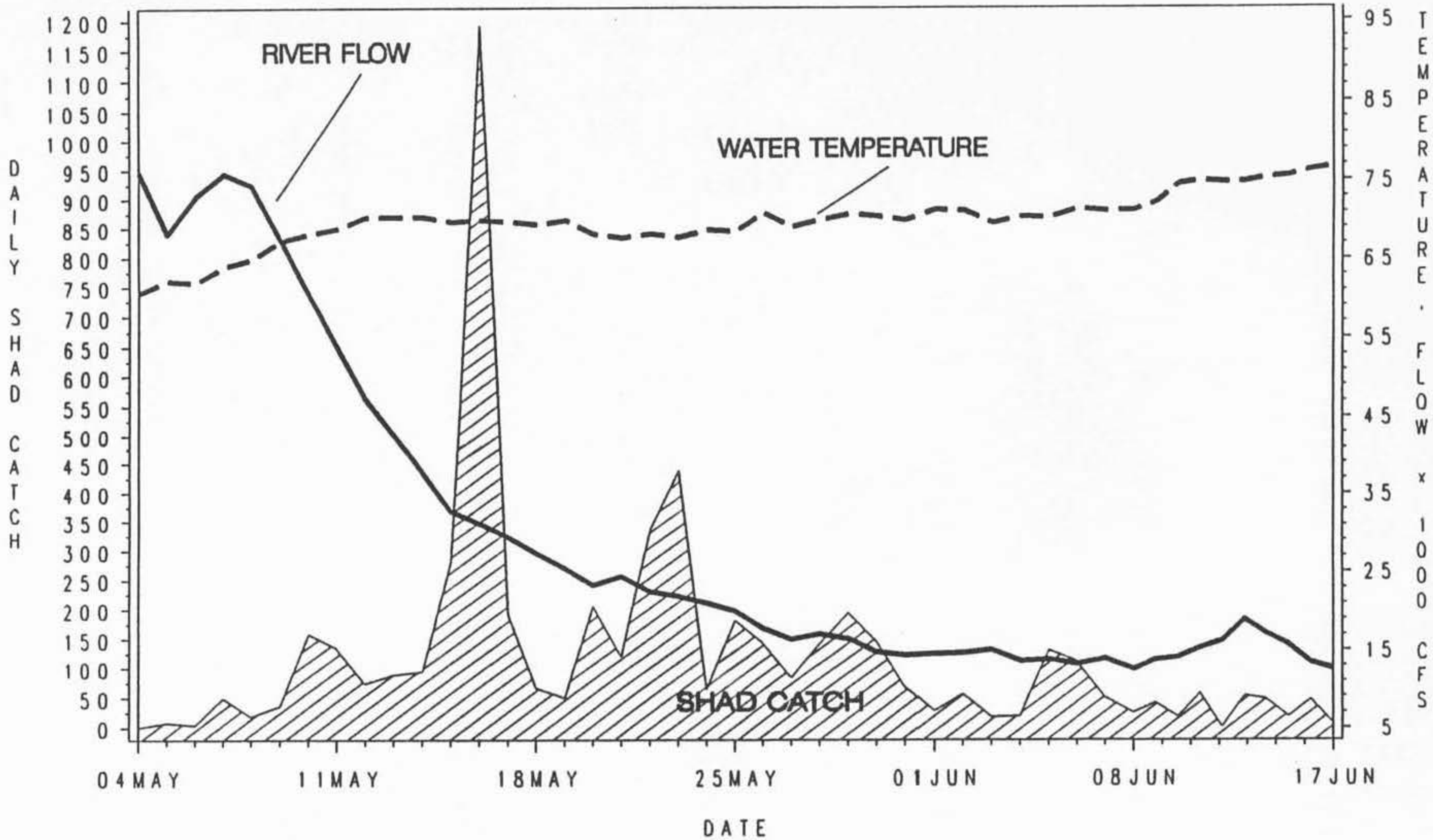

FIGURE 4

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, 1993.

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 1993. The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) goal for 1993 was to obtain a minimum of 30 million shad eggs over a two month period (May-June). In the last 20 years (1973-1993) 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 416 million eggs have been obtained (Table 1). Annual production has ranged from 11 million to 52 million eggs per year.

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 1993 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 or not 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 1 hour), the water is decanted through the mouth of a filtering cloth (approximately 2.0 millimeter aperture) held over the rim of the egg container and five liters each of eggs and clean river water are 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 which has 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 running ripe 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.

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 which 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 which reverses direction every 4-6 hours. For a short period of time, 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 which 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. 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 in order 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 1993 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 10 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 1993 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 in the vicinity of the Holyoke Dam. Because of potential, extensive research for new spawning areas was continued during the spring of 1991. Based on the 1991 experience, effort continues to be conducted between Turners Fall and Sunderland, MA at river miles 187 to 189. Shad were captured by drifted gill-nets. Biologists from Normandeau Associates (Bedford, New Hampshire) directed 1993 Connecticut River egg collection efforts.

RESULTS OF 1993 FIELD COLLECTION EFFORTS

This section provides the results of the efforts in the spring of 1993. 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)

A total of 9.3 million eggs were shipped to the Van Dyke Hatchery on fourteen dates (Table 3). The first shipment was on 10 May and the last on 3 June. Ripe shad were caught at water temperatures which ranged from 57 to 63 °F (mean = 60 °F). Up to 120 shad were captured per night. The total number of shad captured was 1,069.

In 1993, monofilament gill-nets 600-foot x 6-foot with 4.5 inch 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.

A total of 2.97 million eggs was obtained on the Hudson River (Table 4). This included 1.41 million eggs from shad captured by gill-net and 1.57 million eggs from shad captured by haul seine. The Hudson River egg collection program began on 8 May and continued until 26 May, a period of 18 days. In this period, the program included 14 efforts of gill-netting and six efforts of haul seining.

The Wyatt Group field crew initiated field sampling by gill-net off Cheviot, NY on 8 May when the water temperature was 57 °F. For the next nine days (8-17 May) eggs were collected at Cheviot. Then, 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 18-23 May. A second crew utilized drift and stake nets in conjunction with the haul seining effort.

Connecticut River (Massachusetts)

Normandeau Associates began Connecticut River collection efforts on the night of 24 May with a shipment of 11 liters of eggs. A total of 7.44 million eggs was collected and delivered to the Van Dyke Hatchery (Table 5). The Maine Department of Marine Resources and Maryland Department of Natural Resources were provided with .60 million eggs and .45 million eggs respectively. Collection was terminated on 15 June.

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 2300 hours). Water temperature and river flow influence the success of egg collection operation on the Connecticut. River flow can impact the ability to collect eggs on the Connecticut. When flows increase dramatically, shad spawning diminishes and egg collection drops.

Summary of Egg Collection

The total number of eggs delivered to the Van Dyke Hatchery in the spring of 1993 was 19.7 million eggs. An additional 1.05 million eggs were collected and provided to co-operative programs between SRAFRC and resources agencies of Maine and Maryland. The production goal was not reached on any of the rivers.

Results on the Hudson River were much less than anticipated based on previous years experience. This is attributable to several factors. Commercial fishermen (Lake & Nack) reported a 80% decrease in the amount of fish taken from five years ago. River temperatures on the Hudson remained relatively cool at the end of April. Several days of extremely hot weather during the first week of May accelerated the water temperature by

8 °F, which may have shortened the spawning period. The 1993 season was characterized by relatively poor catches that can be seen as part of downward trend (Table 6).

Daily production on the Connecticut River was not as high as the previous year and it has been reported that American shad passing Holyoke Dam have decreased as much as 50% between 1992 and 1993.

TABLE 1. Total number (millions) of American shad eggs collected from various rivers and delivered to the Van Dyke Hatchery, 1980-1993.

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
TOTALS	73.73	56.30	14.25	201.33	70.74	416.32

*Primarily the Pamunkey River and the James River.

TABLE 2. Collecting periods for eggs of American shad, 1993.

River	Dates	Fishing Efforts
Delaware	10 May - 3 June	18
Hudson	8 May - 26 May	20
Connecticut	20 May - 15 June	24

TABLE 3. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1993.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May 10	22.0	732,608	12	61	62.8
11	12.8	724,735	14	63	34.5
13	35.7	855,820	16	63	55.4
16	24.5	798,440	19	63	45.9
17	14.1	430,292	21	61	75.4
18	15.8	543,302	22	59	75.4
19	10.2	354,484	23	56	41.1
23	21.5	656,120	28	57	68.9
24	12.2	401,912	29	59	63.2
25	15.7	605,535	31	61	60.7
26	20.9	982,689	33	63	59.3
27	13.6	651,789	35	63	61.6
June 2	21.2	784,632	40	59	56.5
3	14.3	780,837	42	59	47.1
Total	254.5	9,303,194	Mean =	60	57.0

TABLE 4. Collection data for American shad eggs taken on the Hudson River, New York, 1993.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability	Gear
May 10	8.4	267,864	13	58	76.7	Gill
11	4.8	146,483	15	59	56.8	Gill
13	11.6	386,284	17	60	75.4	Gill
15	9.4	393,065	18	57	79.4	Gill
16	6.5	209,545	20	58	76.1	Gill
19	10.1	377,704	24	61	81.4	Seine/Gill
20	15.2	545,228	25	60	85.1	Seine
21	9.8	326,344	26	63	79.9	Seine
22	8.9	319,245	27	64	85.1	Seine
Total	84.7	2,971,763	Mean =	60	79.2	

TABLE 5. Collection data for American shad eggs taken on the Connecticut River, Massachusetts, 1993.

Date	Volume Eggs (liters)	Number of Eggs	PFC Shipment Number	Water Temp. (°F)	Percent Viability
May 24	11.4	430,745	30	61	88.1
25	11.0	358,483	32	61	76.9
26	10.2	439,398	34	61	81.3
27	14.0	462,000	36	61	0.0
28	10.0	* Delivered to Maine DMR			
29	12.2	557,290	37	61	64.0
30	15.2	924,152	38	60	68.8
31	13.2	591,375	39	61	75.3
June 2	7.4	520,616	41	58	67.8
3	12.0	** Delivered to Manning Hatchery			
4	6.4	402,971	44	63	41.2
5	8.1	366,435	45	62	40.9
7	11.0	522,178	46	63	19.2
8	13.1	553,259	47	63	68.5
9	6.8	290,050	48	64	43.7
10	8.8	390,422	49	64	77.9
11	11.8	483,627	50	65	71.9
12	4.8	259,716	51	67	74.1
14	5.0	215,391	52	69	65.4
15	1.6	67,574	53	68	43.9
Total	204.1	7,835,682		Mean = 63	58.5

*Obtained for Maine Department of Marine Resources.
*Obtained for Maryland Department of Natural Resources.

TABLE 6. Commercial landings of American shad in the Hudson River, New York & New Jersey 1915 - 1991. Source: New York Department of Environmental Conservation.

Year	Total (lbs)	Year	Total (lbs)
1915	68,668	1956	1,681,166
1916	40,173	1957	1,497,680
1917	43,384	1958	1,045,765
1918	234,602	1959	1,171,212
1919	374,974	1960	723,572
1920	199,844	1961	588,989
1921	130,803	1962	527,680
1922	175,186	1963	348,018
1923	121,728	1964	181,865
1924	94,369	1965	237,521
1925	124,334	1966	116,332
1926	265,420	1967	176,358
1927	358,055	1968	254,372
1928	246,231	1969	243,104
1929	196,745	1970	231,571
1930	206,504	1971	170,798
1931	414,611	1972	288,760
1932	539,754	1973	251,601
1933	518,680	1974	231,631
1934	438,000	1975	224,126
1935	847,400	1976	212,279
1936	2,467,900	1977	184,054
1937	2,732,200	1978	417,448
1938	2,467,000	1979	490,150
1939	3,270,700	1980	1,296,970
1940	3,114,400	1981	583,306
1941	3,133,500	1982	345,793
1942	3,185,900	1983	487,624
1943	3,225,350	1984	644,644
1944	3,809,400	1985	733,492
1945	3,477,200	1986	734,766
1946	2,972,143	1987	639,305
1947	1,981,792	1988	698,532
1948	2,354,400	1989	415,217
1949	1,727,370	1990	378,383
1950	1,008,900	1991	301,579
1951	764,100	1992	252,835
1952	1,077,100		
1953	938,722		
1954	1,249,286		
1955	1,510,340		

JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1993

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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 1993 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 1993 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources. Research conducted in 1993 involved comparison of egg viability for Delaware River eggs held until 8:00AM before processing vs controls processed immediately upon arrival at Van Dyke.

EGG SHIPMENTS

A total of 21.5 million eggs (559 L) were received in 53 shipments in 1993 (Table 1). This represented the second lowest number of eggs received since 1981 (Table 2), despite the fact that more shipments were received at Van Dyke than ever before. Overall egg viability (which we define as the percentage which ultimately hatches) was 58.3%. Eleven shipments of egg were received from the Pamunkey River (1.8 million eggs) with a viability of 40.5%. Fourteen shipments of eggs were received from the Delaware River (9.3 million eggs) with a viability of 57.0%. The Hudson River produced 9 shipments (3.0 million eggs) with a viability of 79.2%. Eighteen shipments of eggs were received from the Connecticut River (7.4 million eggs) with a viability of 59.0%.

SURVIVAL

Overall survival of fry was 66%, compared to 41% in 1992 and a range of 70% to 90% for the period 1984 through 1991. Survival of individual tanks followed three patterns (Figure 1). Twenty tanks exhibited 18d survival averaging 84%, typical of survival in the past. Fourteen tanks suffered high mortality between 9 and 14 days of age which resulted in mean 18d survival of approximately

60%. The remaining 10 tanks exhibited even greater mortality between 9 and 14 days of age, resulting in 18d survival of 32%.

Early indications were that the mortality problems experienced in 1992 (Hendricks et al., 1993) would not be repeated. The first eight tanks reared in 1993 exhibited survival exceeding 79%.

On May 24, numbers of 7d old larvae in tank C31 were found floating on the surface of the tank with gas bubbles in the digestive track. Several other tanks also exhibited floating larvae, but less severe than in C31. No saturometer was available but gas bubble disease due to nitrogen supersaturation was suspected. Two additional packed-column degassers (total of 7) and two minnow-mizers were installed to deal with the problem. By the next day, no larvae were found floating and total dissolved gas was 103.04%. While total dissolved gas of 103% is typical of that found at Van Dyke over the last few years, levels as low as 102% have been found to cause gas bubble disease (Piper et al., 1982). Despite the mortality of several thousand larvae due to gas bubble disease, survival in tank C31 was 89.8%, seventh highest overall. Highest daily mortality for C31 was less than 2%, not typical of the severe mortality experienced in 1992. A small number of floating larvae were observed again on June 4 in tank E21. Total dissolved gas was 103.29% and no other tanks were affected.

To further reduce total dissolved gas, an oxygen injection system was installed on June 14. Total dissolved gas was measured at several locations over the next three days and ranged from 98.02 to 101.45%.

The first tank to experience severe mortality problems was tank E11. On May 29, at 7d of age, when mortality is normally low, this tank experienced 5.7% mortality. On June 1, Tank D31 experienced 16% mortality at 12d of age. Tanks E21, F21 and G41 experienced abnormally high mortalities on June 3 and 4. By Monday, June 7, it was clear that the mortality problems of 1992 were re-occurring. Unfortunately, we were at our busiest time. Egg shipments were still arriving daily from the Connecticut River and stocking of the first larvae had begun. On June 8, we initiated a hastily conceived study to learn what we could about the cause of these mortalities.

The goal of the study was to record incidence of feeding and intestinal gas bubbles to attempt to determine the age at the onset of the mortality problems and the relationship between feeding and gas bubbles to the mortalities. Samples of 50 to 100 larvae were collected from selected tanks in the afternoon, several hours after feeding had begun. The larvae were examined under a dissecting microscope for the presence of feed and/or gas bubbles in the intestine. Feed and gas bubble data was recorded as presence or absence, without quantification.

A total of 216 samples were collected from 26 different tanks. In the early stages of the study, sampling was limited due to time constraints. As more tanks were stocked out, more time was available and more sampling was conducted. Six tanks were sampled nearly every day from 4 or 5d of age to stocking.

Incidence of Feeding

Tanks were grouped according to percent survival, and daily mean incidence of feeding was plotted for each group in Figure 2. Tanks with low survival also exhibited low incidence of feeding on days 4 through 9. This implied that the observed mortality problems were related to feeding and occured at or before first feeding at 4 or 5d of age. From day 11 on, incidence of feeding in these tanks was similar to that in tanks with high or moderate survival. This was probably due to the fact that most non-feeding larvae die before 11d of age.

Tanks with high survival exhibited only 10% incidence of feeding on day 4. This anomalous result was due to the fact that only one of the five tanks in the high survival group was sampled at 4d of age.

The relationship between incidence of feeding and survival was further explored by plotting the incidence of feeding against survival for larvae at each age from 4 to 7d of age. At 4d of age, no relationship was apparent, but at 5, 6, and 7d of age there was a clear relationship. Since all three plots were similar and we were interested in predicting survival as early as possible, only the plot for 5d of age was presented (Figure 3). We regressed incidence of feeding at 5d of age and the natural log of incidence of feeding at 5d of age against survival. A better regression was obtained using the natural log (r-squared = 0.76) and that regression was also plotted in Figure 3. The implications of this regression were difficult to believe. Incidence of feeding at 5d of age varied from 10 to 100% with little impact on survival, but small changes in incidence of feeding below 5% resulted in very large changes in survival. One tank exhibited no feeding at 5d of age and 0% survival. If we consider this tank to be an outlier and omit it from the analysis, the regression becomes much more straight and makes more intuitive sense.

Since incidence of feeding data was available, we related it to tetracycline marking to determine if marking impacted incidence of feeding. We used a sign test (Ott, 1977) to compare incidence of feeding on the day of marking to incidence of feeding the previous day for those tanks in which data was available. There were 10 cases where tanks exhibited increased feeding during marking and 18 cases where tanks exhibited decreased feeding during marking. These results were not statistically significant at the .05 level ($z= 1.51$, $zcrit= 1.96$). Despite the fact that we were unable to show it statistically, we suspect that tetracycline marking does result in some decrease in incidence of feeding, however, there was no indication that marking causes mortality. First, millions of larvae in hundreds of tanks were marked from 1985 to 1991 with no increase in mortality. Second, identically marked tanks vary in survival from 0 to 90%.

Incidence of gas bubbles

Mean incidence of gas bubbles in the intestinal tract of American shad larvae declined gradually from 17.3% at 4d of age to 1.7% at 20d of age. Least squares regression resulted in a prediction line of $Y= 17.63 -0.71X$ where Y was the incidence of gas bubbles (%) and X was age in days (r-squared = 0.63, Figure 4). Incidence of gas bubbles at age was plotted against survival for ages 4 through 11 (days). All plots resulted in scatters whic. exhibited no relationship between incidence of gas bubbles anc survival. While the cause of these gas bubbles is unknown there appears to be no relationship between the occurrence of gas in the intestinal tract and survival.

Water Quality Analysis

The fact that some tanks exhibited high survival, while other concurrently reared tanks exhibited low survival, implied that water quality was not causing the mortalities. However, as a precautionary measure, and to eliminate water quality from further concern, 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 on August 3. Tests were conducted for 24 heavy metals, 46 base/neutral extractables and 11 acid extractables. For the heavy metals, only barium, calcium, magnesium and sodium were above detectable limits. None approached toxic levels. For the semi-volatiles, all compounds were below detectable limits. This confirmed that Van Dyke source water is extremely pure and the mortalities were not related to water quality.

Pathology

Pathology reports from 1992 indicated an abundance of etracycline resistant, motile aeromonads present in the gut of arval American shad (Hendricks el al., 1993). Aeromonad ıfections have been linked to American shad mortalities in the ld (Haley et al., 1967). Based on the 1992 pathology data, we ıld not conclude whether the aeromonad infections were primary (causative) or secondary to some other causative factor.

Three bacterial samples were collected in 1993. The first sample was collected in tank B21 (survival 79.5%) on May 13 (before mortality problems became evident). The larvae were examined and no abnormalities or pathogens were observed. Only a few motile bacteria were noted, unlike the 1992 samples in which motile bacteria were extremely abundant. Ten bacterial cultures were obtained from these larvae. Four were motile aeromonads, one was a gram positive bacillus, and five were miscellaneous gram negative bacilli, predominantly non-motile. The motile aeromonads were sensitive to terramycin and neomycin, unlike the 1992 cultures which were resistant to terramycin. Four of the six other cultures were also sensitive to terramycin. These data suggested that the bacterial flora in B21 was more representative of normal bacterial flora than the cultures obtained in 1992.

The second bacterial sample was collected on June 10 from a tank which was exhibiting abnormally high mortalities. Twenty representative colonies were selected for identification. Eight colonies were identified as Pseudomonas fluorescens, 6 colonies were Enterobacter agglomerans, and 2 colonies were Acinetobacter spp. There was also one colony each of Aeromonas hydrophila, Pseudomonas alcaligenes, Pseudomonas spp., and Klebsiella spp. Drug sensitivities suggested that the majority of these were susceptible to terramycin (Pseudomonas fluorescens, 6 colonies; Enterobacter agglomerans, 4 colonies; Acinetobacter spp, 1 colony; Pseudomonas alcaligenes, 1 colony; Pseudomonas spp., 1 colony; and Klebsiella spp, 1 colony). Since tetracycline had been used to mark the otoliths in these fish, most of the bacteria had probably not been present long enough to be associated with the observed mortalities. This suggested that bacterial infections were not the primary cause of the observed mortalities.

A third group of samples was collected on June 21. Three tanks were sampled: tank J31, 11d of age, 68% survival; tank J41, 11d of age, 0% survival; and tank A42, 8d of age, 32% survival. Viral assays for all three tanks were negative. Microscopic examination revealed that fish from tank J41 (high mortalities) were devoid of food, while those from J31 and A42 had some food or brine shrimp cysts in the gut. Motile bacteria were present in the intestines of fish from all three tanks. Histological evaluations revealed the presence of large numbers of bacteria in the intestines of all three groups of fish. The groups with high mortalities (tanks J41 and A42) had large numbers of bacteria in the lumen, areas where bacteria were attached to the intestinal epithelium, and sloughing of the intestinal epithelial cells. The bacterial species associated with these epithelial changes could not be identified, and it was not clear whether these changes were the cause of the reduced feeding and mortalities, or whether they were secondary to some other factor.

Bacterial cultures were obtained from 3 larvae from each tank. A total of 52 pure cultures were isolated. Identification of these cultures was attempted but apparently errors were made in cytochrome oxidase tests and the results were inconsistent. While the resultant identifications were suspect, it was possible to say that there were no major differences in the bacterial flora between the three tanks. Additionally, unlike the first two samples, the majority of the cultures in the third sample were terramycin resistant (J41, 7 of 9; J31, 13 of 17; A42, 12 of 14). It was apparent that a general change occurred in the ratio of the types of bacteria present between the second (June 10) and third (June 21) samples. The fact that there was no apparent difference in the bacterial flora between the three tanks with different levels of mortality suggests that the bacterial infections were secondary to some other causative factor.

Anecdotal information on aeromonad infections has been provided by Sam Chapman (pers. comm.) who operates a small American shad hatchery in Waldoboro Maine. Mr. Chapman noted a kill of tadpoles his hatchery water supply pond. The tadpoles were found rolling on the surface of the pond. They were spotted with open sores, obvious gas bubble disease and were very stressed. Pathology reports from the University of Maine isolated Aeromonas hydrophila. Despite this problem in his source water, Mr. Chapman noted no problems with the American shad in tanks in his hatchery building. He did experience a minor problem with gas in the intestines of American shad larvae in early tank culture. He attributed it to over feeding of AP-100. This also suggested that Aeromonas infections were secondary to some other causal factor.

Use of foam bottom screens on egg jars

Egg shipment 40 (Delaware River eggs) was received on June 3, 1993 and assigned to a research project to determine the affect of delaying processing of eggs until 8:00AM on egg viability (see Appendix 1). Eggs 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. At 18d of age tank J31 was stocked with total 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. 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 recall that some new screens were constructed in 1993 and used for the first shipments. Coincidentally, 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 is related to the unexplained mortalities in 1992 and 1993. We further speculate that the foam may have reacted with sunlight, ozone or iodophor disinfectant to produce toxic substances or that the foam may have broken down and given off minute particles which clogged the digestive tract or otherwise interfered with feeding.

FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 8.4 million. A total of 6.5 million was released in the Juniata River and 790 thousand in the Lehigh River. Some 539 thousand fry were transferred to the Virginia Department of Game and Inland Fisheries for release in the James River. An additional 515 thousand were transferred to ponds in Pennsylvania and Maryland for grow-out and release as fingerlings. Fifteen thousand were transferred to the National Fishery Research and Development Lab in Wellsboro to be used in research, and seven thousand were transferred to Benner Spring raceways 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 were assigned a triple mark on days 3, 13, and 17. Hudson River fry were assigned a triple mark on days 5, 9, and 13. Connecticut River fry were assigned a quintuple mark on days 5, 9, 13, 17, and 21; except two tanks of fry which received a single mark on day 5 and were stocked on day 7. One tank of Connecticut River fry received experimental marks by 2h immersion on days 9 and 17, in addition to 6h immersions on days 5, 13 and 21.

Analysis of otoliths from juvenile American shad collected in the Susquehanna River in 1993 revealed several specimens with marks that did not correspond to the assigned marking regime (see JobIV). We explored the possibility of an error in marking by comparing various data records kept during the rearing season. These records included a wall chart kept to track egg shipments and tank dispositions, a computer generated daily record of TC treatments and associated water quality data, a record of tetracycline inactivation in our small pond, and a running record of tetracycline inventories. The first three of these records correspond to the assigned TC marking regime for all tanks, however the last suggests the possibility of an error in marking. On June 12, four tanks were to have been marked, including tank I21. On the tetracycline inventory record, tank H21 is listed as marked instead of tank I21. If that were true, tank H21 (Delaware River) would have been marked at 3, 11, 13, and 17 days of age and tank I21 (Connecticut River) would have been marked at 5, 13, 17, and 21 days of age. Since the juvenile shad collections recovered 3 shad with marks on days 3, 11, 13, and 17 and 2 shad with a mark on days 5, 13, 17, and 21, we believe that such an error did occur.

American shad fry transferred to Maryland DNR for fingerling culture and release below Conowingo Dam received a double immersion mark at five and nine days of age. All fingerlings released in Pennsylvania received additional marks by feeding tetracycline laced feed. These fish received immersion marks based upon egg source river and unique multiple feed marks for each culture pond (Table 5).

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 immersion marks for American shad was 100% for all groups analyzed, including the experimental 2h marks (Table 6). Small numbers of fish (3-12%) in the Canal Pond and Upper Spring Creek Ponds 2 and 3 did not exhibit the attempted feed mark. These fish were characteristically smaller fish which probably subsisted on natural forage and did not ingest enough treated feed to produce a mark. Maryland DNR ponds in Elkton contained small numbers of juvenile blueback herring which probably entered the ponds via the influent. Sub-samples of these herring were examined for marks and none were found. All American shad otoliths from these ponds exhibited the expected mark.

FINGERLING PRODUCTION

American shad fingerlings were produced in the Canal Pond (Thompsontown) and Upper Spring Creek Ponds. A mark-recapture population estimate was conducted prior to the release of fingerlings from the Canal Pond. Specimens were collected for marking using a conical lift net similar to the one described by Backman and Ross (1990). The lift net was 6 feet (1.9 m) in length and measured 60 inches (1.5 m) in diameter at the top. It was tapered to 29 inches (.7 m) in diameter, 4 feet (1.2 m) from the top. The bottom 24 inches (.6 m) was tapered to fit over a 5 gal.

bucket. The net was mounted on the kettle at the deep end of the pond. Juvenile American shad were attracted above the net by feeding and, using a tripod and boom, the net was lifted to capture the fish in the 5 gal. bucket. The fish were then poured from the 5 gal. bucket into a circular fiberglass tub. They were then transported by truck to the influent end of the pond where they were water brailed and hand-counted into a 5 foot diameter tank. Circular fresh water flow to the tank was established using the pond influent supply and appropriate plumbing fixtures. After approximately 16h, fish which suffered handling mortality were removed and counted. Water level in the tank was lowered to 30 inches, and 73.2g Bismark Brown was added to achieve a concentration of 53 mg/L. Pure oxygen was bubbled into the tank and after a 20 min. immersion, the dyed fish were released into the center of the pond. After waiting several hours for the dyed fish to mix with the population, recapture samples were collected by lift net and the number of marked and unmarked specimens recorded. Drawdown of the pond continued during the recapture sample.

A total of 1,485 juvenile shad were collected in 9 marking lifts. The net appeared to work well and cause little damage or scale loss. Prior to marking, 65 dead (4.4%) were removed from the tank, leaving 1,420 fish for marking. The first four recapture lifts included 17 marked and 989 unmarked specimens, resulting in a population estimate of nearly 88,000 (Everhart et al., 1975). The next five recapture lifts included 45 marked and 1008 unmarked specimens, resulting in a population estimate of 35,400 fish (corrected for the release of the fish from the first four lifts). It is apparent that for the first four lifts, the marked fish (released in mid-pond) had not fully mixed with unmarked fish.

Continued drawdown of the pond during recapture sampling forced the marked fish into the kettle area for the latter five lifts. Therefore, we have chosen to utilize data from the last five lifts only, resulting in a population estimate of 35,400. Ninety-five percent confidence interval was 25,249-45,464.

The Canal Pond was harvested in the same manner as in 1992. 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. The pond was then drained slowly by removing front and rear boards until five front boards remained. At this point the front five boards were removed giving the fish access to the kettle. Water depth was approximately 30 to 36 inches in front of the kettle and 54 to 60 inches in the kettle itself. Juvenile shad were then lured into the kettle using feed. When a large school of shad entered the kettle, boards were reinstalled in front of the kettle trapping the fish. The quick-release was then activated and the kettle 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 kettle allowed to 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 definitely the most successful Canal Pond harvest to date. A very large number of healthy fish were released with very little mortality. Within 2 hours of release we began feeding the fish in Delaware Creek. Tens of thousands of fingerlings could be seen aggressively feeding in dense schools. We consider the 1993 Canal Pond effort to be the standard by which such efforts should be judged.

UPPER SPRING CREEK

The three Upper Spring Creek ponds were stocked with approximately 76,000 22d old fry each on June 8, 1993. The fish did quite well, and at 35 days of age, supplemental feeding was initiated. There were no problems experienced during the rearing period.

A total of 44,000 fingerlings were released into the Juniata River, at Thompsontown, from the Upper Spring Creek ponds in 1993. The fish were 2-4 inches in length and were in good condition. Pond #3 was harvested on September 15, 1993. A mark-recapture population estimate was conducted using the procedures described by Hendricks and Bender (1993). A total of 941 fish were marked. Of the 1,601 fish in the recapture sample, 65 were marked, giving an estimate of 23,177 fish as the pond population. During transport, approximately 5,000 fish were lost, presumably due to overcrowding in some of the compartments. Fish numbers were reduced in succeeding transports and no further losses were encountered. It was estimated that a total of 18,000 live fish were released into the Juniata River from Pond #3.

A population estimate was also done on Pond #2. A total of 1,046 fish were marked. Of the 1,516 fish in the recapture sample, 115 were marked, yielding a total pond population estimate of 13,789 fish. Approximately half the fish were stocked on September 23 and half on September 24; a total of 14,000 from Pond #2.

Approximately 12,000 fish were stocked from Pond #1; 7,000 on October 8, and 5,000 on October 12. A population estimate was not done on Pond #1, but the total number of fish was estimated visually, based on the two previous mark-recapture estimates.

A grand total of 49,000 fingerlings were produced in the Upper Spring Creek Ponds in 1993, representing 21.3 percent survival from fry to fingerling. Of those fish produced, 44,000 were released, in good condition, into the Juniata River at Thompsontown.

SUMMARY

A total of 53 shipments (21.5 million eggs) was received at Van Dyke in 1993. Total egg viability was 58.3% and survival to stocking was 66%, resulting in production of 8.4 million fry. The majority of the fry were stocked in the Juniata River (6.5 million). Fry were also released in the Lehigh River (790 thousand), and the James River (539 thousand released by the VDGIF). A total of 79,400 fingerlings were produced at Thompsontown and Upper Spring Creek and stocked into the Juniata River. An additional 100,000 American shad and blueback herring fingerlings were produced in Maryland DNR ponds at Elkton, and released directly into receiving waters.

Overall survival of fry was 66%, up from 41% in 1992. Survival was negatively impacted by re-occurrence of the mortality problems which occurred in 1992. Data collected in 1993 suggests that the problem was related to feeding and occured at or before first feeding at 4 or 5d of age. There was evidence that re-use of old open cell foam bottom screens in Van Dyke incubation jars may have been the cause of the problem.

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 Elkton and released below Conowingo Dam received a double immersion mark on days 5 and 9. Fingerlings grown-out in Pennsylvania ponds received additional multiple feed marks unique to each individual pond.

Retention of tetracycline marks was 100% for immersion marks, but feed marks were not retained in some specimens.

Delaware River American shad eggs exhibited no significant difference in viability when processing was delayed until 8:00 AM as compared to controls which were processed immediately upon arrival at Van Dyke.

Mark-recapture population estimates were attempted for fingerling shad reared in the Canal Pond and Upper Spring Creek Ponds 2 and 3. An estimated 35,400 fingerlings were released from the Canal Pond, 5,000 from Upper Spring Creek Pond 1, 14,000 from Upper Spring Creek Pond 2, and 18,000 from Upper Spring Creek Pond 3.

RECOMMENDATIONS FOR 1994

1. Continue to disinfect all egg shipments at 80 ppm free iodine.
2. Utilize Maryland's Manning Hatchery for production of marked fry and fingerlings for release below Conowingo Dam.
3. Continue to feed all ponded fingerlings by hand in addition to automatic feeder to ensure complete TC mark retention.
4. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
5. Investigate the effect of new vs. used foam bottom screens in Van Dyke jars.
6. Continue to siphon egg shells from the rearing tank within hours of egg hatch.
7. Continue to disinfect all hatchery equipment between use in each rearing tank.
8. Continue to utilize separate sets of equipment for hatchery work and outdoor work (ponds, river stocking).
9. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
10. Continue to conduct mark-recapture population estimates for pond fingerlings prior to harvest.
11. Alter egg processing protocol to delay processing of Virginia and Delaware River eggs until 8:00AM.

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Table 1. American shad egg shipments recieved at Van Dyke, 1993.

Shipment No.	River	Date Shipped	Date Recieved	Vol. Received (L)	Eggs	Viable Eggs	Percent Viable
1	Pamunkey	4/13/93	4/14/93	4.1	174,883	0	0.0%
2	Pamunkey	4/15/93	4/16/93	3.1	101,027	30,237	29.9%
3	Pamunkey	4/17/93	4/18/93	4.1	133,616	91,797	68.7%
4	Pamunkey	4/18/93	4/19/93	2.4	85,189	22,832	26.8%
5	Pamunkey	4/24/93	4/25/93	4.1	119,661	23,655	19.8%
6	Pamunkey	4/25/93	4/26/93	10.7	301,878	151,519	50.2%
7	Pamunkey	4/26/93	4/27/93	3.6	112,312	59,388	52.9%
8	Pamunkey	4/27/93	4/28/93	6.8	210,585	99,446	47.2%
9	Pamunkey	4/28/93	4/24/93	6.3	192,258	86,307	44.9%
10	Pamunkey	5/1/93	5/2/93	6.2	210,934	117,359	55.6%
11	Pamunkey	5/2/93	5/3/93	2.7	139,511	39,652	28.4%
12	Delaware	5/10/93	5/11/93	22.0	732,608	459,981	62.8%
13	Hudson	5/10/93	5/11/93	8.4	267,864	205,535	76.7%
14	Delaware	5/11/93	5/12/93	12.8	724,735	250,000	34.5%
15	Hudson	5/11/93	5/12/93	4.8	146,483	82,503	56.3%
16	Delaware	5/13/93	5/14/93	25.7	855,820	474,140	55.4%
17	Hudson	5/13/93	5/14/93	11.6	386,284	291,241	75.4%
18	Hudson	5/15/93	5/16/93	9.4	393,065	312,119	79.4%
19	Delaware	5/16/93	5/17/93	24.5	798,440	366,700	45.9%
20	Hudson	5/16/93	5/17/93	6.5	209,545	159,529	76.1%
21	Delaware	5/17/93	5/18/93	14.1	430,292	324,602	75.4%
22	Delaware	5/18/93	5/19/93	15.8	543,302	409,826	75.4%
23	Delaware	5/19/93	5/20/93	10.2	354,484	145,789	41.1%
24	Hudson	5/19/93	5/20/93	10.1	377,704	307,341	81.4%
25	Hudson	5/20/93	5/21/93	15.2	545,228	463,971	85.1%
26	Hudson	5/21/93	5/22/93	9.8	326,344	260,888	79.9%
27	Hudson	5/22/93	5/23/93	8.9	319,245	271,664	85.1%
28	Delaware	5/23/93	5/24/93	21.5	656,120	451,898	68.9%
29	Delaware	5/24/93	5/25/93	12.2	401,912	253,830	63.2%
30	Connecticut	5/24/93	5/25/93	11.4	430,745	379,320	88.1%
31	Delaware	5/25/93	5/26/93	15.7	605,535	367,844	60.7%
32	Connecticut	5/25/93	5/26/93	11.0	358,483	275,683	76.9%
33	Delaware	5/26/93	5/27/93	20.9	982,689	583,221	59.3%
34	Connecticut	5/26/93	5/27/93	10.2	439,398	357,268	81.3%
35	Delaware	5/27/93	5/28/93	13.6	651,789	401,736	61.6%
36	Connecticut	5/27/93	5/28/93	14.0	462,000	0	0.0%
37	Connecticut	5/29/93	5/30/93	12.2	557,290	356,829	64.0%
38	Connecticut	5/30/93	5/31/93	15.2	924,152	636,176	68.8%
39	Connecticut	5/31/93	6/1/93	13.2	591,375	445,277	75.3%
40	Delaware	6/2/93	6/3/93	21.2	784,632	442,986	56.5%
41	Connecticut	6/2/93	6/3/93	7.4	520,616	353,191	67.8%
42	Delaware	6/3/93	6/4/93	14.3	780,837	367,518	47.1%
43	Connecticut	6/3/93	6/4/93	12.0	Delivered to Manning		
44	Connecticut	6/4/93	6/5/93	6.4	402,971	165,888	41.2%
45	Connecticut	6/5/93	6/6/93	8.1	366,435	150,000	40.9%
46	Connecticut	6/7/93	6/8/93	11.0	522,178	50,000	9.6%
47	Connecticut	6/8/93	6/9/93	13.1	553,259	378,929	68.5%
48	Connecticut	6/9/93	6/10/93	6.8	290,050	126,866	43.7%
49	Connecticut	6/10/93	6/11/93	8.8	390,422	304,163	77.9%
50	Connecticut	6/11/93	6/12/93	11.8	483,627	347,637	71.9%
51	Connecticut	6/12/93	6/13/93	4.8	259,716	192,494	74.1%
52	Connecticut	6/14/93	6/15/93	5.0	215,391	140,796	65.4%
53	Connecticut	6/15/93	6/16/93	1.6	67,574	33,070	48.9%
Totals		No. of shipments					
	Pamunkey	11		54	1,781,857	722,191	40.5%
	Delaware	14		245	9,303,194	5,300,071	57.0%
	Hudson	9		85	2,971,763	2,354,791	79.2%
	Connecticut	18		175	7,445,260	4,389,424	59.0%
	Grand Total	53		559	21,502,074	12,766,477	58.3%

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1993.

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

Table 3. American shad stocking and fish transfer activities, 1993.

Date	Tank/ Pond	Number	Mark (days)	Location	Origin	Age	Size
5/26/93	B11	100,500	3,13,17,21	VDGIF (James River)	Pamunkey	32	Fry
5/26/93	B21	160,800	3,13,17,21	VDGIF (James River)	Pamunkey	24	Fry
5/26/93	B31	153,600	3,13,17,21	VDGIF (James River)	Pamunkey	22	Fry
5/26/93	B21	3,000	3,13,17,21	Benner Spring Raceway E1	Pamunkey	24	Fry
6/3/93	B41	123,900	3,13,17,21	VDGIF (Harrison Lake)	Pamunkey	26	Fry
6/3/93	C21	500	5,9	NFRDL	Delaware	17	Fry
6/3/93	I21	7,000	None	NFRDL	Connecticut	0	Fry
6/3/93	D11	37,900	5,9,13	Thompsontown	Hudson	15	Fry
6/4/93	C21	185,200	5,9	Elkton Ponds	Delaware	18	Fry
6/4/93	C21	2,000	5,9	Benner Spring Raceway E2	Delaware	18	Fry
6/4/93	C31	100,000	5,9,13	Canal Pond	Hudson	18	Fry
6/4/93	C31	84,700	5,9,13	Thompsontown	Hudson	18	Fry
6/7/93	C41	205,300	3,13,17	Lehigh River	Delaware	19	Fry
6/7/93	D21	307,300	3,13,17	Lehigh River	Delaware	18	Fry
6/7/93	D31	108,500	3,13,17	Lehigh River	Delaware	18	Fry
6/8/93	C11	230,100	3,13,17	Upper Spring Creek Ponds	Delaware	22	Fry
6/10/93	D41	210,000	5,9,13	Thompsontown	Hudson	21	Fry
6/10/93	D41	500	5,9,13	NFRDL	Hudson	21	Fry
6/10/93	J41	7,000		NFRDL	Delaware	0	Fry
6/10/93	E11	184,200	5,9,13	Thompsontown	Hudson	19	Fry
6/11/93	E21	69,700	3,13,17	Thompsontown	Delaware	19	Fry
6/11/93	E31	120,300	3,13,17	Thompsontown	Delaware	19	Fry
6/12/93	E41	260,400	3,13,17	Thompsontown	Delaware	19	Fry
6/13/92	F11	347,900	3,13,17	Thompsontown	Delaware	19	Fry
6/13/93	J11	541,400	5	Thompsontown	Connecticut	7	Fry
6/14/93	F21	33,000	3,13,17	Thompsontown	Delaware	19	Fry
6/14/93	J21	350,300	5	Thompsontown	Connecticut	7	Fry
6/15/93	F31	150,800	5,9,13	Thompsontown	Hudson	20	Fry
6/15/93	F41	199,900	5,9,13	Thompsontown	Hudson	18	Fry
6/17/93	G11	151,300	5,9,13	Thompsontown	Hudson	20	Fry
6/18/93	G21	85,400	5,9,13	Thompsontown	Hudson	20	Fry
6/18/93	G31	262,100	3,13,17	Thompsontown	Delaware	19	Fry
6/19/93	G41	85,300	3,13,17	Thompsontown	Delaware	19	Fry
6/22/93	H11	208,800	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
6/22/93	H21	227,700	3,11,13,17	Thompsontown	Delaware	21	Fry
6/23/93	H41	306,700	3,13,17	Thompsontown	Delaware	20	Fry
6/24/93	H31	151,300	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
6/24/93	I11	197,400	3,13,17	Thompsontown	Delaware	21	Fry
6/25/93	I21	243,800	5,13,17,21	Thompsontown	Connecticut	22	Fry
6/26/93	I31	287,000	3,13,17	Thompsontown	Delaware	22	Fry
6/28/93	J31	168,500	3,13,17	Lehigh River	Delaware	18	Fry
6/29/93	I41	234,600	5,9,13,17,21	Thompsontown	Connecticut	23	Fry
7/1/93	A12	319,500	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/2/93	A22	301,900	3,13,17	Thompsontown	Delaware	21	Fry
7/3/93	A32	75,200	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/6/93	B12	20,600	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/8/93	B22	178,600	5,9,13,17,21	Thompsontown	Connecticut	23	Fry
7/8/93	B22	2,000	5,9,13,17,21	Benner Spring Raceway E3	Connecticut	23	Fry
7/9/93	A42	38,600	9,13,17,21,25	Thompsontown	Connecticut	26	Fry
7/9/93	B32	66,800	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/9/93	B42	180,700	5,9,13,17,21	Thompsontown	Connecticut	22	Fry

Table 3. (Continued).

Date	Tank/ Pond	Number	Mark (days)	Location	Origin	Age	Size
7/10/93	C12	75,000	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/10/93	C22	91,100	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/11/93	C32	120,700	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
7/13/93	C42	40,900	5,9,13,17,21	Thompsontown	Connecticut	22	Fry
8/18/93	Canal Pond	35,400	5,9,13+ single feed	Thompsontown	Hudson	93	Fing.
9/15/93	Upper Spring Creek Pond 3	18,000	3,13,17 + triple feed	Thompsontown	Delaware	121	Fing.
9/23/93	Upper	7,000	3,13,17 +	Thompsontown	Delaware	129	Fing.
9/24/93	Spring Creek Pond 2	7,000	double feed	Thompsontown	Delaware	130	Fing.
10/8/93	Upper	7,000	3,13,17 +	Thompsontown	Delaware	144	Fing.
10/12/93	Spring Creek Pond 1	5,000	single feed	Thompsontown	Delaware	148	Fing.
10/8/93	Harrison	4,250	3,13,17,21	VDGIF (James River)	Pamunkey	153	Fing.
10/15/93	Lake Ponds	15,000 – 30,000	3,13,17,21	VDGIF (James River)	Pamunkey	160	Fing.
10/18/93	Elkton Pond 2	50,000 *	5,9	Elk River	Delaware	154	Fing.
10/18/93	Elkton Pond 3	30,000	5,9	Elk River	Delaware	154	Fing.
10/20/93	Elkton Pond 1	20,000	5,9	Elk River	Delaware	156	Fing.
10/21/93	PEPCO	15,000	single feed	Patuxent River	Connecticut	135	Fing.
10/22/93	PEPCO	4,500	single feed	Patuxent River	Connecticut	136	Fing.
10/27/93	PEPCO	5,000	single feed	Patuxent River	Connecticut	141	Fing.
10/28/93	PEPCO	8,800	single feed	Patuxent River	Connecticut	142	Fing.
11/2/93	PEPCO	18,000	single feed	Patuxent River	Connecticut	146	Fing.
11/3/93	PEPCO	20,000	single feed	Patuxent River	Connecticut	147	Fing.
11/9/93	PEPCO	20,700	single feed	Patuxent River	Connecticut	153	Fing.

*Of the 100,000 fish stocked from Elkton Ponds, 8,537 were presumed to be blueback herring based upon their frequency of occurrence in the mark retention subsamples.

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1993.

	Site	Fry	Fingerling
Releases	Juniata River	6,541,500	79,400
	Elk River		100,000 *
	Lehigh River	789,600	
	Sub-Total	7,331,100	179,400
Transfers	Canal Pond	100,000	
	Benner Spring Raceways	7,000	
	Upper Spring Creek Ponds	230,100	
	NFRDL (Wellsboro)	15,000	
	Maryland DNR Ponds	185,200	
	VDGIF (James River)	538,800	
	Sub-Total	1,076,100	
	Total Production	8,407,200	
	Viable eggs	12,766,500	
	Survival of fry (%)	65.9	

*Includes 8,537 blueback herring, projected from their frequency of occurrence in mark retention samples.

Table 5. Tetracycline marking regime for American shad stocked in the Chesapeake Bay drainage , 1993.

Size	Pond/ Raceway	Stocking Location	Egg Source	Immersion Mark (days)	Feed mark	No. Stocked
Fry	–	James River	Pamunkey	Quadruple (3,13,17,21)	–	538,800
Fry	–	Thompsontown	Hudson	Triple (5,9,13)	–	1,104,200
Fry	–	Thompsontown	Delaware	Triple (3,13,17)	–	2,271,700
Fry	–	Thompsontown	Delaware	Triple (3,11,13,17)*	–	227,700
Fry	–	Thompsontown	Connecticut	Quintuple (5,13,17,21)*	–	243,800
Fry	–	Thompsontown	Connecticut	Quintuple (5,9,13,17,21)	–	1,802,400
Fry	–	Thompsontown	Connecticut	Single (5)	–	891,700
Fingerling	Canal Pond	Thompsontown	Hudson	Triple (5,9,13)	Single	35,400
Fingerling	Upper Spring Creek Pond 1	Thompsontown	Delaware	Triple (3,13,17)	Single	5,000
Fingerling	Upper Spring Creek Pond 2	Thompsontown	Delaware	Triple (3,13,17)	Double	14,000
Fingerling	Upper Spring Creek Pond 3	Thompsontown	Delaware	Triple (3,13,17)	Triple	18,000
Fingerling	Elkton Ponds	Below Conowingo	Delaware	Double (5,9)	None	100,000 **
Fingerling	PEPCO	Patuxent River	Connecticut	None	Single	92,000
Fingerling	Harrison Lake	James River	Pamunkey	Quadruple (3,13,17,21)	None	19,250 – 34,250

*Unique marks created when a Delaware R. tank was erroniously marked instead of a Connecticut R. tank.
**Includes 8,537 blueback herring, projected from their frequency of occurrence in mark retention samples.

Table 6. Tetracycline mark retention for American shad reared in 1993.

Pond/ Raceway	Egg Source	Attempted Mark Immersion/Feed	Observed Mark Immersion/Feed	Number Exhibiting Mark	Projected Number Stocked	Disposition
Harrison Lake Ponds	Pamunkey	Quadruple/0 (3,13,17,21)	Quadruple	30/30(100%)	19,250 – 34,250	Stocked James River
N/A	Connecticut	Single/0 (5)	Single	Not Evaluated	891,700	Stocked Thompsontown
N/A	Connecticut	Quintuple/0 (5,9,13,17,21)	Quintuple	Not Evaluated	967,600	Stocked Thompsontown
Benner Spring Raceway E3	Connecticut	Quintuple/0 (5,9,13,17,21)*	Quintuple	3/3(100%)	178,600	Stocked Thompsontown
Canal Pond	Hudson	Triple/single (5,9,13)	Triple/single Triple/0	30/34(88%) 4/34(12%)	31,235 4,165	Stocked Thompsontown
Upper Spring Creek Pond 1	Delaware	Triple/Single (3,13,17)	Triple/Single	30/30(100%)	12,000	Stocked Thompsontown
Upper Spring Creek Pond 2	Delaware	Triple/Double (3,13,17)	Triple/Double Triple/Single Triple/0	26/29(90%) 1/29(3%) 2/29(7%)	12,552 483 966	Stocked Thompsontown
Upper Spring Creek Pond 3	Delaware	Triple/Triple (3,13,17)	Triple/Triple Triple/Single	28/29(97%) 1/29(3%)	17,379 621	Stocked Thompsontown
Elkton Ponds	Delaware	Double/0 (5,9)	Double None	75/75(100%)** 0/7(0%)***	91,463 8,537	Direct Release
PEPCO	Connecticut	0/Single	Not yet analyzed		92,000	Stocked Patuxent R.

*Recieved 2h immersions on days 9 and 17
**American shad
***Blueback herring

Figure 1. Survival of American shad fry, Van Dyke, 1993.

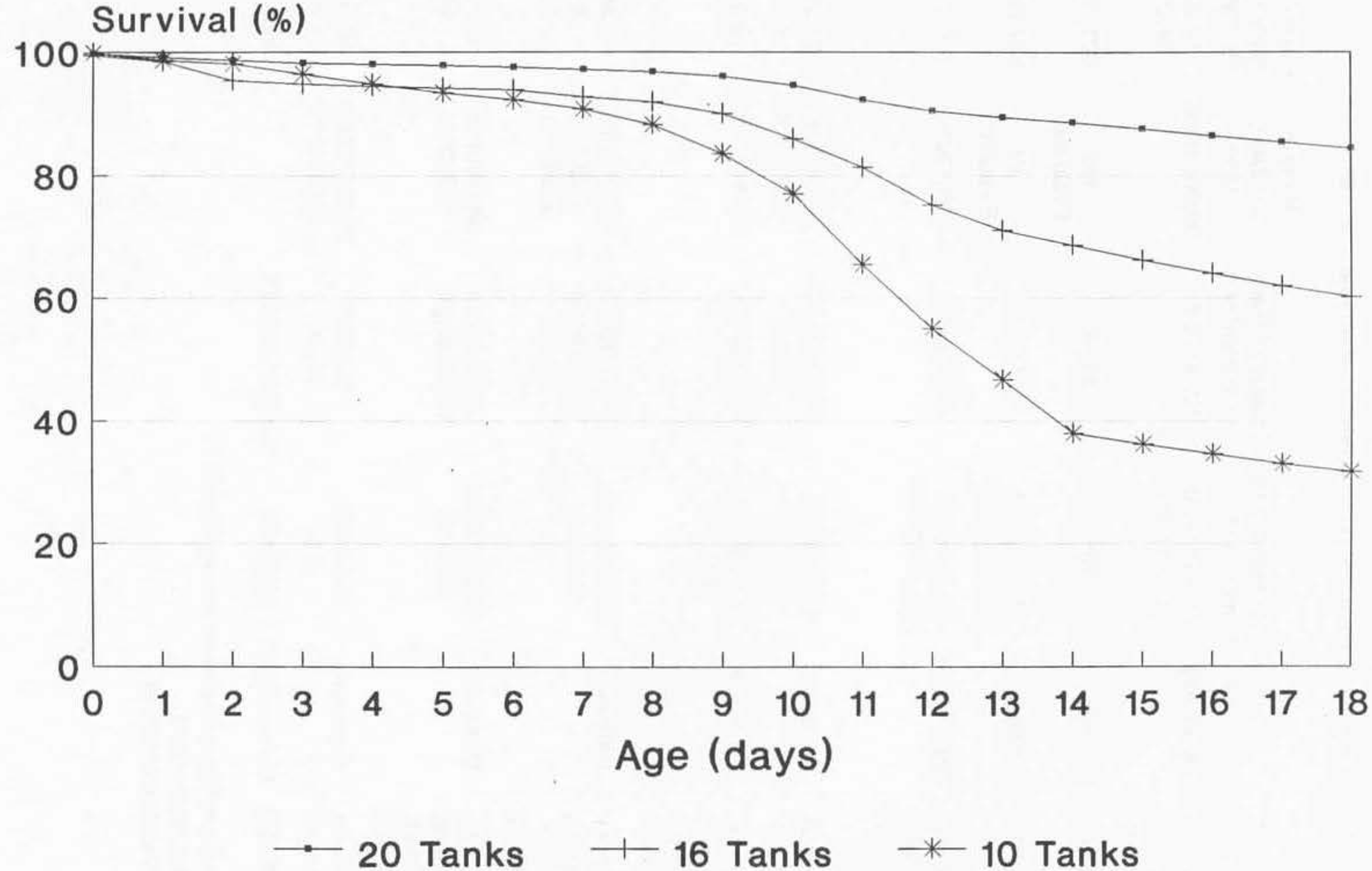


Figure 2. Mean Incidence of feeding in tanks grouped according to % survival, 1993.

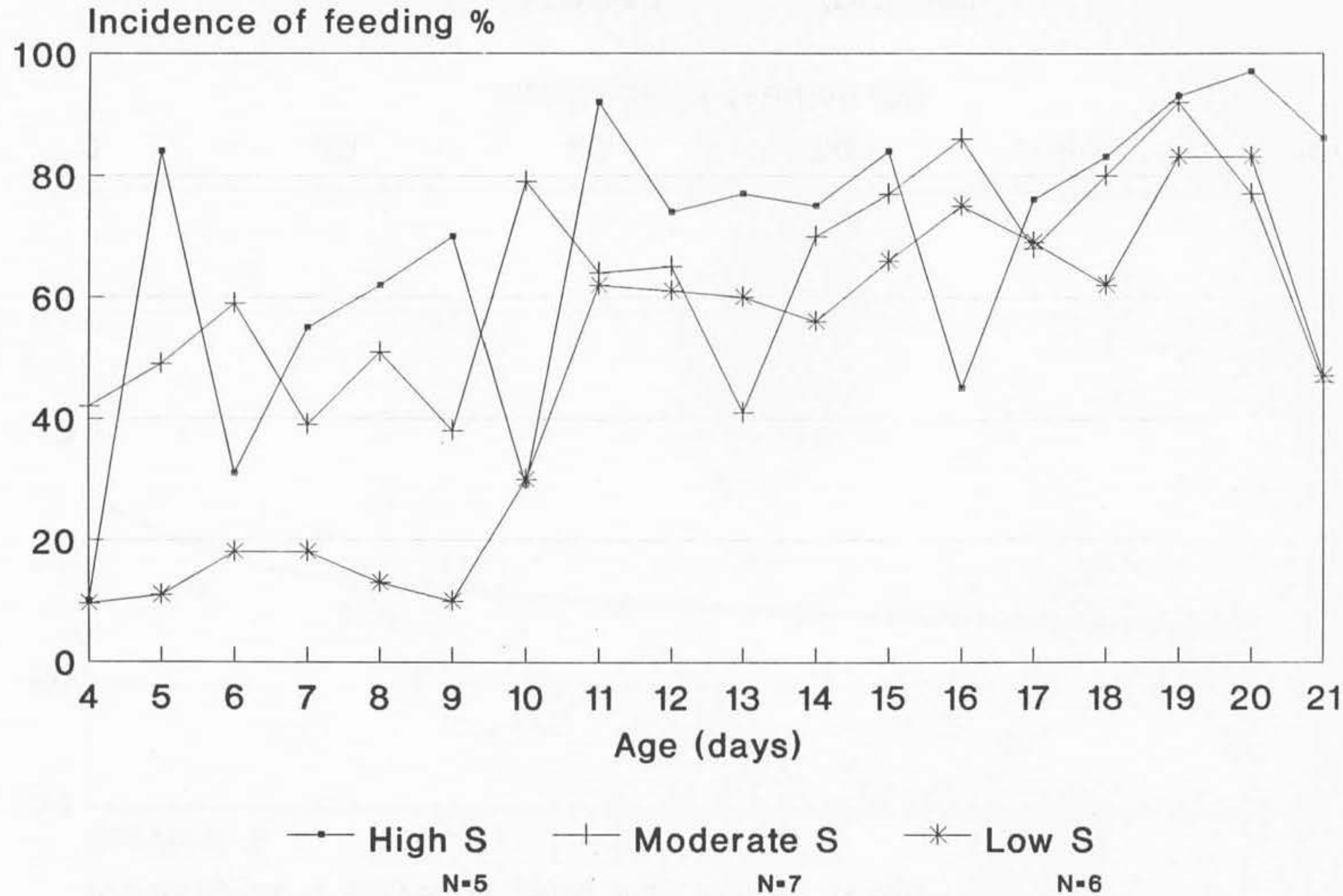


Figure 3. Percent survival vs Incidence of feeding at 5 days of age, Van Dyke, 1993.

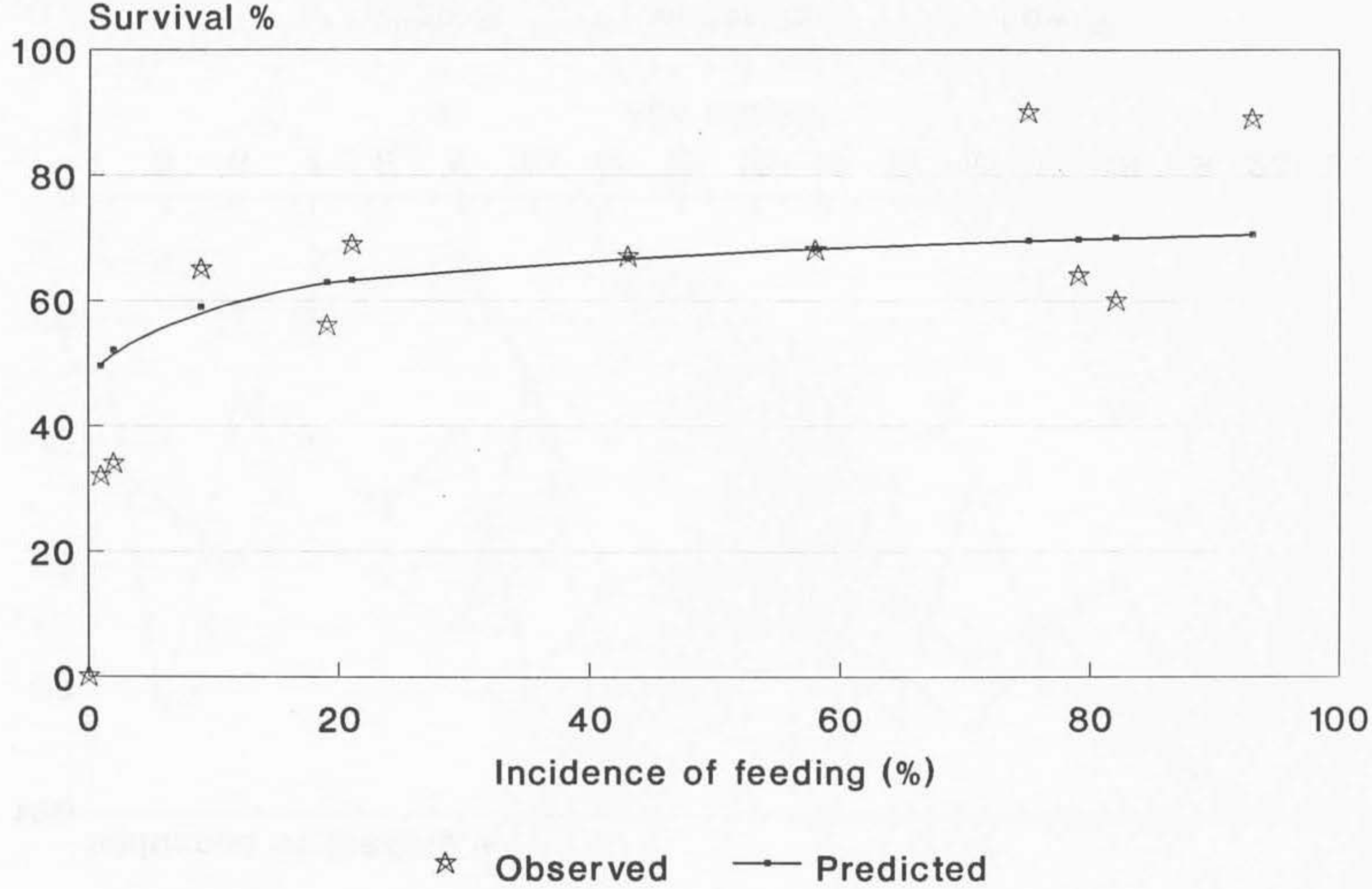
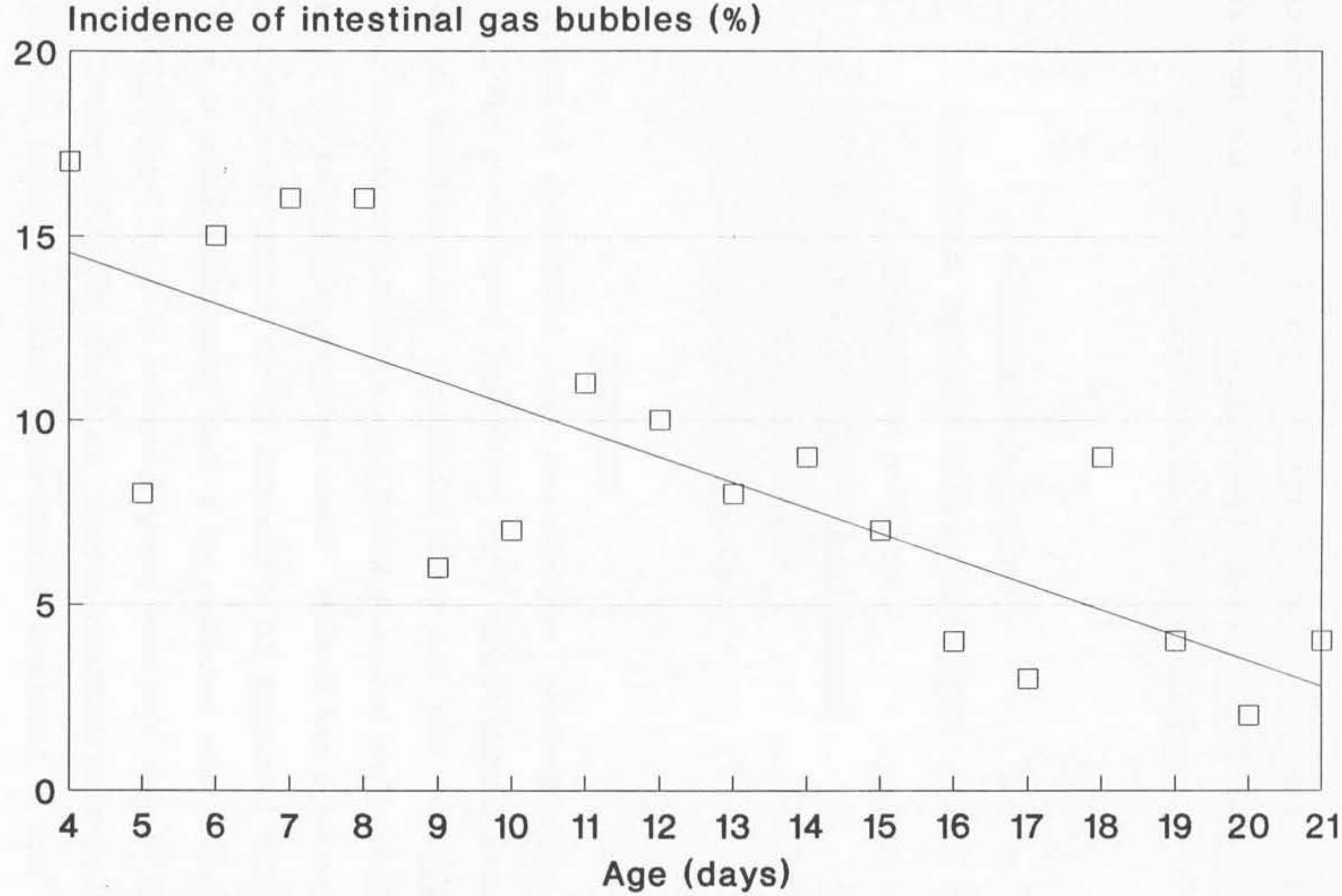


Figure 4. Mean Incidence of intestinal gas bubbles in American shad larvae, 1993.



Appendix 1.

The effect of delaying disinfection and enumeration until 8:00AM on the viability of Delaware River American shad eggs incubated at the Van Dyke Hatchery

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Abstract

Disinfection, enumeration, and incubation of American shad eggs has historically been performed immediately upon arrival of the eggs at the Van Dyke hatchery. This results in logistical problems since Delaware River eggs typically arrive at the hatchery between 2:00 and 3:00AM. Identically handled, paired egg lots were randomly assigned to a control group processed immediately upon arrival at the hatchery or a test group processed at 8:00AM. Egg viability for the test group exceeded that of the control group for eight of the thirteen trials, with one tie. Results of the Sign Test and Wilcoxin's Signed-Rank Test indicated no significant differences between the two groups. These findings will permit delaying egg shipment processing until 8:00AM, thus eliminating the need for a special shift for egg incubation.

Introduction

American shad eggs were collected from running ripe females and artificially fertilized with sperm from males. Running ripe females were available only between dusk and midnight. After fertilization, the eggs were water hardened and packed in plastic bags with a pure oxygen atmosphere for shipping to the Van Dyke hatchery. Time of arrival of eggs at the hatchery depended upon the distance between the hatchery and the egg source. Eggs from the Delaware River typically arrived at the hatchery between 2:00 and 3:00 AM, while those from other rivers arrived between 8:00 and 10:00 AM. Historically, hatchery personnel have always met the driver and processed the eggs (disinfection, enumeration and incubation) immediately upon their arrival. Egg shipments were sporadic and unpredictable, making scheduling of shifts impossible. Hatchery personnel received a telephone call after midnight advising them of egg shipment status. At that time they scheduled their shift for the following day. This became a hardship for hatchery personnel, resulted in fatigue, and impacted performance. Supervision of personnel was also impacted since the hatchery manager could not be present during the majority of the egg processing. Holding Delaware River eggs until 8:00 AM before processing would improve coordination between wage employees and the supervisor and eliminate hardships due to constant shift changes.

The purpose of this experiment was to determine if holding Delaware River source American shad eggs at Van Dyke until 8:00 AM before disinfection and enumeration has an effect on egg viability.

Methods and Materials

Delaware River eggs were stripped, fertilized and water hardened as per standard practice. Eggs from the first and second net runs were kept separate from those collected later and were the only eggs used for the study.

After water hardening, eggs were measured into plastic bags using a scoop and a 1L graduate. Two bags (A1 and B1) were filled concurrently by measuring a liter of eggs into each bag and repeating the process until each bag contained 3L of eggs. Bags were placed in styrofoam coolers and marked as appropriate.
The process was repeated twice more, marking the next two bags A2 and B2, and the next two bags A3 and B3. All remaining eggs from the first two runs were processed normally and were not part of the study.

Upon arrival at Van Dyke, hatchery personnel flipped a coin to determine which group (A or B) was processed immediately (control) or held until 8:00 AM (test). Eggs from all bags in the control group were kept separate and immediately disinfected and processed as per standard Van Dyke procedure. Eggs were incubated in May-Sloan jars, 2.5L per jar. Excess eggs were incubated separately as part of production lots. Eggs from the test group were set aside and processed at 8:00 AM or shortly thereafter. Test group eggs were processed in the same manner as the control group. Egg enumeration, removal of dead eggs, etc. was carried out according to standard Van Dyke protocol.

Results were evaluated based upon egg viability (survival) for paired incubation jars (one control and one test). Two non-parametric statistical tests, the Sign Test and Wilcoxin's Sign-Rank Test, (Ott, 1977) were used to evaluate the data.

Results and Discussion

The test was replicated in six shipments (Table A-1) representing the breadth of the Delaware River fishing season. A total of 13 pairs of test and control jars were tested. Test jars exhibited higher survival than controls for 8 of the 13 trials indicating that survival may actually be improved by delaying processing. Both statistical tests indicated that these results were not statistically significant at a= .05 (Table A-2).

Conclusions

Delaware River eggs which were held until 8:00AM before processing, exhibited no significant difference in survival than eggs which were processed immediately upon arrival at the hatchery. Holding these eggs until 8:00AM before processing will improve hatchery logistics without adversely impacting egg survival.

LITERATURE CITED

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

Table A-1. Survival of Delaware River American shad eggs processed immediately upon delivery, vs. those held until 8:00AM before processing, Van Dyke, 1993.

	Processed Immediately (Control)		Held (Test)		
Egg Shipment	Jar	Survival (%)	Jar	Survival (%)	Pairwise Comparison
16	7	53.8%	11	75.5%	Test
	8	68.9%	10	66.0%	Control
	9	77.6%	12	70.6%	Control
21	13	82.0%	15	82.0%	–
	14	73.2%	16	77.8%	Test
22	17	83.1%	19	87.2%	Test
	18	86.5%	20	83.5%	Control
28	21	73.9%	23	74.4%	Test
	22	58.0%	24	71.3%	Test
31	1	72.5%	3	72.7%	Test
	2	59.9%	5	62.9%	Test
40	7	62.2%	9	68.2%	Test
	8	72.4%	10	66.7%	Control

Table A-2. Results of non-parametric statistical tests used to compare survival of American shad eggs processed immediately upon delivery, vs those held until 8:00AM before processing, Van Dyke, 1993. Ho- no difference in survival between test and control groups.

Test	No. of non-tied pairs (n)	Test statistic	critical value (a=.05)	Results
Sign Test	12	z=1.15	>1.96	cannot reject Ho
Wilcoxin's Signed-Rank Test	12	T=25.5	<14	cannot reject Ho

PRODUCTION AND STOCKING OF AMERICAN SHAD IN MARYLAND

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INTRODUCTION

Since the 1960's the Chesapeake Bay population of American shad (***Alosa sapidissima***) has undergone a period of serious decline followed by the closure of all harvest in 1980. Since that time there has been some increase in the upper bay population, partially due to larval stocking of American shad by Susquehanna River Anadromous Fish Restoration Committee (SRAFRC). However, the fishery remains closed and most rivers support severely depressed shad runs. The Maryland Department of Natural Resources (MDNR) is participating with SRAFRC in efforts to enhance the restoration of American Shad to historic population levels in the Susquehanna River and the Chesapeake Bay. MDNR annually conducts an assessment of the American Shad population in the upper Chesapeake Bay as described elsewhere in this report (JOB VI). MDNR conducted several additional shad restoration activities in 1993, primarily in cooperation with the Potomac Electric Power Company (PEPCo). These activities are described below.

Elkton Pond Culture/Stocking - MDNR

Maryland Fisheries Division staff received 185,200 18 day old American Shad fry on June 6, 1993 from the Pennsylvania Fish and

Boat Commission's Van Dyke Fish Research Station. They were released in three small culture ponds in the town of Elkton MD. The young shad were fed daily with a total of 60 bags of salmon starter used. The culture ponds were drawn down and an estimated total of 100,000 American shad 63.5 mm to 110.2 mm in size were released into Big Elk Creek, a tributary of the upper Chesapeake Bay during October 18 through 21, 1993.

Manning Hatchery and Culture -- MDNR

In 1991, the Maryland Department of Natural Resources (MDNR) entered into a cooperative agreement with the Potomac Electric Power Company (PEPCo) to rear and stock finfish into Maryland waters. Early efforts focussed on striped bass (**Morone saxatalis**). During 1993, MDNR and PEPCo expanded this work to include production of American Shad in cooperation with U.S. Fish and Wildlife Service and SRAFRC. The goals of the work conducted in 1993 included:

1) Incubation of fertilized eggs provided by SRAFRC and larval rearing to juvenile size for stocking.
2) Natural spawning of American shad from ripe adults collected at Conowingo dam fish lift.
3) Experimentation with non-chemical identification tags.

Egg Incubation

On June 4, 12.5L (16.5L wet volume) of fertilized American Shad eggs from the Connecticut River, provided through SRAFRC, were received at MDNR's Manning hatchery in Cedarville MD. Eggs were held in four hatching jars at 64° F and treated daily with formalin to inhibit fungal growth. Hatching occurred at 6-7 days. At 11 and 14 days after hatching, larvae were transported to the PEPCo aquaculture facility in Aquasco, MD and stocked into outdoor ponds. PEPCo culture and stocking activities are described later in this report.

Natural (Tank) Spawning

Seventy seven American shad (36 males, 41 females) adults were collected at the Conowingo fish lift on May 20, May 27 and June 3, 1993 and transported to the Manning hatchery. Shad were transported at 5 ppt static salt and 70° F. Circulation in transport tanks was 28 cm/second. Flows in the natural spawn systems varied between 14 and 28 cm/second. Two shad died during transport. The fish were put in four natural spawn systems and held at temperatures ranging from 66-74° F until July 1. Males and females were equally distributed in each tank. Eggs were collected from the natural spawn systems daily from May 22 until June 30. Most eggs collected were not water-hardened. Four liters (wet volume) of fertilized eggs were collected and placed in hatching jars. These eggs were not treated for fungus. Approximately 20,000 larvae were produced and stocked at eight to fourteen days in an outdoor pond at Manning. Of the original seventy-five adult shad, thirty (22 males, 8 females) survived and were released to the Chesapeake Bay on July 1. Mortalities were attributed to the catheterization process and post-spawning stress.

This effort demonstrates the feasibility of using natural spawning techniques for American shad production. During 1994, natural spawning will be attempted using anesthetic during transport to reduce stress and LHRH~ to stimulate hormone production and egg maturation.

Non-chemical Tagging

Fourteen hundred naturally-spawned juveniles were removed from the outdoor pond, transferred to the hatchery house and tagged with coded wire tags (CWT). A tag retention study was performed on 400 of these fish and on 400 fish grown out at the PEPCo facility. The results indicate good retention and survival. Nine hundred ninety-two CWT tagged shad were stocked in the Patuxent River at Jug Bay. A trawl survey to recapture hatchery-reared shad is currently underway with five shad recaptured as of January 1994.
We believe it will be possible to use coded wire tags on American shad juveniles to aid in population assessment.

Shad Culture at Chalk Point -- PEPCo

The following is a summary of the Potomac Electric Power Company's (PEPCo) American shad aquaculture activities in 1993. All of these activities were conducted in cooperation MDNR personnel.

Stocking of Fry

Four of PEPCo's 0.67 acre aquaculture ponds (Nos. 4, 6, 7, & 8) at Chalk Point were used for the initial culture of American shad fry. All of these ponds were filled 14 to 17 days before stocking with American shad fry with filtered water pumped from the Chalk Point Station's discharge canal. Seven to 10 days before stocking with fry the ponds were fertilized with soybean meal and liquid fertilizer (34-10-0) to promote plankton growth. The ponds were fertilized weekly until mid-July and plankton was the primary source of food. The diet of the fry was supplemented with salmon chow after that time.

Two of PEPCo's aquaculture ponds were each stocked with an estimated 75,000 - 85,000 5-day old American shad fry on June 14, 1993. The fry were obtained from DNR's Joseph Manning Hatchery and were the product of fertilized eggs obtained from Connecticut River fish that were hatched by DNR personnel. All American shad fry were transported from the Joseph Manning Hatchery to PEPCo's ponds in plastic bags filled with water and pure oxygen. Two additional 0.67 acre ponds were each stocked with an estimated 75,000 - 85,000 8-day old fry on June 17, 1993. The total number of American shad fry stocked in the four ponds was between 300,000 and 340,000. No American shad fry were stocked in PEPCo's aquaculture tanks during June .

Phase I Pond Harvest

After 19 to 28 days of growth in the four aquaculture ponds, an estimated 71,000 phase I (2.5 -3.5 cm total length) American shad fry were harvested between July 3 and 15, 1993 using a glass V-Trap borrowed from the Joseph Manning Hatchery. The V-Trap was very effective in trapping 2.5 - 3.5 cm fry but was not effective approximately one month later on August 5 and 6 when the fry were between 4.5 and 5.0 cm total length.

Phase I American shad fry were removed from the trap with a scoop after concentrating small batches of fish in a partially submerged dip net. Phase I fry harvested from the ponds were transported to the aquaculture center's tanks in a 40-gallon trash can. The water was aerated with pure oxygen during transport to the aquaculture center. The phase I harvest removed approximately 50% of the fish in each pond. The fish remaining in the ponds were fed daily with salmon chow and harvested as phase II fry in the fall.

Tank Culture

Phase I American shad harvested from the ponds were stocked in two 20-foot diameter fiberglass tanks located in the aquaculture center. Tank 20E was stocked with approximately 48,500 fry and tank 20C received approximately 22,600 fry. The tank cultured American shad were fed appropriately sized salmon chow at a rate of 8 to 12% body weight per day until mid-November when, at a total length of between 9.5 and 11.0 cm, the fingerlings were released into the Patuxent River.

Phase II Pond Harvest

An estimated 60,000 phase II (8.5 -9.5 cm) American shad fry were harvested from the aquaculture ponds between October 8 and 20, 1993, after 105 - 120 days of culture, and moved to the aquaculture center's tanks for marking prior to release. A 1/8-inch delta mesh 100 x 30-foot net was deployed on the bottom of one corner of the deep end of a pond one day prior to harvesting. The fish were lured to that corner with food until most of the fish in the pond were over the net. The outer edges of the net were then quickly raised and most of the fish over the net were trapped. By working the net inward, the fish were concentrated with minimal contact with the net and removed with a scoop and transported to aquaculture center tanks. Mortality from the phase II harvest was high; approximately 28,200 fish died within two weeks of harvest.

Chemical Marking

All American shad were marked prior to release into the Patuxent River. Fish were fed oxytetracycline laced fish food for 4 days at a rate designed to achieve a concentration of 250 mg active oxytetracycline per kilogram of fish per day. Oxytetracycline is used at the Van Dyke Hatchery in Pennsylvania as a means of placing a visible mark on shads' otoliths. All of PEPCo's American shad were held for at least 7 days after treatment before being released into the Patuxent River.

Shad Stocking

Approximately 92,000 marked phase II American shad fingerlings were released into the Patuxent River at three locations between October 21 and November 11, 1993. Approximately 77,000 were released at the Hallowing Point boat ramp, 10,000 at Benedict, Maryland, and 5,000 near Chalk Point.

Of the 92,000 fish released, approximately 60,200 fish were cultured in tanks since July and the remaining 31,800 were the result of the phase II pond harvest. Most of the phase I fish, 85% (60,200 of 71,100), harvested from the ponds and raised in the aquaculture tanks survived until release while only about 53% (31,800 of 60,000) of the phase II fish removed from the ponds during the fall survived the harvest and were released.

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 1993 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 1993. For their contributions to this report, appreciation is extended to Mark Plummer (Wyatt Group), Chris Frese (RMC), Dale Weinrich (Maryland DNR), Ted Rineer (SHWPC), 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 stocking either in Maryland waters or from upstream releases in Pennsylvania.

A total of 11,171 adult American shad were hauled from the Conowingo fish lifts during early May through mid-June. Most (83%) were stocked above York Haven Dam at Middletown with the remainder being placed at Columbia. Observed transport mortalities amounted to 643 fish (5.7%) and delayed mortality was estimated at about 5% (see Job I). Overall sex ratio (SR) in these transfers was about 1.3 to one favoring males. This stocking level compares with about 14,500 live shad delivered in 1992 (1:1 sex ratio) and 22,000 in 1991 (SR 1.64:1 m/f). With the assumed mortalities and sex ratio, the 1993 spawning population above dams amounted to 4,350 females and 5,650 males. Also in 1993, a total of 1,130 blueback herring and 203 alewives collected at Conowingo were successfully stocked at Middletown.

During the 1993 shad production season, PA Fish and Boat Commission biologists reared and released 6.54 million shad fry and 79,400 fingerlings in the Susquehanna watershed. All fry were stocked between 3 June and 13 July in the Juniata River at Thompsontown. Fingerlings reared in Pennsylvania ponds were stocked at Thompsontown between 18 August and 12 October. Through a cooperative agreement between Maryland DNR and the town of Elkton, an additional 91,500 fingerling shad were stocked into the Elk River at the head of the Bay in mid-October.

The 6.54 million shad fry stocked above dams in the Susquehanna in 1993 compares to 3.04 M, 7.22 M, 5.62 M, and 13.46 M in 1992, 1991, 1990, and 1989, respectively. Combined fingerling shad releases from PA ponds was almost double the number stocked in 1992 but still well below prior year averages.

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 1993 as shown below.

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

Seining was conducted by the Wyatt Group on 23 dates over 15 weeks from mid-July through late October. Most sampling occurred in late afternoon and evening and the net used measured 400-ft. x 6 ft. with 3/8" stretch mesh. The area most consistently monitored was Columbia on 12 occasions. Marietta was sampled on 7 dates, Pequea on 6, Three-Mile Island twice, and Amity Hall once.

At York Haven, shad collections were made by Stone & Webster personnel on several dates in mid-October with a fixed 1-meter square sluiceway sampling net (1/4" mesh). Attempts were made by Wyatt biologists on six dates in September and October to take shad at York Haven with a 10-ft. cast net (3/8" mesh). An 8-ft.

square lift net with 1/2" mesh liner was used by RMC Environmental Services at Holtwood's inner forebay. Lift netting (10/date) occurred during early evening hours twice weekly on 24 dates from 9 September through 2 December.

Cooling water intake strainers at Safe Harbor were sampled 2-3 times each week by plant personnel from 4 October through 1 November and daily thereafter through 28 November. At Conowingo, RMC checked strainers on 14 occasions (1-2 times/week) during 12 October to 3 December. RMC also inspected intake screen washes at Peach Bottom Atomic Power Station three times weekly during 4 October through 1 December. As part of their annual juvenile Alosa recruitment survey, Maryland DNR sampled for shad and herring with electrofishing gear in the Susquehanna Flats 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 1993 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 is 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 period 15 July to 20 October, a total of 689 juvenile shad were taken in 168 seine hauls on 23 dates at five locations. Columbia, Marietta, and/or Pequea were sampled on 21 dates and produced a total of 273 shad in 156 hauls of which 262 were returned for otolith analysis. Of 233 otoliths processed from collections made during mid-July through early October here, 196 (84%) were wild. Hatchery fish exceeded wild fish (21 of 22) in only one seine sample, the final collection made at Columbia on 13 October.

A one-day sampling event occurred at Amity Hall in the lower Juniata River on 28 July. The purpose was to collect a sample of shad for otolith analysis to determine if any natural reproduction occurred in this tributary. Three hauls of the seine produced 265 shad and, as expected, most fish analyzed (97%) were produced at Van Dyke. Three Mile Island above York Haven dam was sampled twice on August 4 and 25 and produced 118 juvenile shad in 9 hauls. Of the 38 otoliths examined from fish in these collections, 22 (58%) were wild - a considerable difference from the ratio noted only 17 miles downstream.

Shad catch-per-unit-effort (CPUE) with seines in the lower river (excluding TMI) in 1993 ranged from a high monthly average of 3.0 fish/haul in September to a low average of 1.0 in August. July and October CPUE values were 2.1 and 1.6, respectively. Table 1 shows juvenile shad catch and effort by date and location for all seine collections in 1993.

York Haven Dam

Limited cast net collections were made in the York Haven headrace in an effort to document first occurrence of shad and to assist Stone & Webster in timing the start of their strobe light study at this site. Although shad first appeared here in early September, they did not reach peak abundance until late October. Strobe tests were conducted on several nights and hundreds of shad were collected in sluice nets. Most of the shad saved for otolith analysis from York Haven samples were inadvertently discarded. A single 27 fish sluice net sample from 22 October and 4 fish taken with cast net on 29 September were processed for marks on otoliths. Of these 31 fish, 18 (58%) were wild and 13 were hatchery.

Safe Harbor Dam

Juvenile shad first appeared in cooling water strainers in the turbine intakes at Safe Harbor on 3 November. During the 7-day period November 3-9, a total of 59 shad were collected in daily samples ranging from 3-19 fish. One additional shad was taken here on 18 November and daily sampling was terminated after 28 November. No juvenile shad were collected at Safe Harbor in 1992.

Holtwood Dam

RMC personnel initiated lift netting at Holtwood's inner forebay on 9 September and continued twice weekly through 2 December. The first three American shad were collected on 28 September; catch peaked during the 15-day period 25 October through 8 November; and the last three shad were taken on 22 November. On 24 sample dates over a 3-month period, total catch amounted to 1,093 juvenile and 6 adult American shad, 173 blueback herring, 24 alewives, and over 71,000 gizzard shad. By contrast, in 1992, a similar amount of effort at this site produced only 39 American shad, one blueback herring, and 15 gizzard shad. Peak collections occurred during five consecutive dates producing 92% of the season catch of juvenile American shad (1,007 of 1,093) with a CPUE of 20 fish/lift. Daily catch of fish with lift nets at Holtwood during autumn 1993 is shown in Table 2.

Otolith analysis was completed on 188 specimens taken by lift net at Holtwood. Earliest collections were comprised mostly (79%) of wild fish (11 of 14). Shad taken during the 2-week peak of abundance were 63% wild (62 of 99), and late run fish were mostly (75%) hatchery origin (56 of 75).

Peach Bottom APS and Conowingo Dam

With the cooperation of Philadelphia Electric 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 October through November. Collections for the season included 26 juvenile and one adult American shad, 28 bluebacks, 2 alewives, and about 63,000 gizzard shad. With a similar amount of effort, Peach Bottom collections in 1992 included only one American shad, 140 gizzard shad, and no herring. In 1993, all juvenile shad were taken at PBAPS between November 3-24 in daily numbers ranging from one to six. All but three fish were taken the first 2-weeks of November.

Cooling water strainers at the Conowingo hydroelectric project were examined for impinged shad once or twice each week during 12 October through 3 December. American shad were taken in small numbers (1-6) on seven dates between 1 November and 3 December. Collections included a total of 17 juvenile American shad, 11 bluebacks, and 31,000 gizzard shad. In contrast, the 1992 Conowingo collections included only 4 American shad, 2 bluebacks, 5 alewives, and 8,583 gizzard shad. Analysis of otoliths from 40 shad taken at Peach Bottom and Conowingo in November showed 60% wild and 40% hatchery.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 31 juvenile American shad by electrofisher from the upper Chesapeake Bay during August through October (compared to four in 1992). An additional 36 shad were taken in DNR's juvenile striped bass index net collections in the upper Bay. Electrofisher collection results by location and date are provided in Table 5 of Job VI. Otoliths from all 67 shad taken in DNR collections were analyzed by PBFC staff and all were wild.

OTOLITH MARK ANALYSIS

Otoliths from 685 juvenile American shad taken in summer and fall collections by Wyatt Group, Stone & Webster, 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 Pennsylvania Fish and Boat Commission in 1993 is described in Job III.

Amity Hall, TMI and York Haven

Otolith analysis was completed on 135 shad provided from the York Haven sluice net (27 fish on 10/22) and cast net (4 fish on 9/29); seine collections from Amity Hall (65 fish on 7/28) and Three Mile Island (38 fish on 8/4 and 8/25); and from a PFBC sample at Clemson Island above Clarks Ferry (one fish on 9/27). Of this group, 92 fish (68%) were hatchery produced including 63 of 65 shad examined from Amity Hall. The Clemson Island specimen and 40 of 69 (58%) fish taken at TMI and York Haven were wild. Based on river of egg origin, 47 (51.1%) of the marked sample were Hudson fish; 38 (41.3%) were Delaware; and 5 (5.4%) were

Connecticut source. One fish had an unidentifiable quadruple mark and the remaining fish was released as a pond-reared fingerling.

Marietta, Columbia, and Pequea

Seine collections made during mid-July through mid-October provided 255 shad for otolith mark analysis. Overall, 58 of the fish (22.7%) were marked and the remaining 197 fish (77.3%) were wild. Hatchery fish occurred as early as 27 July at Marietta and were available in small numbers on all collection dates at Columbia after 18 August. Wild fish dominated all seine collections at Marietta (87%), Pequea (100%), and Columbia through 6 October (77%). The final sample from Columbia on 13 October showed a preponderance of hatchery fish (21 of 22).

Of the 58 hatchery fish in these seine collections, 31 (53.4%) were Hudson River origin; 15 (25.9%) were Delaware source, 7 (12.1%) were Connecticut River, and 5 fish (8.6%) were fingerling releases. Most of the Delaware fish and all fingerling recoveries occurred at Columbia on 13 October.

Holtwood, Peach Bottom and Conowingo

Of the 188 shad otoliths processed from Holtwood lift net collections, 96 (51%) were hatchery origin. Wild fish dominated collections through 8 November comprising 64.6% (73 of 113). Samples from November 11-18 were predominately (56 of 75) hatchery origin (74.7%). As was the case upriver, Hudson River fish were most abundant in the hatchery marked component with 41 fish (43.2%). The Delaware River source produced 27 fish (28.4%) and the Connecticut 8 fish (8.4%). There was one error-marked specimen of unknown egg origin and surprisingly, the remaining 19 specimens (20%) were fingerling releases from Upper Spring Creek and the Thompsontown canal pond.

Otolith mark analysis was completed on 40 shad from November samples taken at Peach Bottom and Conowingo and 60% were wild. Nine of the 16 hatchery fish from screen and strainer collections at PBAPS and Conowingo were Hudson origin (56.3%), 6 were Delaware (37.5%), and one was a fingerling release from Thompsontown.

Upper Chesapeake Bay

As pointed out earlier, all 67 juvenile shad taken in Maryland DNR's electrofisher and seine collections in the upper Chesapeake Bay were wild. This was expected since no marked shad fry were stocked at Lapidum in 1993, and marked fingerlings from the ponds at Elkton were not stocked until late in October.

Otolith Summary

Otolith analysis of shad samples from all collecting dates and sites above Conowingo Dam is presented in Table 3. The 618 shad analyzed included samples from every week between 15 July and 24 November. Monthly sample sizes for otolith analysis ranged from 86 in August to 165 in November for all sites combined. A total of 262 fish (42.4%) were marked and 356 (57.6%) were wild. In 1992, 1991, and 1990, the wild components of the combined upriver otolith analyses were 39%, 22%, and 2%, respectively.

Hudson River fry comprised 49.2% of all identifiably marked fish in collections above Conowingo Dam (128 of 260). Of the remainder, Delaware River fry made up 33.1% of the marked collection (86 fish), Connecticut fry comprised 7.7% (20 fish), and 10% (26 fish) were from fingerling pond releases. Excluding the single Amity Hall sample which was 51% Delaware fry origin, Hudson River shad dominated marked fish all seine collections other than that at Columbia on 13

October. Though most marked fish in that last seine sample were Delaware fry releases (13 of 21), it also included 5 pond stocking recaptures. Combined Holtwood samples closely reflected the overall river or origin composition noted above, except that fingerling releases made up 20% of the catch.

DISCUSSION

In-Stream Movements and Outmigration Timing

Of the 275 juvenile shad collected with seines at Columbia, Marietta, and Pequea during the 1993 season, 242 fish were taken prior to October outmigration. Based on analysis of 223 otoliths from these collections, 188 fish (84%) were naturally produced. Considering the late timing of the adult run at Conowingo, it is likely that most reproduction took place in the release vicinity (above and below York Haven Dam) and that the free-flowing stretch of river from York Haven to Columbia was used as a summer nursery. The fact that some reproduction occurred upstream from Harrisburg is evidenced by the collection of two wild fish at Amity Hall on 28 July and another fish at Clemson Island above Clarks Ferry on 27 September.

All Pequea fish were wild. Of the 35 shad in July-September seine samples from Marietta and Columbia which carried hatchery marks, 29 (83%) were Hudson origin, 5 (14%) were Connecticut, and one was Delaware source. The 1.1 million Hudson fry were stocked at Thompsontown in eight lots between June 3-18. Since Hudson fish first appeared at Marietta on 27 July, they made this 50-mile downstream journey in 39-54 days at an average rate of 1 to 1.3 miles/day. Movement of Connecticut fish was much less ambitious. They first appeared at Marietta and Columbia in August 18-26 collections and, being specially marked, we know they came from a stocking of 891,700 fry at Thompsontown on June 13-14.

April river flow in the Susquehanna River was extremely high causing a 1-month delay in trapping operations at Conowingo Dam. Based on Safe Harbor records, flows subsided quickly through May and remained well below long-term average values through October (Figure 2). This situation differed dramatically from that in 1992 which was characterized by large and rapid flow fluctuations and average monthly flow rates well in excess of long-term averages. Most shad taken with seines at Marietta, Columbia, and Wrightsville in 1992 were collected in July, and St. Pierre (1993) theorized that this was related to the high flows. Since hatchery released shad made similar movements in 1993 under lower than normal flow conditions, the mechanism responsible for this early dispersement is unclear.

Based on analysis of 38 otoliths from shad taken in seine collections at Three Mile Island on August 4 and 25, 42% were hatchery origin including 13 Hudson and 3 Connecticut River fish. The first Delaware source shad did not appear in lower river seine collections until 30 September and they dominated the hatchery component at Columbia on 13 October and in the York Haven sluice sample on 22 October. Delaware shad apparently behave differently from Hudson and Connecticut fish. The 2.5 million Delaware fry were stocked at Thompsontown between 11 June and 2 July and their late movement to downstream sampling areas may relate to a spike in river flow and a 3°C temperature decline during 30 September - 5 October. A similar behavior was noted for Delaware River shad in 1992.

The seine collection at Amity Hall on the lower Juniata River on 28 July was mostly hatchery fish (63 of 65 examined) comprised of 51% Delaware, 46% Hudson, and 3% Connecticut. A similar collection here in 1992 contained all hatchery fish, mostly from Hudson River source.

Hatchery fish dominated the final seine collection at Columbia on 13 October (21 of 22 fish) with most of these being Delaware River fry (62%) and Upper Spring Creek pond released fingerlings (24%). All fingerlings from this source were stocked at Thompsontown within the prior 37 days, and one of the recoveries at Columbia (USC Pond 1) had made the 50-mile trip in 5 days or less. Numbers of shad available for strobe light testing at York Haven peaked during 26 October through 3 November (Stone & Webster data). This coincided with a period of increasing flows and a temperature decline to about 10°C, conditions typical of autumn outmigration.

Of the 60 shad taken from strainers at Safe Harbor in 1993, 59 occurred during November 3-9 at an average river flow of about 22,000 cfs and water temperatures of 7-9°C. Small numbers of juvenile shad (15 fish) were taken with lift nets at Holtwood during the first 3-weeks of October. Peak outmigration occurred here during 25 October through 8 November (1,007 fish), and numbers dropped off substantially thereafter with the last 3 shad being collected on 22 November.

Prior to the peak of passage at Holtwood, most fish (79%) were wild. Otolith analysis from Holtwood samples taken during the peak weeks were comprised of 53% hatchery fish (93 of 174) including fish from all fry and fingerling release sources. Successful shad collections at Peach Bottom and Conowingo Dam coincided with the migration noted at Holtwood and included 40% hatchery fish.

Timing of juvenile shad outmigration from the Susquehanna River was clearly defined in 1993, occurring for hatchery and wild fish at all recovery sites within the 23-day period 25 October through 16 November. During this period daily flows generally increased from 12,000 cfs to about 30,000 cfs and water temperatures declined from 14° to 6°C (Safe Harbor data).

Abundance

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 and Three Mile Island samples, a total of 156 seine hauls were made from Marietta to Pequea on 21 dates over 15 weeks in 1993. With a catch of 275 juvenile shad, the overall catch per unit effort (CPUE) was about 1.76. CPUE was highest during the late July nursery period (2.9) and at outmigration after mid-September (3.3). The table below compares stocking numbers and juvenile recovery data from 1993 with overall shad catch and effort using seines at similar sites in the river below York Haven Dam during the prior 3-years.

Year	Adult Females	Fry Stocked	Seine Dates	Shad Catch	Number Hauls	Juvenile CPUE
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
1990	6,315	5.62M	8/1-11/2	351	87	4.03

Cooling water strainers at Safe Harbor and Conowingo and intake screens at Peach Bottom are passive samplers. 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 1993 at Safe Harbor, Peach Bottom, and Conowingo is compared below with the prior 3 years for those periods encompassing the catch.

Location	Catch (Shad) Per Unit Effort (Days) 1993	1992	1991	1990
Safe Harbor	3.75	0.00	3.30	3.35
Peach Bottom	1.08	0.03	0.16	1.07
Conowingo	0.49	0.18	0.69	0.33

This comparison indicates that juvenile shad abundance during outmigration in 1993 was similar to that of 1990-1991 but, contrary to the seine data, suggests a very weak run in 1992. CPUE data at these sites should be viewed cautiously since they are based on very small yearly samples.

The lift net at Holtwood produced 1,093 juvenile shad in 170 lifts during late September through November, 1993. RMC has effectively sampled with this gear for 9 years at Holtwood and the table below compares catch and effort for that period.

Year	Dates	Effort (lifts)	Shad Catch	CPUE
1993	9/28-11/22	170	1,093	6.43
1992	9/17-10/29	130	39	0.30
1991	10/14-12/16	210	208	0.99
1990	9/26-11/16	200	3,980	19.90
1989	9/22-10/26	116	556	4.79
1988	10/26-12/7	154	929	6.03
1987	9/10-11/20	358	832	2.32
1986	10/6-12/2	393	2,928	7.45
1985	10/16-12/19	378	3,625	9.59
	Average	234	1,577	6.74

Analysis of this data indicates that stock size at outmigration in 1993 was comparable to the long-term average, considerably greater than that of 1991-1992, but only about one-third as strong as that of 1990. The comparison with 1990 lift net CPUE agrees with seine data.

Abundance of wild shad in summer/fall collections appeared considerably greater in 1993 than in prior years. Based on otoliths analyzed from all collections above Conowingo Dam, naturally produced fish comprised 58% compared to 39% in 1992, 22% in 1991, and only 2% in 1990. Although the number of adult shad stocked in 1993 was less than in each of the prior 3 years, improved reproductive success and juvenile survival may be related to favorable river conditions and food availability.

Finally, the electrofishing collection of 31 juvenile shad from the Susquehanna Flats during August through mid-October 1993, compares to 4 fish in 1992, 17 in 1991, and 23 in 1990 with similar effort. It is not surprising that these fish and the 37 shad taken in DNR seine surveys were all wild. Cultured fry were not stocked below Conowingo in 1993, no unusual summer/fall high flow event occurred in the river, and Elkton fingerlings were stocked too late for recovery.

Growth

Wild juvenile shad collected with seines at Marietta and Columbia averaged 57 mm total length (TL) in mid-July (range 39-65 mm) and grew to an average 129 mm (range 115-144 mm) by late September (Figure 3). Growth rate during this period averaged 1.0 mm/day. Hatchery fish in these collections were only slightly smaller with mean lengths improving from 68 mm in late July (range 61-74 mm) to 128 mm in late September (111-135 mm) with an average growth rate of about 1.0

mm/day. These growth rates are similar to those recorded in 1992 and 1991. Wild fish from Pequea collections in July were considerably larger than those upstream, averaging 79 mm (69-90 mm).

The two wild fish in the Amity Hall shad sample from 28 July had a mean TL of 80 mm, while hatchery fish averaged 67 mm (range 43-80 mm). Hudson and Delaware River source fry were about the same mean size at 68 and 66 mm, respectively, and the two Connecticut fish were 43 mm and 65 mm. In the 1992 Amity Hall collection, Hudson fish were 20% larger than Delaware. Hatchery fish at both Amity Hall and Columbia were the same size in late July.

Outmigration at York Haven apparently occurred during mid-October through the first week in November. Mean size of hatchery fish in the 22 October sluice net collection here was 126 mm while wild fish averaged 147 mm (range 120-187 mm). Among the 18 wild fish in this collection were three specimens over 180 mm. This unusually large size of wild fish above York Haven suggests that reproduction may have occurred earlier here than below York Haven (i.e. the fish were older), or that they grew at an exceptional rate, perhaps related to less competition for food.

Wild juvenile shad in lift net collections at Holtwood from early October through late November displayed no trend in mean fish size. All weekly collections averaged 126-132 mm, with individual fish ranging 118-149 mm (n = 85). Hatchery fish from upstream fry stockings in Holtwood samples showed a general decline in mean size from 126 mm in late October to 118 mm in mid-November. Fingerlings stocked at Thompsontown appeared in relatively high abundance at Holtwood on November 11-15. These 18 fish were considerably smaller than hatchery shad stocked as fry, averaging 100 mm (range 89-127 mm). Most of these fish (16 of 18) came from Upper Spring Creek ponds 2 and 3, stocked during September 15-24. Wild and hatchery fish in collections from Peach Bottom and Conowingo during November were slightly larger than those at Holtwood.

Other than the Amity Hall sample noted above, our only opportunity to compare shad growth among the various egg sources stocked as fry at Thompsontown, came from combined Holtwood samples taken during 26 October through 15 November. Fish lengths were available from 73 hatchery shad including 38 Hudson, 27 Delaware and 8 Connecticut River fish. Mean lengths for Hudson and Delaware shad were both 123 mm with a combined size range of 91-144 mm. Both groups were approximately the same age with median release dates of June 15 and June 22 at 19-20 days old. The two Connecticut River fish stocked on June 13-14 at 7 days of age (single day 5 TC mark) averaged 124 mm, whereas the 6 fish from this source released later (median date 6/25 at 22 days old) showed a mean length of only 115 mm (range 105-121 mm). These results are almost identical to that found in 1992.

Stock Composition and Mark Analysis

Of the 6,541,500 shad fry stocked at Thompsontown in 1993, 2,937,900 (44.9%) were Connecticut River origin released on 14 dates between 13 June and 13 July. Of these, 891,700 fry carried a single TC mark and were stocked at 7-days of age on June 13-14. The remaining Connecticut fish were quintuple marked and stocked at 22-26 days old. Delaware River shad fry comprised 2,499,400 (38.2%) of the total Juniata River stocking in 1993, with 12 releases between 11 June and 2 July. The remaining 1,104,200 fry (16.9%) were Hudson River origin stocked at Thompsontown on six dates between June 3-18.

Although Hudson River fish comprised the smallest percentage of total fry stocked upstream, as was the case in 1992, they were the dominant component of tetracycline marked shad in most juvenile collections. Hudson fish comprised 49.2% (128 of 260) of marked shad of known origin from all collections above Conowingo Dam. Their frequency of occurrence ranged from 45% to 53% of marked samples from the various collecting areas. Depending on survey location, Delaware fish comprised 26%-42% of collections and Connecticut fish made up 6%-12%. Frequency of pond-released fingerlings in collections was 1%-18% with most being recovered in late season samples from Holtwood.

Survey Area	Collection frequency from various stocked sources Hudson	Delaware	Conn.	Ponds
Above York Haven	52%	42%	6%	1%
Marietta-Columbia	53%	26%	12%	9%
Holtwood-PB-Cono.	45%	30%	7%	18%

Recovery rates (number recovered/number stocked) for the three egg source strains stocked as fry were 0.000116 for Hudson (about 1 in 9,000), 0.000034 for Delaware (1 in 29,000), and 0.000007 for Connecticut (about 1 in 150,000). Relative survival to recovery of Hudson fish exceeded that of Delaware and Connecticut fish by factors of 3.4 and 16.6, respectively. Somewhat surprisingly, two lots of Connecticut River fry which were stocked in mid-June at only 7 days of age with a single TC mark were recovered at a rate over four times that of the remaining Connecticut lots stocked at 22-26 days old with multiple marks (0.000013 vs. 0.000003).

A total of 79,400 specially marked fingerling shad were stocked from Pennsylvania ponds into the Juniata River including 35,400 Hudson fish from the Thompsontown canal pond on 18 August at 93 days of age, and 44,000 Delaware fish from three

Upper Spring Creek ponds during 15 September through 12 October at 121-148 days old. With 26 of these fish taken in downstream collections, their recovery rate of 0.000327 (1 in 3,000) was almost three times greater than the best fry source (Hudson). Numbers of shad released and collected, recovery rates, and relative survival from various egg sources stocked in the Susquehanna River during 1988 through 1993 are shown in Table 4.

Based on otolith analysis of 618 shad from all collections above Conowingo Dam in 1993, 58% (356 fish) were naturally produced. This compares to 39% in 1992, 21.5% in 1991, and 1-4% each year during 1987-1990. With the late adult trapping season in 1993, about 4,350 female shad were successfully transferred from Conowingo and released above dams. Although this is considerably fewer than the estimated 6,300 to 8,300 females stocked each year in 1990-1992, improved reproductive success and juvenile survival in 1993 probably related to favorable environmental conditions and food availability. Unlike the past few years, spawning shad and their progeny were not exposed to unusual flow or temperature fluctuations or drought conditions.

SUMMARY

The haul seine was effective in taking juvenile shad at several lower river sites during mid-July through mid-October. Catch per unit effort with this gear of 1.76 shad/haul was comparable to that from 1992 and considerably greater than in 1991 when larger numbers of adults and hatchery fry were released in the river.

Hudson River source juveniles stocked as fry at Thompsontown appeared simultaneously in collections at Amity Hall and Marietta in late July. Delaware source fish did not appear in downstream collections until October. Successful reproduction of transplanted adult shad was well documented with the collection of unmarked wild fish at all netting sites during July through October.

River flow conditions during the summer and fall of 1993 were stable and slightly below long-term average values. Outmigration from the river occurred during the period 25 October through 16 November and, based on collections at all points below York Haven, the outmigrant population was considerably stronger than in 1991 and 1992.

Hatchery released fry grew well, reaching an average size of about 123 mm within 4-months of release. Later released Connecticut River shad in collections were slightly smaller than Hudson and Delaware juveniles. Wild shad grew at about the same rate as hatchery fish but generally maintained a slight size advantage in combined collections.

Relative to their abundance at stocking, Hudson River source juvenile shad were recaptured at 3.4 to 16.6 times greater frequency than Delaware and Connecticut River fish, respectively. Pond-reared fingerlings were very well represented in late season collections within several weeks of release in the Juniata River.

REFERENCES

St. Pierre, R. A. 1993. Evaluation of movements, abundance and growth of juvenile American shad in the Susquehanna River. In Restoration of American shad to the Susquehanna River. 1992 Ann. Prog. Rep. to SRAFRC, Harrisburg, PA.

Table 1. Summary of Juvenile American Shad Collected with Seines in the Susquehanna River, July-October, 1993

Date	Location	No. Hauls	No. Shad
7/15	Columbia	7	2
	Marietta	2	10
7/16	Pequea	8	11
7/20	Pequea	6	27
7/21	Columbia	4	0
	Marietta	3	4
7/27	Marietta	6	24
7/28	Amity Hall	3	265
8/3	Pequea	9	0
8/4	Columbia	3	1
	Marietta	2	8
	Three Mile Isl.	1	109
8/12	Marietta	5	2
8/13	Pequea	8	0
8/17	Marietta	4	22
8/18	Columbia	4	8
	Pequea	9	0
8/25	Three Mile Isl.	8	9
8/26	Marietta	8	12
9/1	Columbia	8	13
9/2	Pequea	7	1
9/8	Columbia	10	20
9/15	Columbia	6	15
9/21	Columbia	8	35
9/30	Columbia	8	27
10/6	Columbia	6	11
10/13	Columbia	7	22
10/20	Columbia	8	0
	Totals	168	658

Table 2. Summary of Fish Collections with Lift Net in the Holtwood Hydroelectric Project Forebay during Autumn 1993. Effort was 10 lifts per event.

Date	American Shad*	Blueback Herring	Gizzard Shad	All Other
9/09	-	-	634	8
9/13	-	-	51	1
9/16	-	-	528	13
9/20	-	-	287	6
9/23	-	-	368	47
9/28	3	1	3684	13
9/30	3	-	2380	32
10/4	2	1	2239	25
10/7	3	1	25097	36
10/12	2	-	4785	25
10/14	2	-	4024	12
10/18	1	1	2967	6
10/21	1	2	5947	9
10/25	145	14	1447	5
10/28	206	24	7639	4
11/01	166	16	1540	3
11/04	130	12	260	0
11/08	360	60	1948	6
11/11	20	12	1344	2
11/15	46	6	120	4
11/18	2	2	103	3
11/22	3	4	31	0
11/24	-	17	209	0
11/29		cancelled due to high water		
12/02	-	-	3605	3
Totals	**1,093**	**173**	**71,237**	**263**

* juveniles only

Table 3. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1993.

Collection Site	Coll. Date	Immersion marks: Day 5	Days 5,9,13	Days 3,13,17	Days 3,11, 13,17	Days 5,13, 17,21	Days 5,9,13, 17,21	Feed marks: Canal Pond	USC Pond 1	USC Pond 2	USC Pond 3	Total Marked	Wild Micro-structure Not Marked	Total
Amity Hall	7/28/93	1	29	32			1					63	2	65
Clemson I.	9/27/93											0	1	1
Three Mile	8/4/93	1	10									11	18 *	29
Island	8/25/93	2	3									5	4	9
York Haven	9/29/93		4									4		4
	10/22/93		1	5	1					1		9 **	18	27
												0		0
Marrietta	7/15/93											0	10	10
	7/21/93											0	4	4
	7/27/93		5									5	17	22
	8/4/93											0	7	7
	8/12/93											0	2	2
	8/17/93		1									1	18	19
	8/26/93	2	2									4	8	12
Columbia	7/15/93											0	2	2
	8/18/93	1	1									2	6	8
	9/1/93	1	2									3	10	13
	9/8/93	1	3									4	16	20
	9/15/93		3									3	12	15
	9/21/93		4									4	21	25
	9/30/93		8	1								9	18	27
	10/6/93		1	1								2	7	9
	10/13/93	1	1	13			1		1	3	1	21	1	22

TABLE 3. (Continued)

Collection Site	Coll. Date	Immersion marks: Day 5	Days 5,9,13	Days 3,13,17	Days 3,11, 13,17	Days 5,13, 17,21	Days 5,9,13, 17,21	Feed marks: Canal Pond	USC Pond 1	USC Pond 2	USC Pond 3	Total Marked	Wild Micro– structure Not Marked	Total
Pequea	7/16/93											0	11	11
	7/20/93											0	26	26
	9/2/93											0	1	1
Holtwood	9/28/93											0	2	2
	9/30/93											0	1	1
	10/4/93		1									1	1	2
	10/7/93		2									2	1	3
	10/12/93											0	2	2
	10/14/93											0	2	2
	10/18/93											0	1	1
	10/21/93											0	1	1
	10/26/93		7	1				1				9	16	25
	10/28/93		5	4								10 ***	14	24
	11/1/93	2	4	2	1		2					11	14	25
	11/8/93		2	5								7	18	25
	11/11/93		7	4		1		1			5	18	2	20
	11/14/93		8	4	1	1	1					15	10	25
	11/15/93		5	5			1	1		5	6	23	5	28
	11/18/93											0	2	2
Peach Bottom	11/3–11/24/93		5	4								9	15	24
Conowingo strainers	11/5–11/22/93		4	2				1				7	9	16
Totals		12	128	83	3	2	6	4	1	9	12	262	356	618
Percent		4.6	48.9	31.7	1.1	0.8	2.3	1.5	0.4	3.4	4.6	42.4	57.6	

* Includes one specimen with hatchery microstructure and no mark
** Includes one specimen with marks on days 3,5,14,18 - unknown origin
*** Includes one specimen with marks on days 3,5,11,15 - unknown origin

Table 4. Relative survival of American shad fry from various egg source rivers, stocked in the Susquehanna River, 1988–1993.

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
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

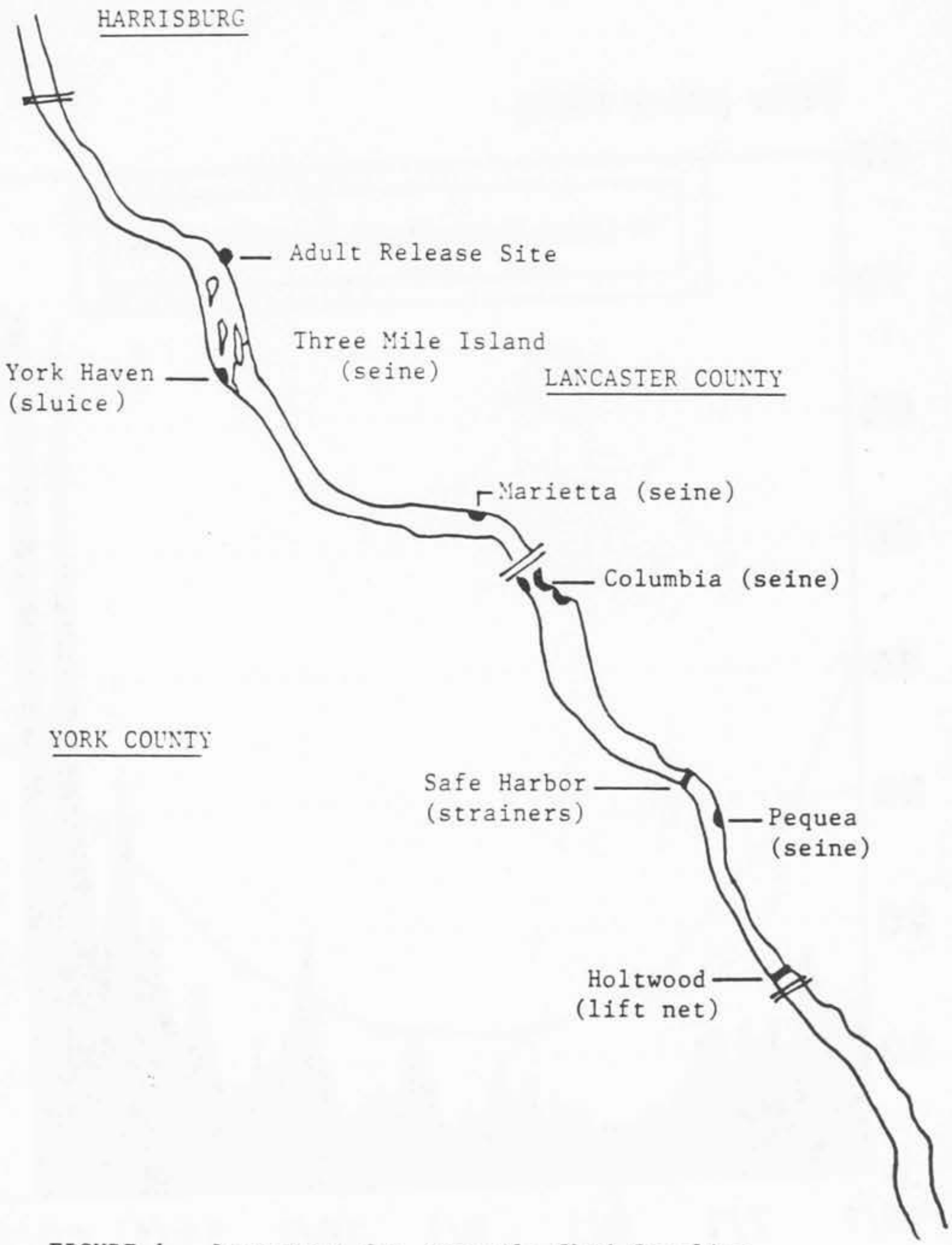


FIGURE 1. Locations for Juvenile Shad Sampling During July - October, 1993.

Figure. 2. Comparison of River Flow during June-November, 1993 with Long-Term Monthly Mean Flow.

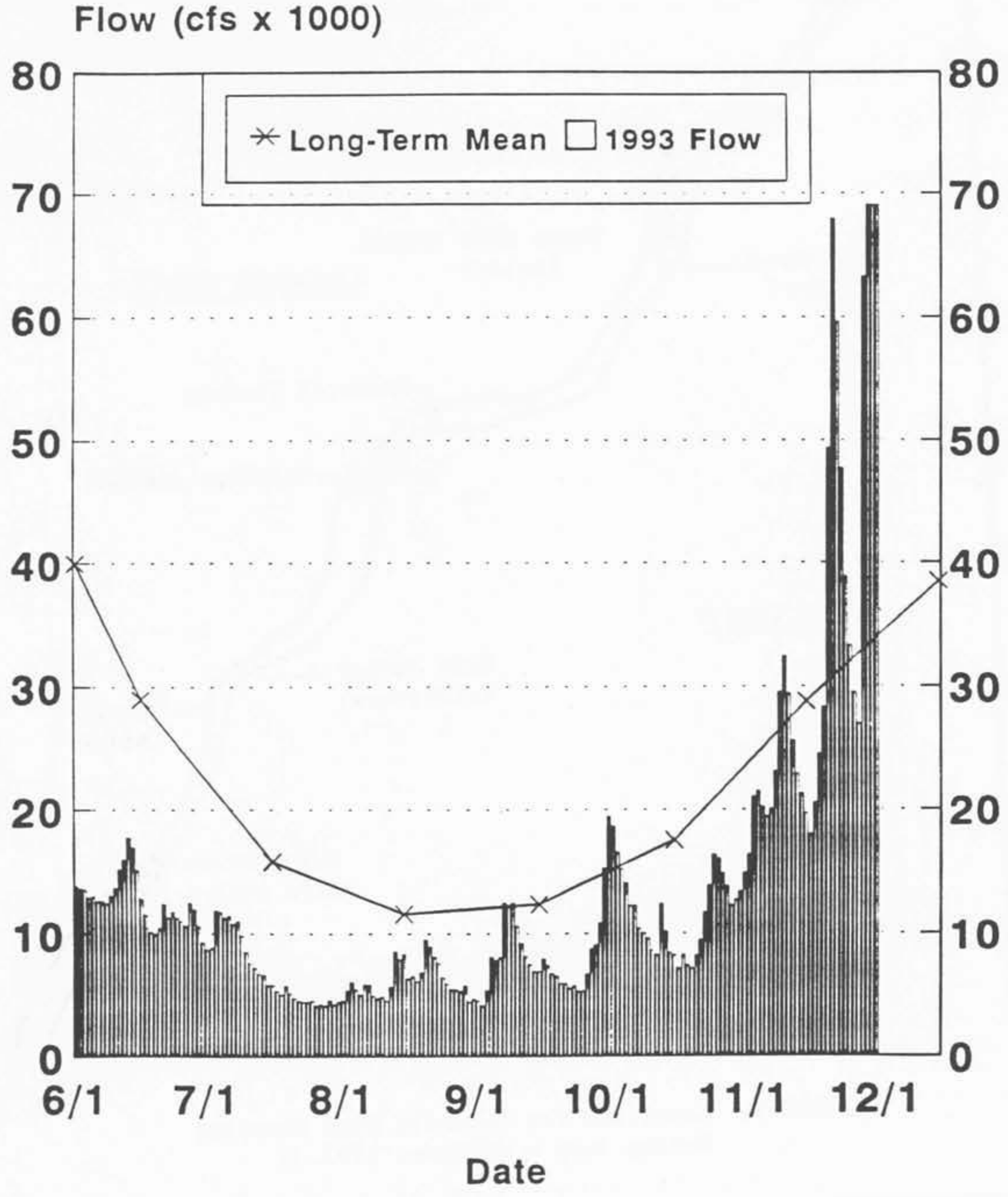
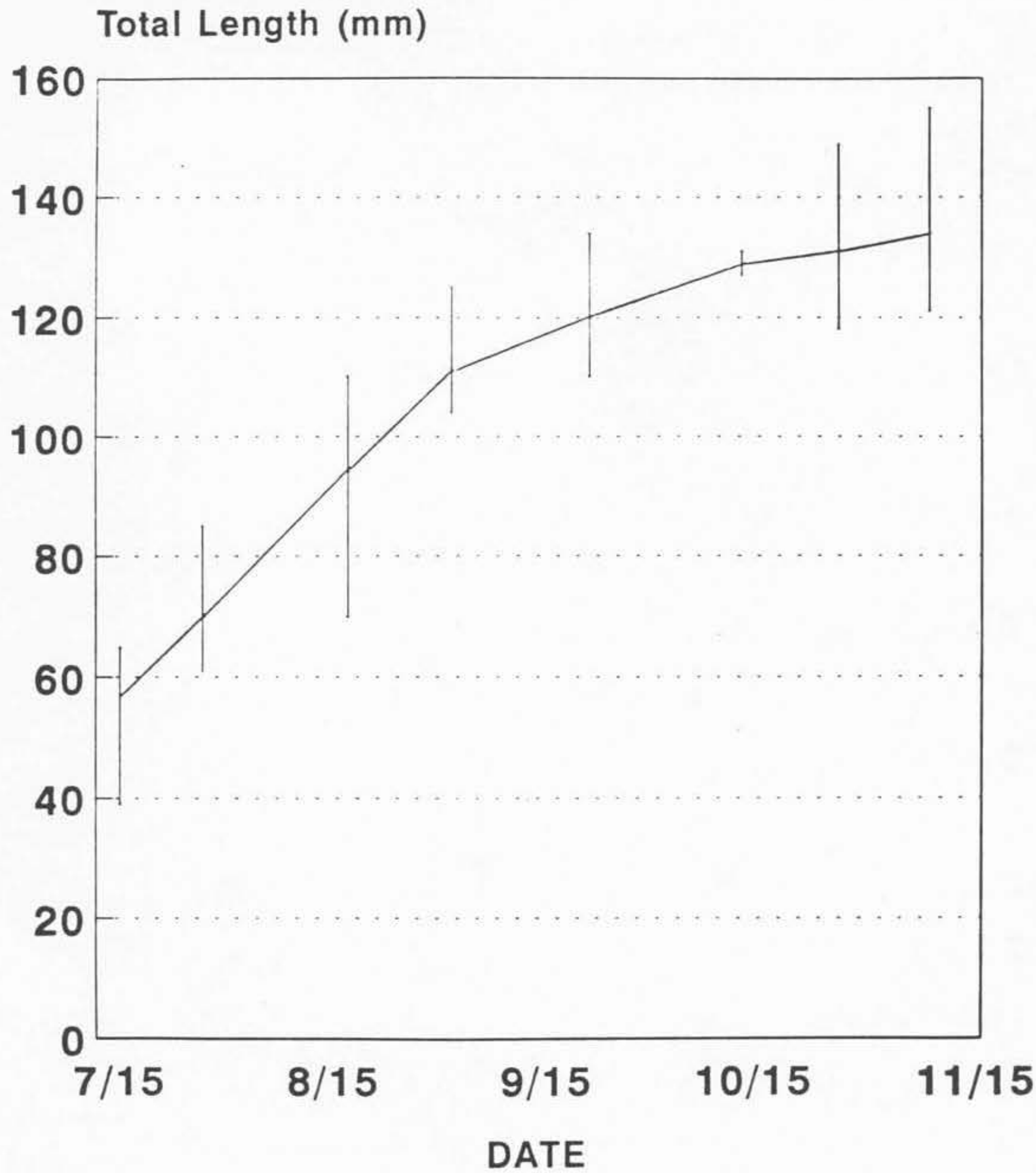


Figure. 3. Growth of Wild Juvenile Shad in the Susquehanna River in 1993.



July-October Data from Seines at Columbia and Marietta (n = 86); November Data from Holtwood and Peach Bottom (n = 60).

JOB V, TASK 1

TURBINE PASSAGE SURVIVAL OF JUVENILE AMERICAN SHAD (ALOSA SAPIDISSIMA) AT CONOWINGO HYDROELECTRIC STATION (FERC PROJECT NO. 405), SUSQUEHANNA RIVER, MARYLAND

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SUMMARY

At the direction of the Susquehanna River Technical Committee, the Susquehanna Electric Power Company (SECO) sponsored a study to estimate the survival of juvenile American shad (Alosa sapidissima) in passage through a new Kaplan type turbine (mixed-flow) at Conowingo Hydroelectric Station. The study was conducted between 28 October and 6 November 1993 at the newly installed turbine Unit 8, when it was operating at 55-56% wicket gate opening, a less than efficient mode of operation. The HI-Z Turb'N Tag-recapture technique (U.S. Patent 4,970,988) was utilized in the study. Water temperature ranged from 11-14°C (51.8-57.2°F) during the study.

A total of 108 juvenile American shad (100-149 mm fork length) was introduced into the turbine; an equal number was released near the turbine discharge as controls. The recapture rate of turbine exposed American shad was about 88% and that of controls about 93%; fish were generally recaptured within six minutes after release. The estimated short-term survival (1 h) was 94.9% (95% CI=86.2-100%); the long-term (48 h) survival was estimated at 92.9% (95% CI=83.9-100%). The survival of control and turbine exposed fish was not significantly different ($P > 0.05$). These survival rates are similar to those obtained for juvenile alosids at other hydro dams equipped with Kaplan type turbines.

The actual survival of naturally entrained juvenile American shad will most likely be higher than estimated herein because inflated tags recaptured without fish, fish preyed upon, or fish of unknown status were considered dead; tag separation from live fish was observed in turbulent waters. Due to personnel safety concerns fish could not be retrieved prior to tag separation. Additionally, tagged fish experienced multiple stress of capture, transport, tagging, induction, and recapture which naturally entrained fish do not experience.

Based on the findings of this and similar other studies it appears that passage of juvenile American shad through Kaplan type turbines at Conowingo Dam is relatively benign.

1.0 INTRODUCTION

Successful downstream passage of emigrating juvenile American shad (Alosa sapidissima) at hydroelectric dams is necessary to sustain, increase, or restore the population of returning adults to rivers of their origin. Of the several causes of mortality to juvenile American shad on their seaward journey, passage through hydro turbines is of major concern. Efforts to restore American shad population to the Susquehanna River have been underway for several years via trap and transport of pre-spawned adult American shad, which bypasses the four hydroelectric dams, and to stock hatchery-reared fry/fingerlings above these dams (Figure 1-1). Juveniles produced from these sources must successfully negotiate the four hydro dams in order to reach the Atlantic Ocean to mature.

Efforts have been directed to provide safe passage depending upon the magnitude of turbine-related mortality at each of the dams upstream of Conowingo. Many juvenile American shad are diverted away from the turbines at the upstream most dam, York Haven, by behavioral exclusionary devices. Passage survival at Safe Harbor (equipped with Kaplan turbines) was quite high (97%) but lower (60-80%) at Holtwood (equipped with Francis turbines). Feasibility of behavioral devices at Holtwood is being determined at present. Due to the paucity of reliable data at the Conowingo Dam (FERC Project No. 405), the last dam juvenile shad encounter on the Susquehanna, there has been a serious concern whether shad are safely negotiating this dam on their seaward journey. A need for potential mitigation can be evaluated or considered based on reliable data on the magnitude of the difficulty the entrained American shad encounter at Conowingo.

As a result of the above concerns the Susquehanna River Technical Committee (SRTC) at its February 18, 1993 meeting recommended that the PECO Energy Company's subsidiary Susquehanna Electric Company (SECO) conduct a study to reliably estimate survival of emigrating juvenile American shad in passage through a Francis turbine at the Conowingo Dam. The

Committee members recommended that prior to the implementation of a full-scale study, a detailed Study Plan be developed for their review and comments. Subsequently, SECO directed RMC Environmental Services, Inc., Drumore, PA (RMC) to develop such a Study Plan. RMC prepared the Study Plan and distributed it to the members for review and comments. All comments received were incorporated in the study plan.

The Study Plan provided procedures for reliably estimating survival of juvenile American shad upon passage through a Francis turbine at Conowingo Hydroelectric Station using the HI-Z Turb'N Tag (Turb'N Tag) recapture technique (U.S. Patent 4,970,988). It provided specific details of methodology, a brief literature review, study design, sample size, source of specimens, and reporting schedule. The Study Plan took into consideration prior knowledge, experience, and relevant existing data.

Although the Study Plan envisioned estimation of juvenile American shad survival in passage through one of the Francis turbines (Units 1-7) the study was conducted 28 October through 6 November 1993 at turbine Unit 8, a newly installed Kaplan type turbine (mixed flow) with fixed runner blades. All committee members were informed of this change in plans, none objected. The purpose of conducting the study at Unit 8 was to determine if the juvenile American shad survival is high at this new turbine. If survival was high then this turbine could be operated to release the required minimum flow instead of using a Francis turbine during the peak period of American shad emigration. Also with a high survival rate, similar turbine replacements will be planned for units 9, 10, and 11 in the future. All of these units could be utilized to pass emigrating juvenile American shad. Some very recent studies have shown that the survival of juvenile clupeids in passage through Kaplan type turbines may be higher than through some Francis turbines (EPRI 1992; Heisey et al. 1992; RMC 1991, 1992a,b,c,1994; Mathur et al. 1994a,b). Juvenile American shad passage survival through Kaplan type turbines has been reported to be more than 95% in some of these studies (Heisey et al. 1992; Mathur et al.

1994a,b); survival through Francis turbines was quite variable, ranging from 68 to 78% (24 h) at two large Francis units (RMC 1992c) and 94% (48 h) at a smaller unit with slow rotational speed (75 rpm) (RMC 1994). A feasibility study to estimate juvenile American shad survival conducted at Conowingo's Francis turbines in 1989 (RMC 1990) provided inconclusive results.

The principal objectives of the study were to estimate short (1 h) and long-term (48 h) survival of juvenile American shad in passage through Kaplan turbine Unit 8, and to evaluate the nature and source of injury. The study was conducted when the turbine was operating with the wicket gate opening of 55-56% to simulate a "worst case" scenario; survival of fishes is reported to be lower at inefficient turbine operation (Bell 1981; Eicher Associates 1987).

Prior to initiating the study, SRTC members were informed of the schedule and were encouraged to witness the study, offer comments, and make recommendations. Several members and their associates witnessed the study.

1.1 Project Description

The Conowingo Hydroelectric Station, built in 1928, is located at river mile 10 on the Susquehanna River (Figure 1-1). The powerhouse has a peaking generating capacity of 512-MW and a hydraulic capacity of 85,000 cfs. The powerhouse contains 7 vertical Francis (numbered 1-7) and 4 Kaplan turbines (numbered 8-11). The four Kaplan turbines were installed in 1964. Each has a hydraulic capacity of 10,000 cfs. The old Unit 8 has been recently replaced with a more efficient new Kaplan type turbine; the flow pattern within the new turbine is also smoother. The study was conducted at the new Kaplan turbine operating at 55-56% (50-MW or a discharge of 8,000 cfs) wicket gate opening, a less than efficient mode of operation. The optimum operating efficiency (93%) is reached at a wicket gate opening of approximately 75-80%.

Figure 1-2 shows a schematic of turbine Unit 8 along with the fish release locations. The turbine has six fixed blades with a runner speed of 120 revolutions per minute (rpm), and a runner diameter of 18.75 ft. It is identical to the new turbines (designated mixed-flow) recently installed at the Safe Harbor Hydroelectric Station (Heisey et al. 1992) on the Susquehanna River. Table 1-1 provides additional data on hydraulic and physical characteristics of the turbines.

Table 1-1 Physical and hydraulic characteristics of the Kaplan turbines at Conowingo Hydroelectric Station. Data supplied by the Susquehanna Electric Company.

Configuration	Kaplan (new)*	Kaplan (old)
No. of Units	1	3
Manufacturer	Voith	Allis chalmers
Name plate horsepower	85,000	85,000
Number of blades	6	5
Rated head (ft)	90	90
Rated output (MW)	62	62
Approximate flow at rated output (cfs)	10,000	10,000
RPM	120	120
Runner diameter (in) maximum	225	225
Hub diameter (in)	90.4 (top); 54.5 (bottom)	91.0 (top); 53.5 (bottom)
Clearance between blades (in): Hub	31	37
Tip	67	80
Water passage diameter at runner (in)	225.5	225.5
Blade tip speed (fps)	118	118
Number of wicket gates	24	24
Space between wicket gates (in)	23	23

* Kaplan type unit also designated "mixed-flow"

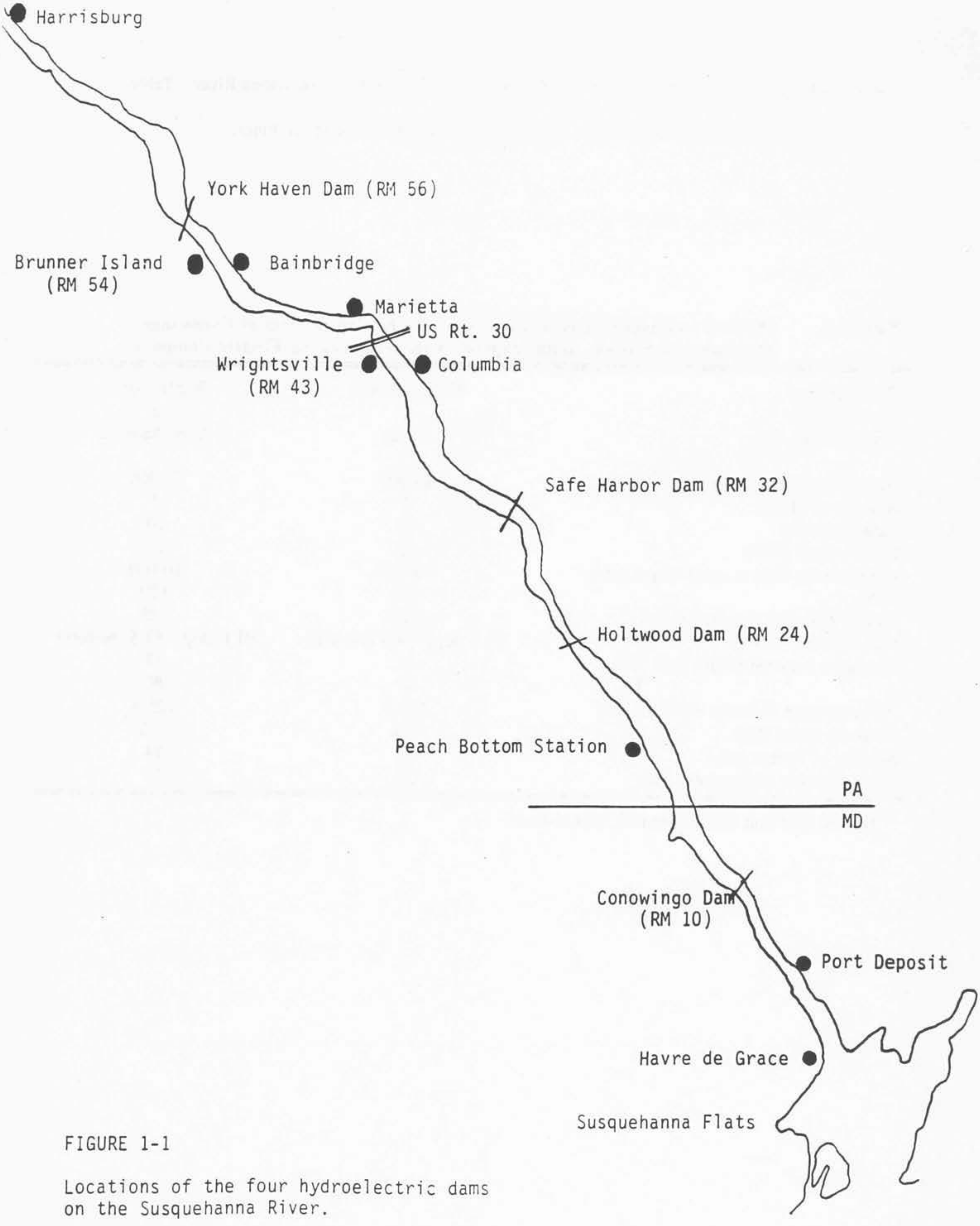

FIGURE 1-1

Locations of the four hydroelectric dams on the Susquehanna River.

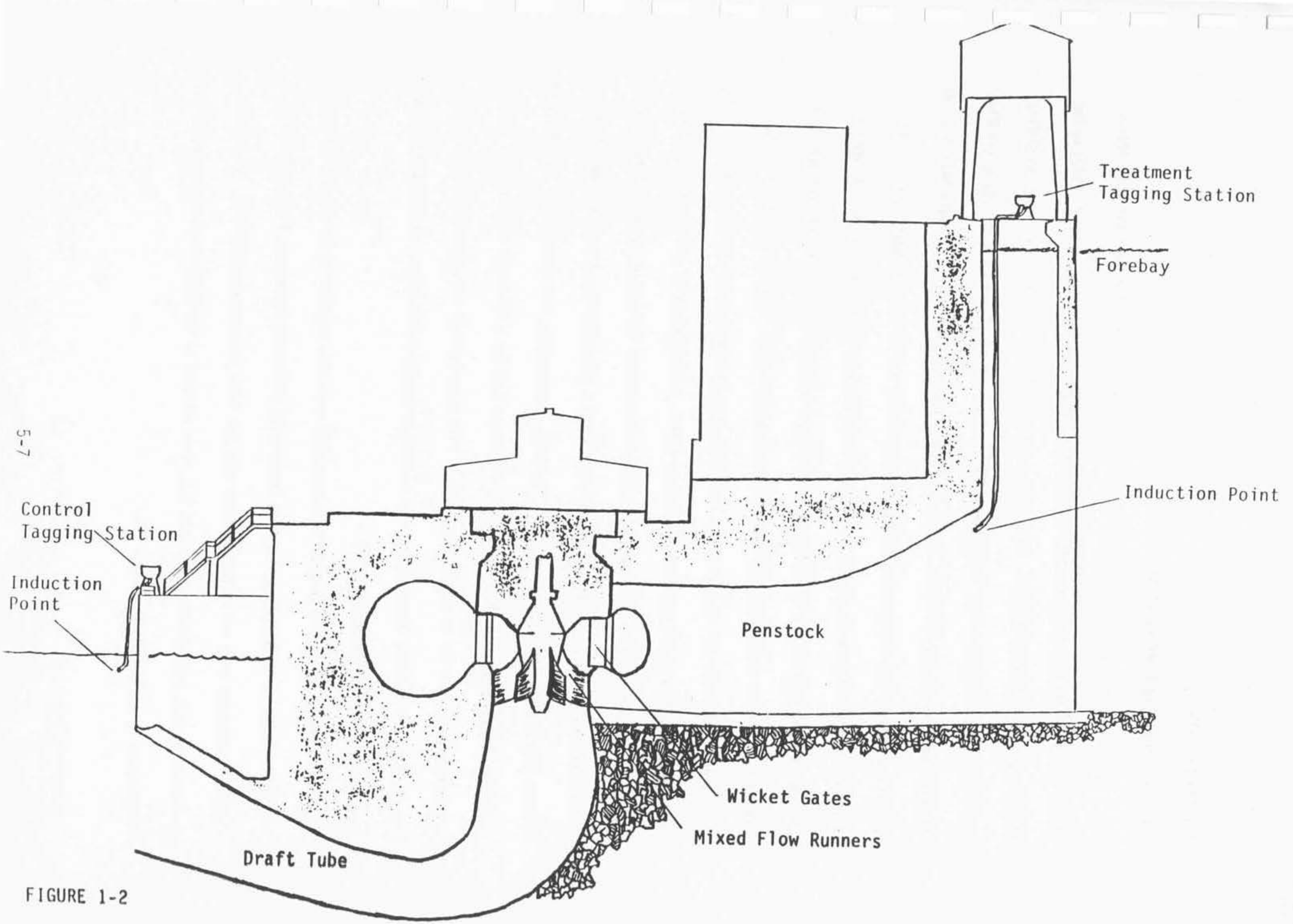

FIGURE 1-2

General configuration of Unit 8 Turbine and fish release locations at Conowingo Hydroelectric Station.

2.0 METHODS

2.1 Collection and Holding of American Shad

Juvenile American shad (100-149 mm fork length) were collected from the inner forebay of the Holtwood Hydroelectric Station by a specially designed lift net (Heisey et al. 1992) in late October and early November 1993. These fish were considered representative of the emigrating population. Upon capture, fish were transported in sealed 20 gal plastic circular tubs to the RMC Muddy Run Ecological Laboratory, Drumore, PA. At the laboratory, the fish were held in a 300 gal tank equipped with water recirculating system; salinity was maintained near 5 ppt. When sufficient number of juvenile American shad had accumulated, within a day or two of capture, they were transported to the Conowingo Dam in 50 gal tanks mounted on a pick-up truck. Fish were transported in oxygenated salt water (approximately 5 ppt). Upon arrival at the test site, shad were held in 600 gal circular tanks, located at the concrete deck off the East Side Fish Lift, and supplied with a continuous flow of ambient water. A 50 lb block of salt was added when fish were stocked and on subsequent days when fish were removed for testing. The 50 lb block of salt dissolved slowly over an 8-10 h period and maintained a concentration of approximately 5 ppt. These procedures minimized the effects of handling, transporting, and transferring; little mortality of fish occurred during the holding period. Fish were held for a minimum of 24 h prior to tag and release to allow for an acclimation period. Fish were handled with extreme care including water to water transfer, direct netting was avoided to minimize scale loss. The water temperature ranged from 11-14°C (51.8-57.2°F).

Approximately 500 juvenile American shad were also supplied by the Joseph Manning Hatchery which is operated by Maryland Department of Natural Resources, Fishery Division. These specimens were not utilized because wild fish were subsequently collected. All juvenile American shad, both hatchery and wild fish, were released to the Conowingo Hydroelectric Sta tailwaters at the end of the study.

2.2 Tagging of American Shad

Fish used for tagging were concentrated within a net and then water brailed from the holding pools and placed into 5 gal circular tubs filled with 5 ppt NaCl-buffered river water. Fish (5-10 specimens at a time) were carried to the tagging sites. Each fish was fitted with a neutrally buoyant miniature radio transmitter and a Turb'N Tag. The tagged fish were released by an induction system either into the turbine penstock (treatment) or turbine discharge (control). Just prior to release into the induction system the tag was activated by injecting 1-1.5 ml of catalyst.

Details of the tag and release technique are given in Heisey et al. (1992). Briefly, un-inflated Turb'N Tags were made of bright colored latex, were pear shaped with a maximum length and width of 38 mm (1.5 in) and 13 mm (0.5 in), respectively. Each tag weighed about 1.5 g. Upon inflation the tags measured 75 mm (3 in) long and 50 mm (2 in) in diameter. Each radio tag was approximately 10 x 31 mm, weighed 1.7 g, and propagated radio signals through a 27 cm thin wire antenna. Tags were attached by a single stainless steel pin through the dorsal musculature near the insertion of the dorsal fin. The pin was inserted with a modified ear piercing gun and secured by a small plastic disc. Figure 2-1 shows the steps involved in tagging and recapture of fish using the Turb'N Tag. Figure 2-2 shows the uninflated and inflated tag on juvenile American shad.

2.3 Induction of American Shad

Tagged fish were introduced individually into the penstock of turbine Unit 8 (treatment) or near its discharge (control) by an induction apparatus consisting of a small holding basin attached to a 7.6 cm (3 in) supply/delivery line (Figure 2-3). A gasoline powered trash pump supplied water to the system to ensure that fish were transported quickly within a continuous flow of water through the reinforced plastic delivery line deployed in the headgate slot (Figure 1-2). Control fish were tagged and released individually through a similar induction apparatus in an area between the discharge "boil" of Unit 8 and Unit 7. The excessive turbulence in the discharge "boil" of

Unit 8 created serious personnel safety concerns in retrieving control fish. Consequently, control fish had to be released in an area between Units 7 and 8 discharge. Thus, control fish may not have experienced equivalent level of turbulence as did the post turbine-entrained juvenile American shad.

2.4 American Shad Recapture

Turb'N Tags inflated shortly after release, usually within 5 minutes, and buoyed the fish to the surface for retrieval. Fish were located by homing on radio signals and/or visually spotting the inflated Turb'N Tag(s). Radio signals from tagged fish were received with a boat mounted 5-element Yagi antenna coupled to a programmable scanning receiver (Advanced Telemetry Systems, Inc., Isanti, MN). Fish which failed to surface were monitored via radio signals for at least 30 minutes.

Immediately upon retrieval, each fish was carefully examined for injury and tags removed by a modified pliers (Heisey et al. 1992). Later, fish were transferred via 5 gal buckets to a 600 gal holding pools to assess the long-term (48 h) effects of turbine passage. The treatment and control fish were held in separate pools containing approximately 5 ppt salt water. These pools were continuously supplied with ambient river water and covered to prevent escapement and minimize external stressors. A 50 lb block of salt was placed in each of the pools (treatment and control) to maintain the desired salinity. Additional salt was added, generally after 20-24 h. The addition of salt in the holding pools minimized the potential adverse effects of handling and transfer as juvenile clupeids are known to be extremely sensitive to handling stress (Heisey et al. 1992; Ruggles 1993). To further minimize handling stress, fish were measured (fork length in mm) at the end of the 48 h assessment period or at the time of mortality; however, little mortality occurred among the fish held for 48 h. Mortalities were examined at 24 and 48 h. The average length of treatment fish was 118 mm and of controls 117 mm (Table 2-1).

2.5 Classification of Recaptured American Shad

Recaptured fish were classified as follows to estimate the short-term (≤ 1 h) effects of passage through the turbine: (1) *recaptured alive* denotes *short-term (1 h) survival*; (2) *alive but not recovered, sighted swimming* denotes *live*; (3) *recaptured dead* denotes *immediate mortality*; (4) *tags only recaptured* were classified as *tag separation*; (5) *unrecovered fish with a transmitting radio tag* was assigned a status based on movement pattern of the radio tag. Fish were assigned a status *short-term mortality* if the tag remained stationary, *predation* if movement patterns were typical of predator (i.e., rapid movements throughout the tailrace, movement into areas of strong current, and aerial signals from gulls); and (6) *unknown* - neither fish nor tag were recovered within 30 minutes after release and status could not be ascertained from the radio signal.

The status of unrecovered radio tagged fish was determined by the characteristics of the radio signal transmissions or recovery of inflated detached tags. For the purpose of a conservative estimate of survival all fish classified as tag separation, predation or unknown were also categorized as mortalities (Heisey et al. 1992; Mathur 1994a). Survival of fish exposed to turbine, adjusted for control mortality, was estimated with the formula given by Burnham et al. (1987):

$$\hat{S} = \frac{(r_t/R_t)}{(r_c/R_c)}$$

where $\hat{S}$ = survival of fish after passage through turbine
r_t = number of live treatment fish recaptured
R_t = number of live treatment fish introduced into turbine
r_c = number of live control fish recaptured
R_c = number of live control fish released

$$Variance\ of\ \hat{S} = (\hat{S})^2\left[\frac{1}{r_t} - \frac{1}{R_t} + \frac{1}{r_c} - \frac{1}{R_c}\right]$$

$$Standard\ error\ (\hat{SE})\ of\ \hat{S} = \sqrt{Var(\hat{S})}.$$

The statistical significance in the differences in mortality and recapture rates of treatment and control groups was determined by a chi-square analysis as recommended by Burnham et al. (1987). Data were analyzed using the Statistical Analysis System (SAS Institute, Inc., Version 6.03).

Table 2-1 Fork length (mm) distribution of American shad used for the turbine passage survival study at the Conowingo Dam Unit 8, October-November 1993.

Length	Control	Test	Total
LE 100	2	.	2
110	18	16	34
120	39	34	73
130	14	20	34
140	5	5	10
150	1	.	1
TOTAL	79	75	154*
Minimum	100	104	
Maximum	149	135	
Mean	117	117	
Standard Deviation	9	7	

* Not all tagged fish released could be measured.

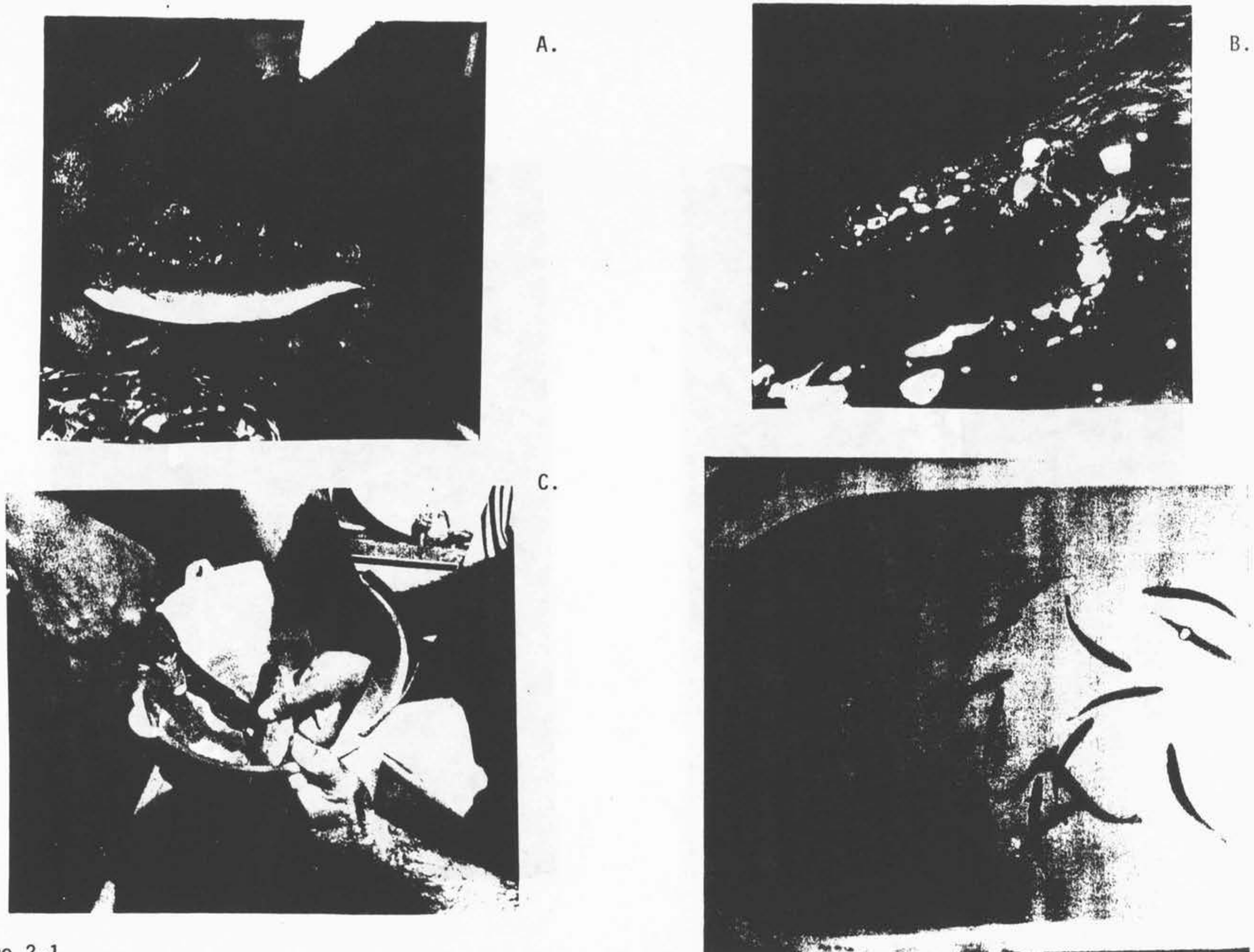

Figure 2-1

Example of Turb'N Tag-recapture procedures on juvenile salmon. A. Tagged fish prior to release. B. Fish buoyed to surface after passage through station. C. Removing tags. D. Recaptured fish in long-term assessment tank.

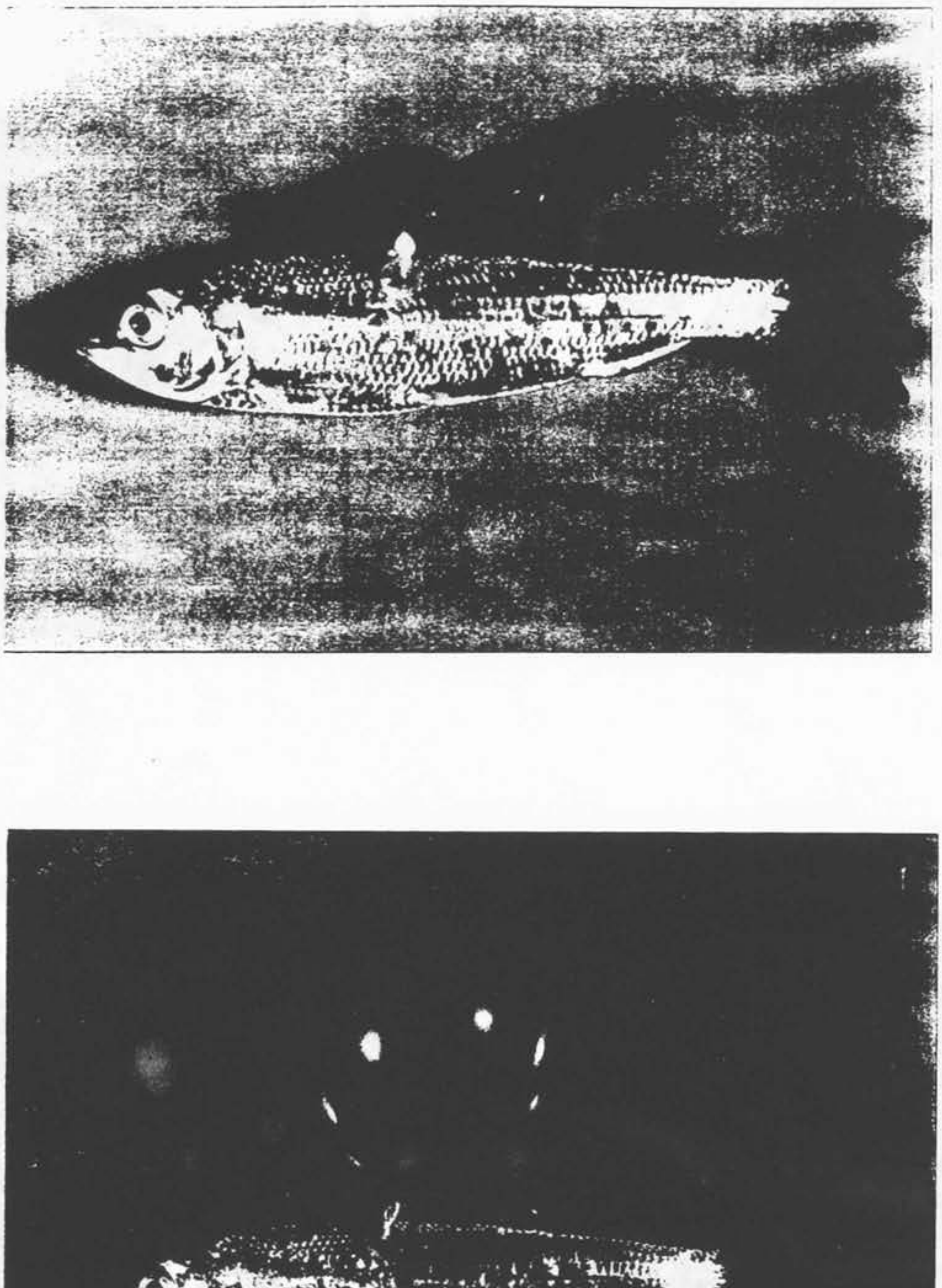

Figure 2-2 Uninflated and inflated Turb'N Tags on a young American shad. Reproduced from Heisey et al. (1992).

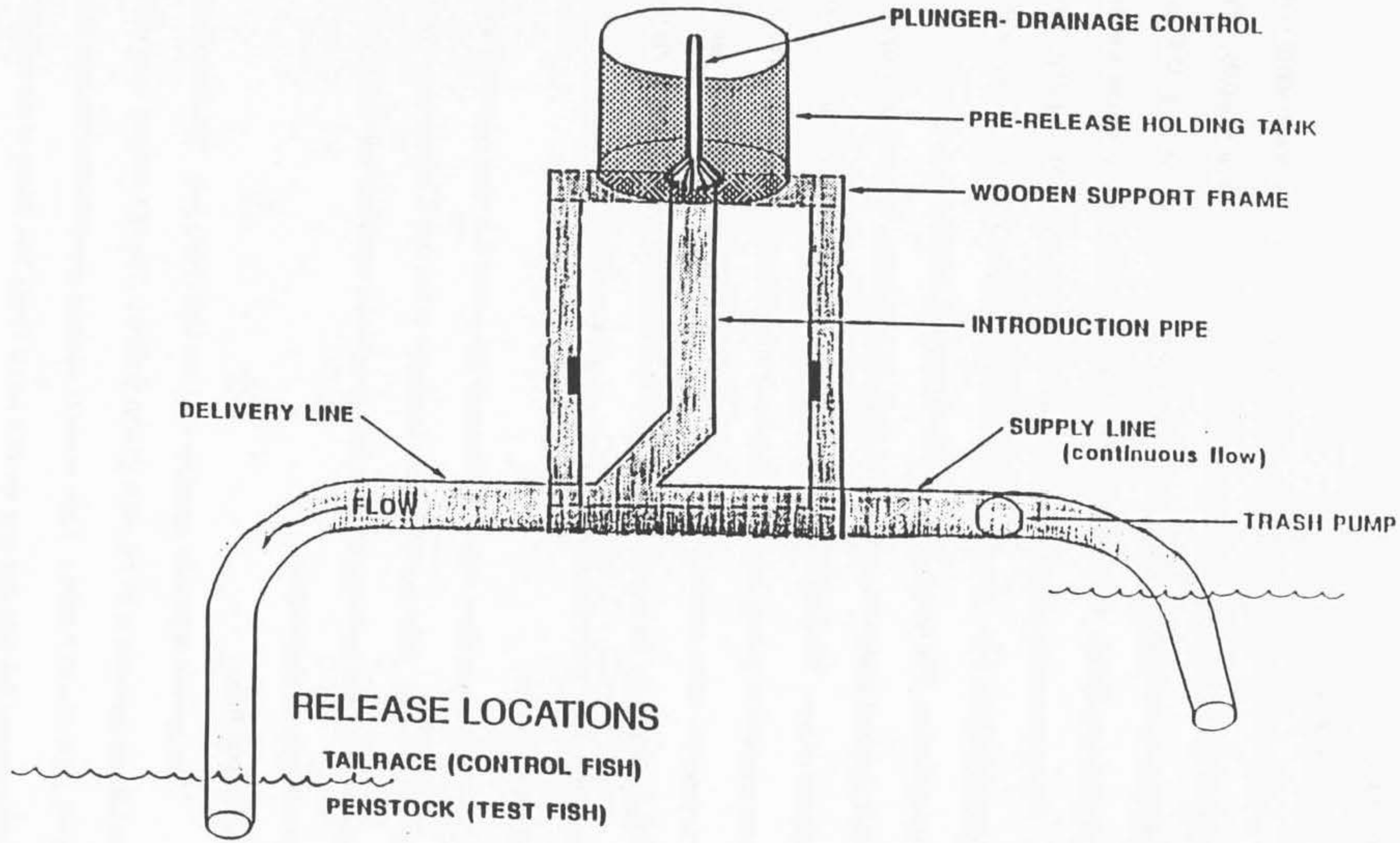

Figure 2-3 Schematic representation of the portable fish induction system.

3.0 RESULTS

3.1 Recapture Rates

A total of 108 treatment and 108 control juvenile American shad was released (Table 3-1). Recapture rates of both groups were relatively high and statistically similar ($P > 0.05$). The recapture rate of treatment group (physically recaptured live and dead) was about 88% and that of control group was 92.6%. Only one each of treatment and control fish recaptured was dead.

The non-recovery of tag-bearing fish could be partially attributable to gull predation and tag separation (Table 3-1). About 5.6% of the treatment (6 fish) and 6.5% (7 fish) of the controls were preyed upon. The recapture of 7 (6.5%) inflated tags without fish in the treatment group, although classified dead in the analysis fish, might have survived. None of the controls showed detachment of tags. The juvenile American shad have relatively soft flesh and some tags may have become separated in passage through turbulence of the turbine discharge "boil". The control fish, due to personnel safety reasons, could not be released directly into the discharge "boil" of Unit 8 and thus probably did not experience an equivalent amount of hydraulic forces as did the turbine-exposed fish; they were released between Units 7 and 8 discharge in an area subject to only moderate turbulence.

The recapture times of both the treatment and control fish were relatively short and quite similar (Table 3-2). Most specimens were recaptured in less than 6 min; average was 6 min for treatment and 4 min for controls. Thus, both groups were exposed to tailrace conditions approximately for similar times.

3.2 Survival Rates

The survival of juvenile American shad was high (Table 3-1). The short-term (1 h) survival was estimated at 94.9% (95% CI=86.2-100%). The 48 h survival was estimated at 92.9% (95% CI=83.9-100%). Little mortality occurred after immediate passage; only 2 of the 94 turbine-exposed fish held died over the 48 h period (Table 3-1). None of the controls died over the long-term assessment period. Differences in survival of treatment and control fish were nonsignificant ($P > 0.05$) at 1 h or 48 h.

3.3 Injury

All recaptured fish (live and dead) were carefully examined for type and location of injury, scale loss, and unusual behavior (Table 3-3). Only one treatment fish was severed and appeared to have suffered a lethal direct strike from a turbine blade or other structural component. Some specimens (treatment, 11; controls, 10) had scale loss which was attributed to tagging and recapture procedures. Other infrequently observed injuries included lacerations (2 treatment, 1 control) and bruises (1 treatment, 3 control). These injuries were lethal to only two of the treatment fish during the long-term (48 h) assessment period. All live specimens (both treatment and control) were in good condition at the end of 48 h.

Table 3-1 **Recapture and survival rate of juvenile American shad introduced into turbine Unit 8 (treatment) and turbine discharge (control) at Conowingo Hydroelectric Station. The unit operated at inefficient wicket gate setting of 55-56% (50 MW) during the study.**

	Turbine	Control
No. Released	108	108
No. Recaptured Live	94	99
No. Dead or Lost		
Recaptured Dead	1	1
Tags Only	7	0
Unknown	0	1
Lost to Predation	6	7
Estimated short-term (1 h) survival = $\frac{94/108}{99/108}$ = 94.9%		
95% CI	86.2 - 100.0%*	
Estimated long-term (48 h) survival = $\frac{92/108}{99/108}$ = 92.9%		
95% CI	83.9 - 100.0%*	

* Upper limit truncated at 100%.

Table 3-2 **Recapture times (time from release until recapture of fish or inflated tags) of treatment (turbine exposed) and control (released into turbine discharge) fish released at turbine Unit 8 of the Conowingo Hydroelectric Station, October-November 1994. The turbine operated at 55-56% wicket gate setting during the study.**

	N	Mean	Standard Deviation	Minimum	Maximum
Treatment	103	6.0	6.7	1	62
Control	101	4.1	2.7	2	23

Table 3-3 Matrix of American shad injury type for fish released in turbine unit 8 of the Conowingo Hydroelectric Station, October and November 1993.

INJURIES	TREATMENT				CONTROL	
	SINGLE INJURY	MAJOR SCALE LOSS	MINOR SCALE LOSS	STRESS	SINGLE INJURY	MAJOR SCALE LOSS
Lacerations	1	1 *				1
Bruises/ hemorrhaging				1	3	
Major scale loss	2			1	2	
Stress	5				4	
Minor scale loss	7			2	7	
Severed body parts			1			
TOTALS	**15**	**1**	**1**	**4**	**16**	**1**

* - this fish also exhibited stress

4.0 DISCUSSION

The survival of fishes in passage through turbines, spillways, or bypasses can be reliably estimated with the fulfillment of assumptions associated with the procedures used in a study. To obtain a valid survival estimate for the Conowingo study we made the following explicit assumptions: handling, tagging, and release do not differentially affect the survival rates of treatment and control groups; recapture probabilities for the treatment and control groups are the same; and recapture crews do not differentially select retrieval of either group of fish. The assumptions were considered fulfilled as follows. Although insertion of the tag, fish induction, and tag removal requires handling and may result in some injury or mortality our results indicated that these processes had minimal effects over the 48 h assessment period. The 48 h survival of live recaptured control fish was 100% (99 of 99). The survival of recaptured live treatment fish was 97.8% (92 of 94). The survival of treatment and control groups was not significantly different ($P > 0.05$); little mortality occurred beyond 1 h and nearly all fish appeared to be swimming normally.

The assumption that treatment and control fish were equally vulnerable to recapture was not violated. Chi-square tests indicated homogeneity ($P > 0.05$) in recapture and survival probabilities of control and treatment fish. No recovery crew was specifically assigned to retrieve control or treatment fish; the fish were recaptured by the available crew. The average recapture times for the treatment and control groups were virtually identical. Thus, the recapture crew bias was minimized.

Two of the major obstacles in obtaining reliable turbine passage survival estimates of fishes, particularly juvenile alosids, have been the inability of investigators to quickly recapture a high proportion of fish for careful physical examination and to minimize injury/mortality due to recapture process at large hydro-dams (Heisey et al. 1992). The recoverable tag recapture technique used in the present study overcame these limitations. Since the tag is chemically based and inflates quickly no special or elaborate systems were required to retrieve each buoyed fish. The recapture crews were trained in handling of juvenile alosids and retrieved the buoyed fish with minimal damage; thus, the mortality due to recapture process was minimized.

Heisey et al. (1992) noted that in past studies on juvenile alosids, using conventional methods (e.g., netting) a combination of high recapture rates and low control mortality has been generally unattainable. The tag-recapture procedures performed well during the present study. Over 90% of the fish (treatment and controls combined) were recovered. This contrasts with some net studies in which recovery rates were sometimes quite low. For example, Taylor and Kynard (1985) reported average recovery rates for turbine-exposed juvenile clupeids less than 6% and those of controls averaged less than 15%. Burnham et al. (1987) and Ruggles (1993) indicated that the reliability of turbine passage survival rates increases substantially with low control mortality and high recapture rates. Both these criteria were fulfilled in the study. Over 87% of the treatment fish and nearly 93% of the control fish were quickly recaptured for observation and separation of injury/mortality due to handling, tagging, induction, and tag removal from that due to turbine exposure. Thus, the survival estimate, though conservative, for the present study is considered accurate.

Evidence is emerging that survival of juvenile alosids in passage through Kaplan type turbines is high (>90%) and remarkably similar. Our direct estimate of 92.9% is similar to that reported in some recent studies at other low-head (<100 ft) hydro-dams equipped with Kaplan type turbines (Heisey et al. 1992; Mathur et al. 1994a,b). Heisey et al. (1992) estimated survival of juvenile American shad (95-140 mm fork length) at 97% in passage through the Safe Harbor Hydroelectric Station (55 ft head, turbine discharge 8,500-9,200 cfs, 5-7 turbine blades rotating at 76-109 rpm) on the Susquehanna River, Pennsylvania. Mathur et al. (1994a) reported survival of juvenile American shad at 97.3-100% in passage through Hadley Falls Station (50 ft head) on the Connecticut River, Massachusetts. The discharge of the turbine unit ranged from 1,500 to 4,200 cfs. The turbine has five runner blades with a rotational speed of 128 rpm. At the Crescent Dam (27 ft head, 1,500 cfs discharge, turbine runner speed of 144 rpm, and 5 blades) on the lower Mohawk River, New York the survival of juvenile blueback herring (Alosa aestivalis, 75-105 mm total length) was estimated at 96% (Mathur et al. 1994b).

The actual survival of juvenile American shad at Conowingo Dam may be higher than estimated herein. The assumption of including all inflated detached "tags only" recoveries among the dead fish category was conservative and most likely underestimated survival. Observations indicated that some treatment fish which became trapped in the discharge "boil", for personnel safety reasons could not be retrieved, were alive but the tags became detached within minutes in the turbulence. Evidence from other similar studies indicates that fish equipped with two Turb'N tags are alive in many instances when one of the tags has been dislodged or malfunctioned. An example is a recently completed study on yearling fall chinook salmon smolts (Oncorhynchus tshawytscha) at the Rocky Reach Dam, Columbia River, Washington, where tag malfunction/separation was observed on some fish equipped with two Turb'N Tags (RMC and Skalski 1993). Many of these turbine exposed fish buoyed to the surface by only one tag were alive.

Additionally, some studies have reported that survival of entrained fish is greatest when a Kaplan turbine is running at the highest operating efficiency, i.e., wider wicket gate openings. High fish survival generally coincides with peak turbine operating efficiency (Cramer and Oligher 1964). The tested turbine at Conowingo operated at a less than efficient wicket gate opening of 55-56%. The passage survival should be higher when the turbine at Conowingo is operated at or near its optimum operating efficiency.

Survival was also reported higher for naturally entrained fish than those subjected to the stress of handling, tagging, and release (Bell 1981; Ruggles et al. 1990). Ruggles et al. (1990) reported that the survival of naturally entrained juvenile alewife (Alosa pseudoharengus) was 86%

in passage through the Annapolis Royal "S" type turbine on the Sissiboo River, Nova Scotia while those handled and force-fed into the turbine was only about 33%. Handling and marking of young alewife caused high mortality of both the control and turbine exposed fish. Any stress related mortality associated with handling would not be a factor for naturally entrained specimens at Conowingo.

Earlier studies on juvenile alosids have reported substantially lower survival (conversely higher mortalities) in passage through Kaplan type turbines than found in very recent studies including the present one. Immediate survival of juvenile clupeids through Kaplan turbines at the Hadley Falls Station was reported to range from 18-38% (Taylor and Kynard 1985). Approximately 95% of the fish in that study were juvenile blueback herring. Stokesbury and Dadswell (1991) reported a survival of 53% for juvenile clupeids at the Annapolis Royal Project (STRAFLO turbine). Generally, the low survival estimate of juvenile clupeids has been explained on the basis of their sensitivity and specific vulnerability to pressure changes (Taylor and Kynard 1985; Stokesbury and Dadswell 1991). However, these studies utilized relatively small recovery nets to recapture treatment and control specimens; the use of nets for these delicate fish may contribute substantially to the low survival estimates. Net impingement or abrasion results in injuries or mortalities (Stokesbury and Dadswell 1991). This generally results in high estimates of mortality for both the treatment and control fish and makes it difficult to separate sampling mortality from turbine-induced mortality. This problem may be further compounded by low recapture rates. When recapture rates are low the survival estimates based on the ratio of relative proportions of live treatment and live control groups may result in higher estimates of turbine-related mortality (Mathur et al. 1994a).

There are three principal causal mechanisms for injury/mortality to entrained fishes in turbine passage at low-head dams (< 100 ft): direct blade strike or collision with structural components, changes in pressure, and hydraulic shear forces (Bell 1981; Eicher Associates 1987;

EPRI 1992). These causes, however, are not universally applicable to all species and their life stages at all hydro-dams. Fish mortality/injury due to any of these factors is generally manifested immediately, though the quantification and separation of these causes have proven difficult in the past (Eicher Associates 1987). The present study, in our view, succeeded to a large extent in quantifying the sources of immediate injury/mortality to juvenile American shad. We attributed short-term mortality of only one treatment fish recaptured dead to direct contact with turbine blades or associated structures. No mortality or injury was attributable to cavitation or pressure changes (e.g., embolism, air bladder rupture). Similarly, at other low-head hydro-dams equipped with propeller type turbines when a large proportion of treatment fish was available for examination, pressure or cavitation-related injury/mortality was not observed (Heisey et al. 1992; Mathur et al. 1994a,b). This is in contrast to some other studies in which these factors have been implicated as sources of juvenile alosid mortality at projects with net head of less than 50 ft (Taylor and Kynard 1985; Stokesbury and Dadswell 1991). Cada (1990) indicated that fish exit through hydro turbines is instantaneous and therefore little pressure change is expected, particularly at low-head projects (< 100 ft) such as Conowingo. A most likely causative agent for the higher rate of observed injury in other studies appears to be the sampling gear, namely, recapture netting system. Ruggles et al. (1990) have pointed out several problems with mark-recapture studies using nets, especially that the injury rates are high.

5.0 CONCLUSIONS

The relative survival of juvenile American shad (100-149 mm fork length) was estimated in passage through a newly installed Kaplan type turbine Unit 8 at Conowingo Hydroelectric Station, Maryland in early November 1993 at water temperatures of 11.0-14.0°C (51.8-57.2°F). The turbine operated with 55-56% wicket gate opening (a less than efficient mode of operation) to simulate a "worst case" scenario.

The recapture rates of turbine-exposed (88%) and control fish (fish released in turbine discharge), 92.6%, were high and similar allowing separation of the effects of turbine exposure from those due to handling, tagging, and induction and provided reliable estimate of survival.

The estimated short-term (1 h) relative survival of juvenile American shad was 94.9%. Long-term (48 h) survival was 92.9%; little mortality (2.0%) occurred after the immediate losses. Differences in survival of turbine-exposed and control groups were not significant ($P>0.05$). The observed mortality of turbine-exposed American shad was attributed to mechanical causes; no hydrostatic pressure/cavitation-related injury/mortality was observed.

The actual survival of juvenile American shad may be higher than estimated herein because recoveries of all inflated non-fish bearing tags, fish of unknown status and fish preyed upon were considered indicative of fish mortality. Some instances of tag separation during passage was likely attributed to turbulent waters, particularly in the turbine discharge; field observations indicated that on some turbine exposed fish the tag became separated but due to personnel safety reasons fish could not be retrieved prior to tag separation. Additionally, the survival of fish is generally high when a turbine is operating at or near optimum efficiency; the tested turbine was operating at a less than efficient wicket gate opening. The survival of naturally emigrating fish may also be higher than estimated for the tagged fish because the wild fish would not experience multiple stresses of capture, transport, tagging, induction, and recapture.

The estimated high relative survival of juvenile American shad (92.9%) is similar to that reported for juvenile alosids in passage through low-head hydro dams equipped with Kaplan type turbines in recent studies (96-100%). Based on these findings it is concluded that juvenile American shad should incur low mortality in passage through Kaplan turbines at Conowingo.

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Job V., Task 2. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1993

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Abstract

A total of 135 adult American shad were sacrificed for otolith analysis at the Conowingo Dam fish lifts in 1993. Based on tetracycline marking and otolith microstructure, 17% of the 124 readable otoliths were identified as wild and 83% hatchery. Ninety-seven 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 83% in 1993.

Wild fish represented a significantly higher proportion of the catch in samples collected in Upper Chesapeake Bay pound nets (52%) than that found in Conowingo Fish Lift collections (17%).

During 1989-1992, double marked fish (releases below Conowingo Dam) represented only 5% of the marked fish in the Conowingo Lift samples. In contrast, 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 1993.

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 six 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 (In Press) 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 1993.

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. (In press) 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., In Press):

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

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

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., In Press), 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 135 shad was sacrificed from the lift catch at Conowingo Dam in 1993. For 11 of those, otoliths were broken, not extracted, or had unreadable grinds, leaving 124 readable otoliths (Table 1). A total of 21 (17%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 83% of the specimens were identified as hatchery in origin. Four otoliths (3%) had hatchery microstructure and no tetracycline mark. Ninety-six otoliths (77%) exhibited tetracycline marks including single, double, triple and quadruple immersion marks. One otolith (1%) exhibited a single, day 5 mark and wild microstructure, indicating rapid growth in the hatchery. Two specimens (2%) exhibited feed marks, applied as pond-reared fingerlings. One of the specimens exhibited a triple feed mark but did not exhibit an immersion mark due to auto-fluorescence. The other feed marked specimen exhibited a single feed mark and immersion marks at 12 and 19d of age. The nucleus of this otolith appears to be ground out leading us to conclude that this fish was marked at 5, 12, and 19d of age, with the day 5 mark ground out. This fish was apparently from one of two groups of fingerlings, released in 1987, which received triple immersion marks (5, 12, 19d) and single feed marks: (1) 309 fish reared in the rearing pond at Van Dyke and (2) 60,000 fish reared in the Canal Pond.

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 1989-1993 ranged from 67% to 83% (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, and 97% in 1993. This was expected, as unmarked hatchery cohorts constitute a decreasing proportion of the population over time. The percentage of fish with hatchery microstructure which also exhibit a tetracycline mark should reach an asymptote corresponding to mark retention to adulthood. We had no reason to believe that marks retained to 100d of age would not be retained to adulthood. Mark retention was likely to be more a function of our ability to produce consistently good grinds than it was actual loss of the 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 has ranged from 24 to 31% (Table 2). This was 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 (Table 1) suggests that the pound nets and fish lifts are sampling different populations. Wild fish constituted 52% of the pound net catch and only 17 % of the lift catch (Table 1). Based on a Chi-square Test of Independence, we concluded that the proportion of wild and hatchery fish was dependent upon the collection site (Chi-square = 22.8, df =1) and therefore the populations at those two sites have different constituencies. 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). Of the 392 marked specimens examined during 1989-1992, only 18 (5%) exhibited a double mark, while 374 (95%) exhibited marks identifying them as fish released above Conowingo Dam. During the period 1984 to 1989, 21 million larvae (28% of the total) were uniquely marked and released below Conowingo Dam (Table 3). Consequently, releases below Conowingo Dam accounted for 28% of the total larvae released, but only 5% of the adults recovered. This could be the result of lower survival of larvae released below Conowingo Dam or it could be further evidence that Upper Bay stocks do not have strong urge to move into the lifts.

In 1993, recovery of double marked shad improved dramatically. Twenty double marked fish were recovered in the Lift sample, representing 16% of the total and 21% of the marked fish (Table 1). Three double marked fish were recovered in the pound net samples representing 6% of the total and 25% of the marked fish. Thus, the catch of double marked shad in 1993 conflicted with similar data collected during 1989-1992. While it was clear from the catch composition data that the pound nets and fish lifts are fishing different populations, the question of the relative survival of larvae released below Conwingo Dam was still unresolved.

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Figure 1. Estimated composition of fish lift catch at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1993.

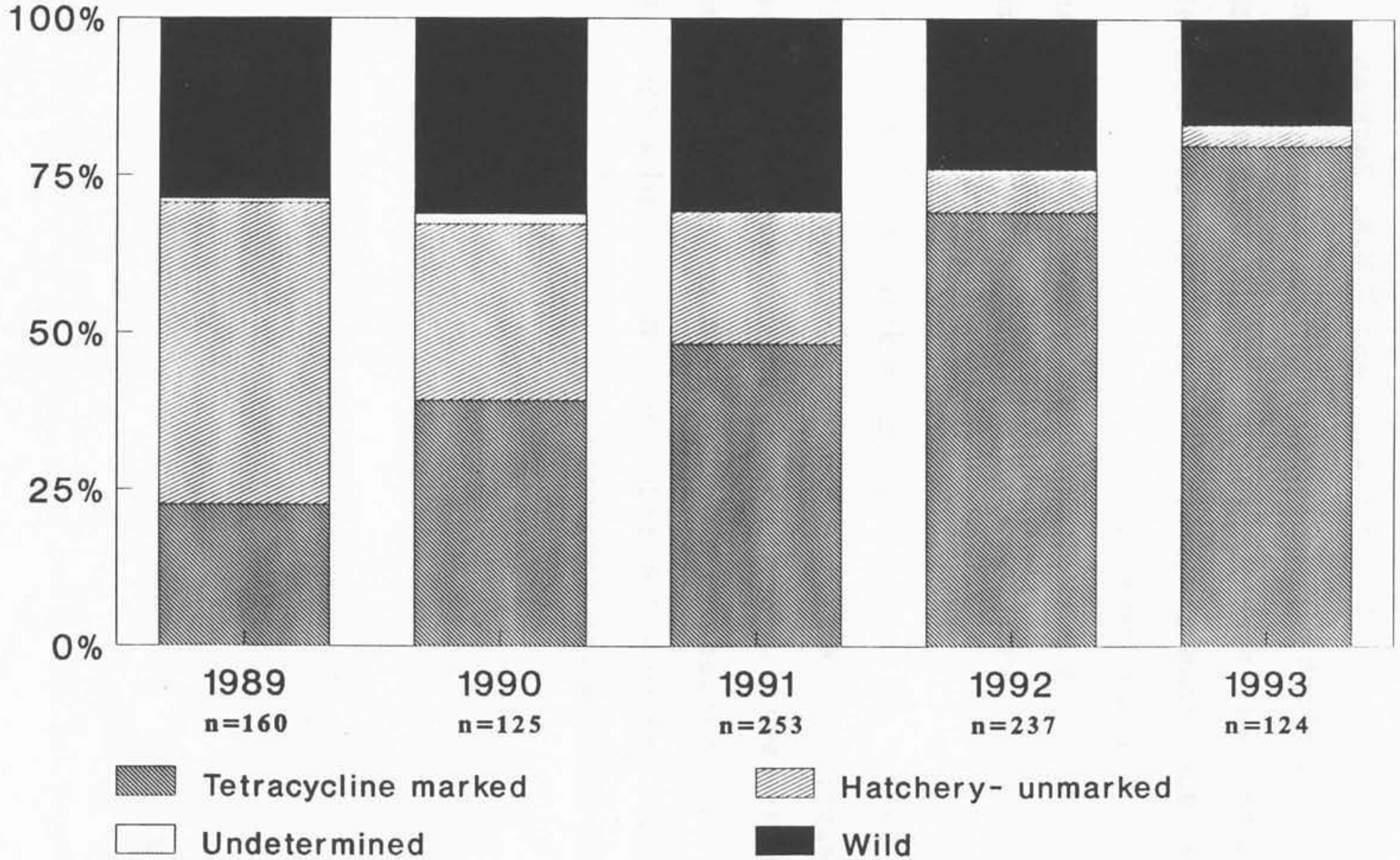

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts and Susquehanna Flats pound nets, 1993. One of every 100 fish collected in each lift was sacrificed.

			Conowingo Dam		Susq. Flats	
			N	%	N	%
Wild Microstructure, No TC Mark			21	17%	25	52%
Hatchery Microstructure	No TC Mark*		4	3%	11	23%
	Single TC Mark	Day 5	31 **	25%	4	8%
		Days 5−8 or 5−9	2		3	6%
		Days 15−18 or 15−19	2	2%		
	Double TC Mark	Days 5,9	20	16%	1	2%
		Days 9,13	1			
		Days 5−8,15−18			2	4%
	Triple TC Mark	Days 5,9,13	33	27%	2	4%
		Days 3,13,17	3	2%		
	Quadruple TC Mark	Days 5,9,13,17	5	4%		
	Feed Marks	Days 12,19 + single feed mark	1	1%		
		Days ??? + triple feed mark	1	1%		
		Total Hatchery	103	83%	23	48%
		Total readable otoliths	~~124~~ [illegible] dk		48	
		Unreadable Otoliths***	11			
		Total	135		48	

*Includes otoliths in which autofluoresence may obscure mark and poor grinds.
**Includes one specimen with wild microsructure(fast growth) and tetracycline mark.
***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, 1989–1993. Estimates of population proportions were derived from sample classifications corrected based on error rates from a blind classification trial.

	1989			1990			1991			1992			1993		
	Sample		Population	Sample		Population	Sample		Population	Sample		Population	Sample		Population
	n			n			n			n			n		
Wild Microstructure:	29	18%	29%	32	26%	31%	68	27%	31%	54	23%	24%	21	17%	17%
Microstructure unknown	1	1%	1%	2	2%	2%	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%
Tetracycline marked	36	23%	23%	49	39%	39%	122	48%	48%	164	69%	69%	99	80%	80%
Total Hatchery	130	81%	71%	91	73%	67%	185	73%	69%	183	77%	76%	103	83%	83%
Total	160			125			253			237			124		

Table 3. Summary of American shad stocking in the Susquehanna River and Upper Chesapeake Bay, 1984–1992.

	Above Conowingo Dam		Below Conowingo Dam	
Year	Larvae	Fingerling	Larvae	Fingerling
1984	11,996,000	30,500	–	–
1985	6,228,000	91,300	–	23,200 *
1986	9,899,000	61,200	5,171,000	–
1987	5,180,000	81,500	4,409,000	–
1988	6,451,000	74,000	3,650,000	–
1989	13,465,000	63,850	7,652,000	–
Total	53,219,000	402,350	20,882,000	23,200

JOB V, TASK 3

1993 EVALUATION OF BEHAVIORAL FISH PROTECTION TECHNOLOGIES AT THE YORK HAVEN HYDROELECTRIC PROJECT

Prepared for

Metropolitan Edison Company

FINAL REPORT

February 1994

Prepared by

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SECTION 1

INTRODUCTION

Beginning in 1988, the Electric Power Research Institute (EPRI), Metropolitan Edison Company (Met-Ed), and the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) co-funded a study of strobe and mercury lights for diverting outmigrating juvenile American shad (*Alosa sapidissima*) at Met-Ed's York Haven Hydroelectric Project on the Susquehanna River. The objective of this study was to determine whether these devices could be used to divert shad away from the plant turbines and through an existing trash sluiceway near the downstream-most unit. The results of the relatively small-scale study in 1988 demonstrated that strobe lights effectively and consistently repelled juvenile shad and directed them through the sluiceway. Mercury lights had no apparent effect on shad.

Based on the positive results from the 1988 study, a large-scale study was conducted in 1989 with strobe lights placed in front of Units 1 through 6. These are the units which are most likely to be operated during the fall outmigration of juvenile American shad. The purpose of the 1989 study was to determine whether an expanded strobe light system could significantly reduce turbine passage of juvenile shad at the York Haven powerhouse. A strobe system was installed in the fall of 1989 and was fully operational when the juvenile shad began to migrate downstream in early October. Unfortunately, heavy rains and unit outages resulted in high levels of dam spillage. Consequently, most downstream migrants passed over the dam, severely limiting the evaluation of the strobe light system. Studies of the strobe light system were continued in 1990. However, flow conditions and powerhouse operations were similar to those experienced in 1989 resulting in a second year of limited testing.

Strobe light studies were continued in 1991 when low spill levels and powerhouse operations lead to large concentrations of juvenile outmigrants in the station forebay. Sufficient data were obtained to demonstrate that the strobe light system effectively and repeatedly repelled actively migrating juvenile American shad away from the turbine intakes and out the sluiceway (EPRI 1992). Based on net catches from the sluiceway and Unit 1 discharges, it was demonstrated that the strobe light system diverted about 94% of the fish through the sluiceway during light activation periods.

The proven ability of the strobe light system to repel and guide juvenile shad at York Haven in 1991 prompted the concerned parties to develop a refined strobe light system that was specifically designed for permanent installation. A new strobe light system was developed in 1992 and was designed to be low in cost and could be easily installed and removed on a yearly basis. The modified system was composed of new strobe lights specifically designed for underwater applications and modular float assemblies for supporting the lights and power converters. Although the equipment functioned as planned, outages of units near the sluiceway limited the number of fish that congregated in the area near the sluiceway (i.e., where the new strobe light system was installed). However, the new strobe light system effectively and repeatedly repelled and diverted the relatively few fish that were present in the test area.

The purpose of the 1993 study was to verify the effectiveness of the modified strobe light system under more typical plant operating conditions that produce large numbers of outmigrants moving through the York Haven forebay and approaching the powerhouse. As in past years, the distribution of fish at the York Haven Project would be dependent on environmental conditions and powerhouse operations. Additionally, an evaluation of a high-frequency transducer sound system was included in the 1993 study plan. In recent years, high-frequency sound has demonstrated an ability to repel juvenile clupeids away from water intakes (Dunning et al. 1992; Ross et al. 1993; RMC 1993). The sound system studies were jointly funded by Met-Ed and the Pennsylvania Power & Light Company (PP&L). Sound system installation and operation was conducted by Sonalysts, Inc. The purpose of the high-frequency sound tests was to determine the system's ability to repel juvenile American shad and potentially guide them through the sluiceway without increasing turbine passage. Tests were also performed to evaluate the two behavioral devices used together to divert fish through the sluiceway and away from the turbine intakes.

SECTION 2

SITE DESCRIPTION

The York Haven Hydroelectric Project is located on the Susquehanna river at river mile (RM) 52, about 15 miles south of Harrisburg, Pennsylvania. The project is operated by the Metropolitan Edison Company. The plant (i.e., powerhouse, offices, and machine shop) is located on the west bank of the river. A dam 8000 ft in length angles downstream from the east bank to the project forebay and powerhouse (Figure 2-1). The powerhouse has six Kaplan and fourteen Francis turbines, each with a flow capacity of about 800 cfs. The station has a generating capacity of 19.6 MW with an operating head of 23 ft. The forebay and site layout are shown in Figure 2-2. The corner of the forebay between the powerhouse and a cableway contains a sluiceway which typically is used to pass downstream any debris that has accumulated on the unit trashracks and in the forebay.

York Haven is the fourth dam on the river, located upstream of Conowingo (rm 16), Holtwood (rm 23), and Safe Harbor (rm 31). A part of an American shad restoration program for the Susquehanna River, a fish lift was installed at Conowingo in 1972. Subsequently, adult American shad have been trucked from Conowingo and released into areas upstream of the York Haven Project for spawning purposes. In addition, hatchery-reared fry have been released into watershed areas upstream of York Haven. Returning adult populations have increased from less than 1000 fish in the 1970's to about 27,000 in 1991. As part of the restoration program, upstream passage facilities for American shad currently are being designed for the three projects upstream of Conowingo including York Haven.

Juvenile American shad usually migrate downstream past the York Haven Project between late September and early November, depending on environmental conditions (e.g., water temperature and flow levels). River discharge usually is at low levels during the fall outmigration of juvenile shad. Low river discharge results in most of the river flow passing through the York Haven powerhouse, typically through Units 1 through 10. During periods of low or no dam spillage, juvenile shad congregate in large numbers in the project forebay and may be required to pass through the turbines in order to continue downstream.

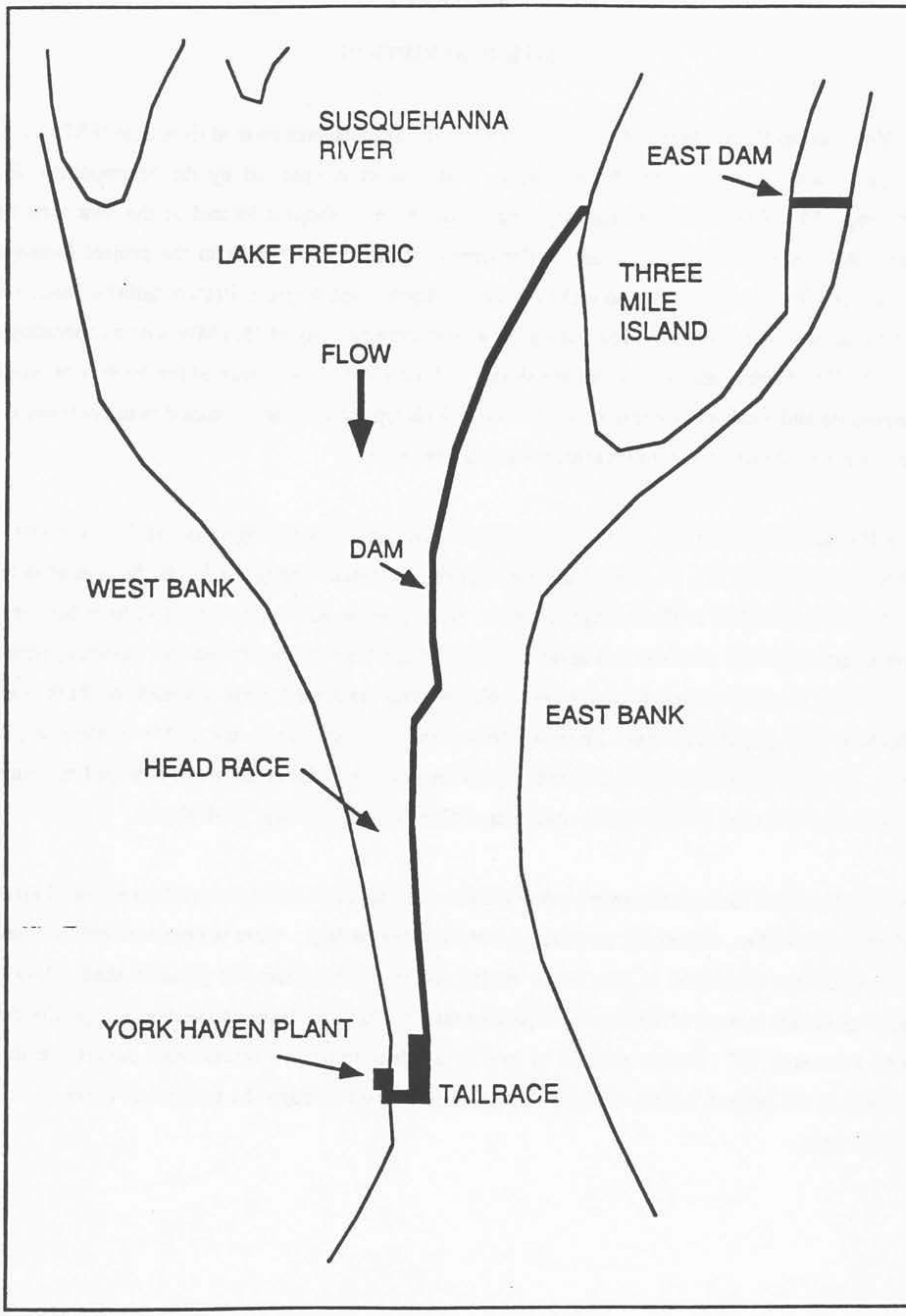


Figure 2-1
York Haven Site Location

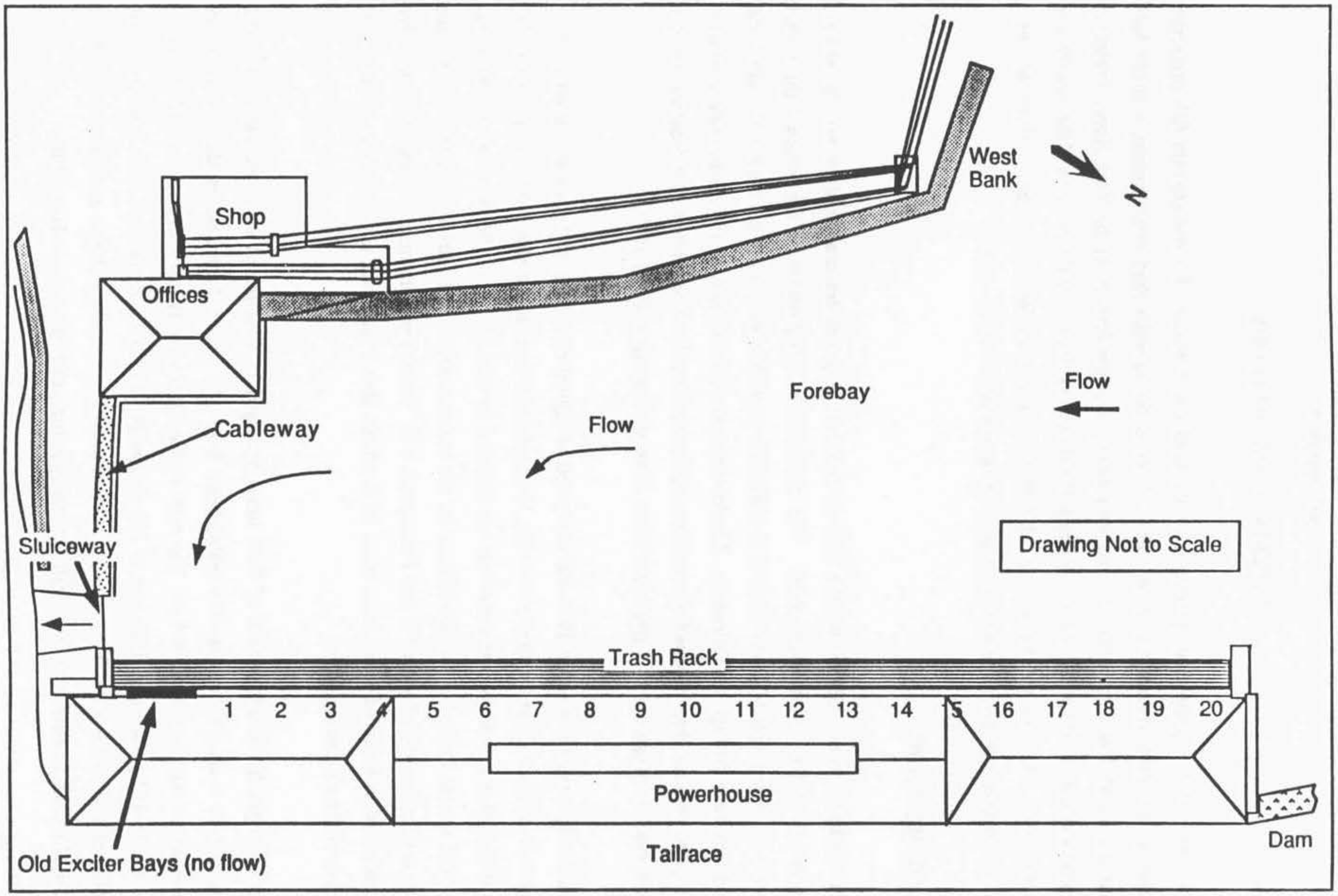


FIGURE 2-2
Site Layout
York Haven Hydroelectric Project

SECTION 3

MATERIALS AND METHODS

Two behavioral fish protection systems were installed and evaluated for downstream fish protection purposes at the York Haven Project in 1993. Prior to the juvenile shad outmigration, a strobe light system and a high-frequency sound system were deployed in the forebay of the York Haven Project in the vicinity of the lower ten unit intakes and near the sluiceway (located at the junction of the powerhouse and cableway). Although both behavioral fish deterrent systems are designed to operate alone, and were tested as singular systems, they also were tested as a combined-device system.

3.1 STROBE LIGHT

The strobe light system used during the 1993 study specifically was designed to allow easy installation and removal of the system equipment. The deployment configuration of the strobe light system (Figure 3-1; Photograph 3-1) was selected to effectively repel fish away from the intakes of Units 1 and 2 and divert them through the sluiceway. The forebay area in the vicinity of the downstream most units was targeted because observations from previous studies conducted at York Haven have demonstrated that juvenile shad congregate in this area when these units are operating (EPRI 1992).

The strobe light system tested in 1993 was composed of eight strobe lights, eight power converters, four fiberglass float modules, and a three conductor, 12 gauge underwater armor-shielded buoy interface cable. Two strobe lights and two power converters are mounted on each of the four floats and all are connected to a power source located in the powerhouse by the interface cable. The strobe light and float module designs are presented in Figure 3-2 and Photograph 3-2. The electrically interconnected float modules were anchored in a curved array from about 10 ft off the Unit 2 trashrack to the cableway about 50 ft upstream of the sluiceway.

The strobe light flashheads consist of flash tubes packaged in glass-sealed units, similar in size and construction to a standard automobile sealed-beam headlight. Each flash head is about 9 inches in diameter with a weight of about 8.5 lb. The eight strobe lights were synchronized from a 115-V, 60-Hz power source and pulsed at a fixed rate of 300 flashes per minute (same as flash rates used during all previous studies conducted at York Haven). All strobe light equipment (lights and power converters) were supplied and manufactured by Flash Technology, Inc., of Nashua, New Hampshire.

Each float module has two foam-filled buoyancy pods in a pontoon configuration, a galvanized steel pole through the center for strobe light mounting, and a water-tight fiberglass cover on top for encasing the strobe light power converters (Figure 3-2). A three-point anchor system was used to moor the four floats in fixed position for the duration of the study period. A "quick-disconnect" power connecter is located on the masthead (i.e., steel pole) of each float for fast and dependable hook-up of the power converters to the power cable. The strobe lights were mounted on the steel poles which are suspended through the center of the float. Each pole supported two lights that were located at depths of 3 and 9 ft below the water surface when the floats were deployed. A complete float module assembly weighs about 500 lb. Two people using a standard hoist-operated buoy tender can install an array of four floats in approximately 1 day. The current strobe light system design was developed from field experience and observations made during the previous studies conducted at York haven. The current system is intended to be an effective downstream fish protection system that is easy to install and maintain and that will operate reliably at a relatively low overall cost.

3.2 HIGH-FREQUENCY SOUND

A FishStartle™ system was used to produce the high-frequency sounds to repel fish at York Haven. The FishStartle™ system was developed and patented by Sonalysts, Inc, of Waterford Connecticut. Deployment and operation of the FishStartle™ equipment was conducted by Sonalysts personnel with the aid of Stone & Webster staff. The FishStartle™ system was installed on a wooden raft that was specifically constructed for the sound evaluation. All of the FishStartle™ hardware (with the exception of the transducers) were placed inside a weather proof enclosure on the raft. Two narrow-beam and one wide-beam transducers were mounted on a steel frame that was attached to the raft. Two narrow-beam transducers and one wide-beam transducer were added to the system after the first two nights of testing were completed. The additional narrow-beam transducers were mounted on light floats #1 and #2 (the two floats closest to the cableway) and the wide-beam was used either on light float #2 or placed on a boat positioned against the powerhouse trashracks upstream of the raft.

The sound raft was tied to two anchors placed in the forebay. By manipulating the anchor ropes, the raft could be moved upstream and downstream of the anchor positions, as well as at varying distances from the trashracks. During testing, the raft was placed at several different locations between Unit 10 and Unit 4 (Figure 3-3). Also, the raft was placed either flush against the trashracks or about 8 to 10 ft away. The number and type of transducers, as well as location of the raft and the boat-mounted transducer, varied considerably among the tests that were conducted (see Figure 3-3 for general locations). The sound system configuration that was used for each test was determined by Sonalysts personnel. The sound frequencies and pressure levels also varied among tests.

Because FishStartle™ is a patented technology, many of the system components (hardware or computer software) and parameters (frequencies and sound pressure levels) are considered proprietary in nature by Sonalysts. Additional information regarding the sound system setup and configuration is provided in an appended report prepared by Sonalysts (Appendix A).

3.3 SCANNING SONAR

Two scanning sonar systems, a WESMAR Model HD600FM and a Model SS390, were used to monitor fish behavior and response to the strobe lights and high-frequency sound. The HD600FM sonar system included a sonar control console, a transducer and preamplifier with connecting cables, a time lapse video recorder, a color video monitor, and a power supply. The HD600FM sonar control console and video equipment were placed in a wooden enclosure located in the cableway and similar equipment for the SS390 were placed on the sound barge. The HD600FM transducer and preamplifier were mounted on a small float placed in the forebay and the SS390 transducer was mounted on a wood plank extending off the sound barge.

The HD600FM sonar transducer float was located between, and slightly upstream of strobe light floats #2 and #3. This position allowed fish movement within the forebay area affected by the behavioral devices to be monitored. Also, depending on the sonar system settings (e.g., range), this location optimized sonar monitoring of the fish target areas immediately in front of the sluiceway along the trashracks. Additionally, fish response could be effectively recorded at the preferred 50-foot sonar range. The SS390 sonar system was deployed on the sound raft to provide additional coverage of forebay areas that were within the range of the sound system. The SS390 typically was set to scan at a range of either 50 or 100 ft.

The range, gain, and transducer angle settings were selected to achieve maximum detection and coverage of fish schools moving through the study area both during tests and under ambient conditions. The sonar systems were calibrated several times (prior to, during, and upon completion of the study) with fixed mechanical targets that had known acoustical back-scattering characteristics. During a test, the HD600FM sonar was set to scan a sector of the water column in the area between the strobe light array and the sluiceway. During sound or combined-device tests, the sonar may have been set to scan larger areas of the forebay depending on the location of sound system transducers (i.e., sector scan was set to cover all forebay areas ensonified by the sound system). Generally, the sampling rate for sonar data recording was maximized by selecting the smallest possible scanning area. Data were recorded from the sonar systems in VHS format by time lapse VCR's.

3.4 AUTOMATED SYSTEM CONTROL

In addition to monitoring fish movement during ambient and test conditions, the HD600FM sonar system was evaluated as part of a fully automatic, closed loop control system which would not require plant personnel to operate. The heart of the detection and sequence control for bypassing downstream migrating fish is incorporated into the HD600FM sonar. The sonar control console has a "joy stick" for positioning two cursors on the monitor screen that create a rectangular shaped box (i.e., fish target zone). These cursors can be pre-adjusted to define the size of the desired fish target zone at any scanning range. Once the target zone boundaries are selected, fish that enter the zone from any direction increment a counter. The system operator can preselect a "fish count" threshold level. When fish abundance in the target zone exceeds the preset level, a relay closure signal is transmitted to the main control sequencer.

To assure that a fish biomass that is detected is reasonably accurate, and that the mass of fish are in the proper position for being pulsed through the sluicegate by the strobe lights, consecutive scan rates can be averaged over a period of time before the command signal is transmitted. This command can begin a sequence of opening the sluiceway bypass gate, turning on the strobe lights, shutting off the lights, and closing the gate on a fully automatic, controlled basis. System operation data can be placed on spreadsheets showing the time and date of gate bypass opening, a relative estimate of the quantity of fish passed, and total fish bypassed over time. To evaluate the ability of the sonar system to detect various levels of fish abundance, several fish target zone sizes and fish counter levels were evaluated during the testing of the behavioral devices.

3.5 TAILRACE AND SLUICEWAY NETTING

Visual observations of fish response to the strobe lights in the previous studies indicated that juvenile shad form a tight school and quickly pass through the sluiceway when the strobe lights are activated. It is possible that some fish, particularly fish that are deeper in the water column and cannot be detected by the sonar, are repelled towards and through the trash racks. Attempts were not made in 1988 and 1989 to quantify the number of fish passing through the turbines during strobe light tests. In 1990, a moveable trammel net was fabricated and placed at different locations in front of the trash racks to collect fish. Results indicated that fish were not passing through the trash racks. However, juvenile shad may not have been in a migratory mode at the time these observations were made (EPRI 1992). In 1991, fish sampling was conducted with partial-flow nets placed at the Unit 1 draft tube exit and the sluiceway during testing of the strobe light system. For 1992, it was concluded that the most effective method for quantifying turbine and sluiceway fish passage was to continue sampling with partial-flow nets located in the tailrace (nets were used to sample Unit 1 and Unit 2 discharge) and sluiceway.

For the 1993 study, a third tailrace net was added in front of the Unit 10 discharge. The Unit 10 discharge net sampling was conducted specifically as a part of the high-frequency sound system evaluation. All three tailrace nets were installed similarly and consisted of identical system components (Figure 3-4). The sluiceway net was installed immediately downstream of the sluiceway gate and in the center of the discharge (Figure 3-5). The tailrace nets and frames were supported from parallel steel cables anchored to the powerhouse wall and the bottom of the Unit discharge structure.

Each net had a 1-m^2 opening, measured 4 m in length, and had 0.5-inch mesh with a 0.2-inch cod mesh liner. The sluiceway net was positioned to sample the full depth of the water column passing through the sluiceway. About 33% of the sluiceway flow passed through the net. The tailrace nets were positioned near the centerline of the unit draft tube exits with the top of the frame just below the water surface. Approximately 4% of the turbine unit discharge passed through the tailrace net.

The number of fish that was caught in each net was adjusted for the amount of flow sampled. For the sluiceway adjustment, the actual number of fish that was netted was multiplied by 3.3 (i.e., the sluiceway net samples about 33% of the sluiceway flow). For the tailrace nets, the adjusted catch was calculated by multiplying the number of fish caught by 25 (i.e., tailrace nets sample approximately 4% of a unit's discharge flow). The adjustment factor for tailrace net catches was confirmed in 1991 during three releases of dead fish into the Unit 1 intake (EPRI 1992). The rate of recapture for the three releases were 3.1, 3.4, and 4.4% with a mean of 3.6%.

3.6 SUPPLEMENTAL SAMPLING

In order to document the lighting and hydraulic conditions to which fish are exposed at the York Haven Project, supplemental sampling of strobe light intensity, water quality (i.e., turbidity and clarity), and water velocities in the station forebay was conducted. Mapping of the light field in front of a strobe float was performed on several occasions to assess strobe light penetration. Light mapping was conducted under nighttime conditions with the strobes lights operating. The frequency of light mapping was based on changing turbidity conditions. Turbidity was monitored quantitatively on a daily basis using a Hach portable turbidity meter (model 2100P). Additionally, water clarity was assessed on a daily basis using a Li-Cor model LI185B photometer and a secchi disk. Water clarity sampling was conducted in front of the sluiceway at about the same time each day (usually between 3:30 pm and 5:00 pm).

Water velocity measurements were recorded along the trashracks and across the station forebay (along transects perpendicular to the powerhouse) with a Swoffer propeller meter. Velocity measurements along the front of the trashracks were taken at a depth of 3 ft and at a distance of about 2 ft from the trashracks. Forebay velocity transects were established opposite the intakes for Units 1 through 3. Water velocities were measured at depths of 3 and 8 ft about every 10 ft along these transects which extended from the trashracks across the forebay towards the plant offices (i.e., west bank). Velocity measurements were repeated periodically to collect data over the range of plant operating conditions that occurred during the study period.

3.7 TESTING PROTOCOL AND DATA ANALYSIS

The evaluation of strobe lights and high-frequency sound consisted of testing the effectiveness of each device alone and in combination. The objective of tests with only strobe lights and with a combined-device system was to determine the effectiveness of the behavioral devices to repel fish from the turbine intakes and through the sluiceway. The objectives for sound-only tests were to determine if the high-frequency sound could elicit an avoidance response from juvenile shad, to assess the sound systems effective range, and to evaluate the sound systems ability to repel fish away from the turbine intakes and through the sluiceway (see Appendix A for a more detailed description of the objectives for sound system tests). The testing protocol was the same for each device tested alone and the combined-device tests when assessing turbine and sluiceway passage. The testing protocol was slightly different for sound tests that to evaluate the ability of high-frequency sound to simply repel juvenile shad and to assess the effective range of the system.

Strobe light and combined-device evaluations were comprised of sequential control (behavioral devices not activated) and test periods (behavioral devices activated). Sound tests were conducted with the control and test period sequence or by observing and recording the behavioral response of fish after the sound system was activated. Tailrace and sluiceway netting were conducted for all tests that were performed to evaluate the effectiveness of a device or the combined-device to guide fish through the sluiceway without increasing turbine passage. The control/test period sequence was conducted in the following manner for single device and the combined-device tests:

Single Device Tests

Control. Strobe light (2-minute duration) or sound (3-minute duration) control period sequence: tailrace net(s) lowered and sluiceway net deployed; sluiceway gate open; 2 or 3 minutes later sluiceway gate closed; tailrace net(s) raised and sluiceway net retreived; captured fish from all nets identified and counted.

Test. Strobe light (2-minute duration) or sound (3-minute duration) test period sequence: tailrace net(s) lowered and sluiceway net deployed; sluiceway gate open and strobe lights or sound activated; 2 or 3 minutes later sluiceway gate closed and strobe light/sound deactivated; tailrace net(s) raised and sluiceway net retreived; captured fish from all nets identified and counted.

Combined-Device Tests

Control. 3-minute control period sequence: tailrace net(s) lowered and sluiceway net deployed; sluiceway gate open; 3 minutes later sluiceway gate closed; tailrace net(s) raised and sluiceway net retreived; captured fish from all nets identified and counted.

Test. (a) 3-minute test period sequence: tailrace net(s) lowered and sluiceway net deployed; sluiceway gate opened; sound activated; 1 minute later lights activated; 2 minutes later both devices deactivated; sluiceway gate closed; tailrace net(s) raised and sluiceway net retreived; captured fish from all nets identified and counted.

or

(b) 3-minute test period sequence: tailrace net(s) lowered and sluiceway net deployed; sluiceway gate opened; sound activated; 1 minute later sound deactivated and strobe lights activated; 2 minutes later sluiceway gate closed and strobe lights deactivated; tailrace net(s) raised and sluiceway net retreived; captured fish from all nets identified and counted.

Ambient netting periods were conducted in the tailrace each night to determine turbine passage of juvenile shad under ambient conditions (i.e., no behavioral device or sluiceway gate operation). Ambient net sets generally were performed prior to the first behavioral test conducted each night and between tests conducted during an evening. Ambient net sets typically were performed for 0.5- or 1-hr periods. For each test and ambient netting period, all fish were identified to species or family (all clupeids were identified to species). Live fish were immediately returned to the river downstream of the powerhouse. Netting mortalities were disposed of in a sanitary and approved manner.

Testing usually began around dusk which corresponded to the typical arrival time of juvenile shad at the York Haven Project during the outmigration. The testing schedule for each night was not fixed and often was modified based on observations of fish behaviors and abundance throughout a night. However, strobe light tests were given the highest priority followed by high-frequency sound and combined-device tests. Ambient netting also was conducted on a flexible schedule based on juvenile shad abundance and unit operation schedules.

Behavioral device effectiveness was determined by comparing net catches from the tailrace and sluiceway during test periods. Net catches during control periods were used to verify that very few juvenile shad pass through the sluiceway under normal conditions (i.e., behavioral devices not operating). The effectiveness of behavioral barriers evaluated at York Haven is solely dependent on their ability to guide downstream migrants through the sluiceway without considerably increasing turbine passage. However, it should be noted that the evaluation of the sound system was preliminary in nature and the results may not be representative of a full-scale system specifically designed to guide fish through the sluiceway without increasing turbine passage. Such a full-scale system cannot be developed without preliminary tests that provide the necessary information on to the influence of fish behavior, local hydraulic conditions, and site layout on behavioral device effectiveness.

For strobe light tests, light mapping, water clarity, and water velocity data also were examined to identify trends in the observed results. All of these factors are expected to contribute to the distribution and behavior of fish at York Haven, especially during test periods when the strobe lights are activated. If the influence of water clarity and velocity on strobe light effectiveness can be determined for a wide range of environmental conditions and powerhouse operation scenarios (i.e., which units are on and off line and how much flow is passing through the plant and over the dam), the strobe light system may be modified for increased effectiveness over the same range of conditions.

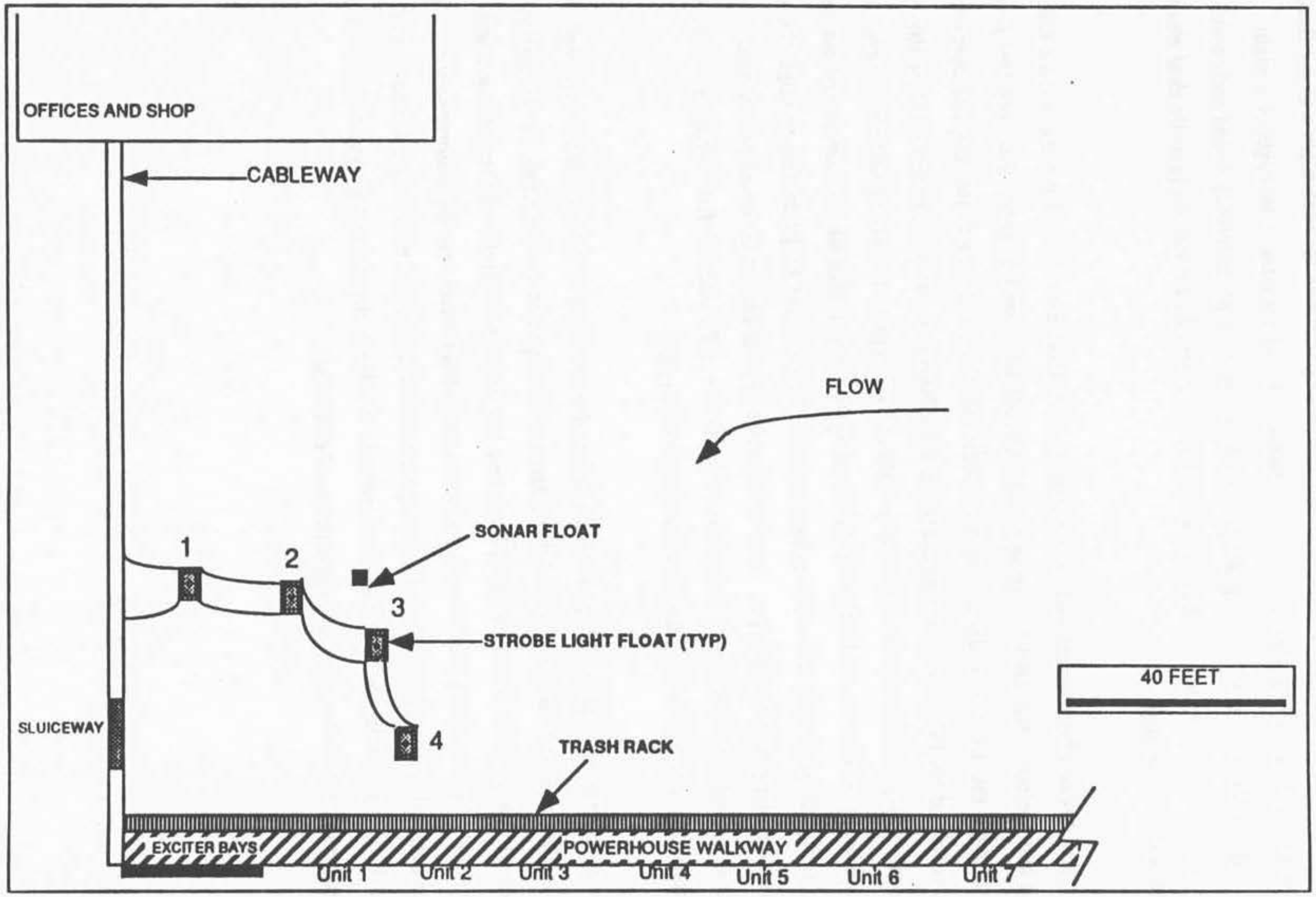


FIGURE 3-1
Forebay schematic showing the positioning of
the strobe light floats and the HD-600 FM sonar float

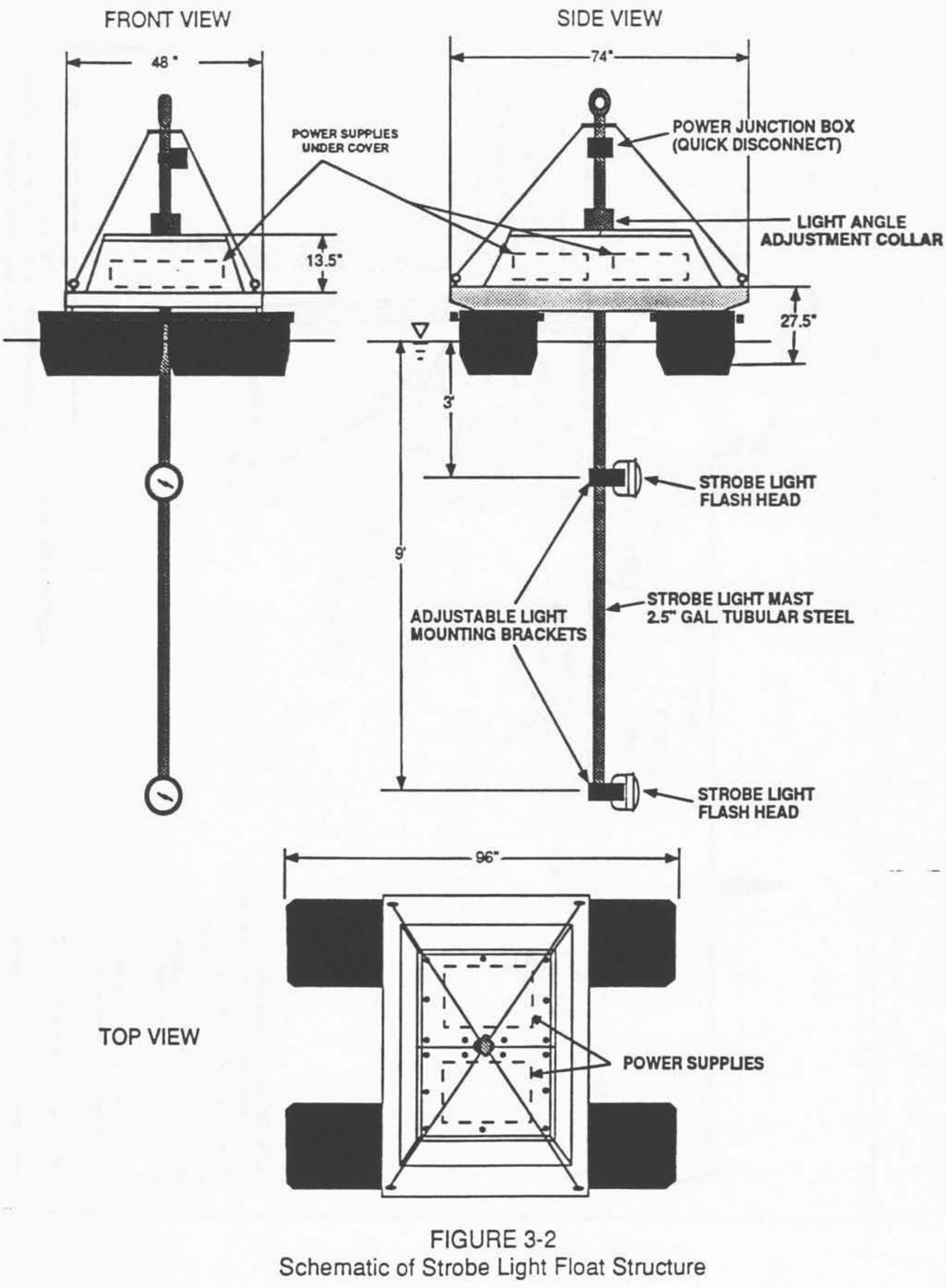


FIGURE 3-2
Schematic of Strobe Light Float Structure

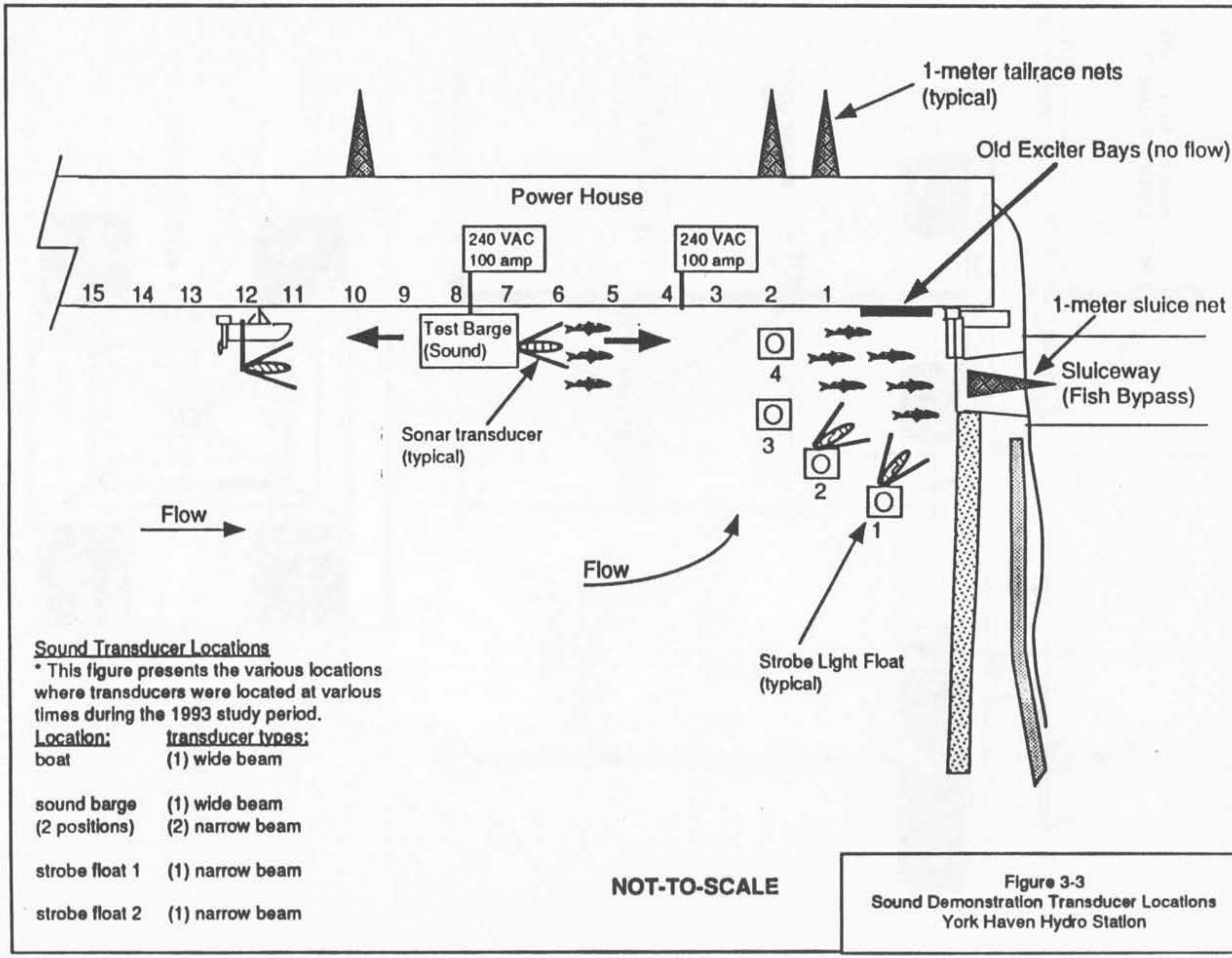


Figure 3-3
Sound Demonstration Transducer Locations
York Haven Hydro Station

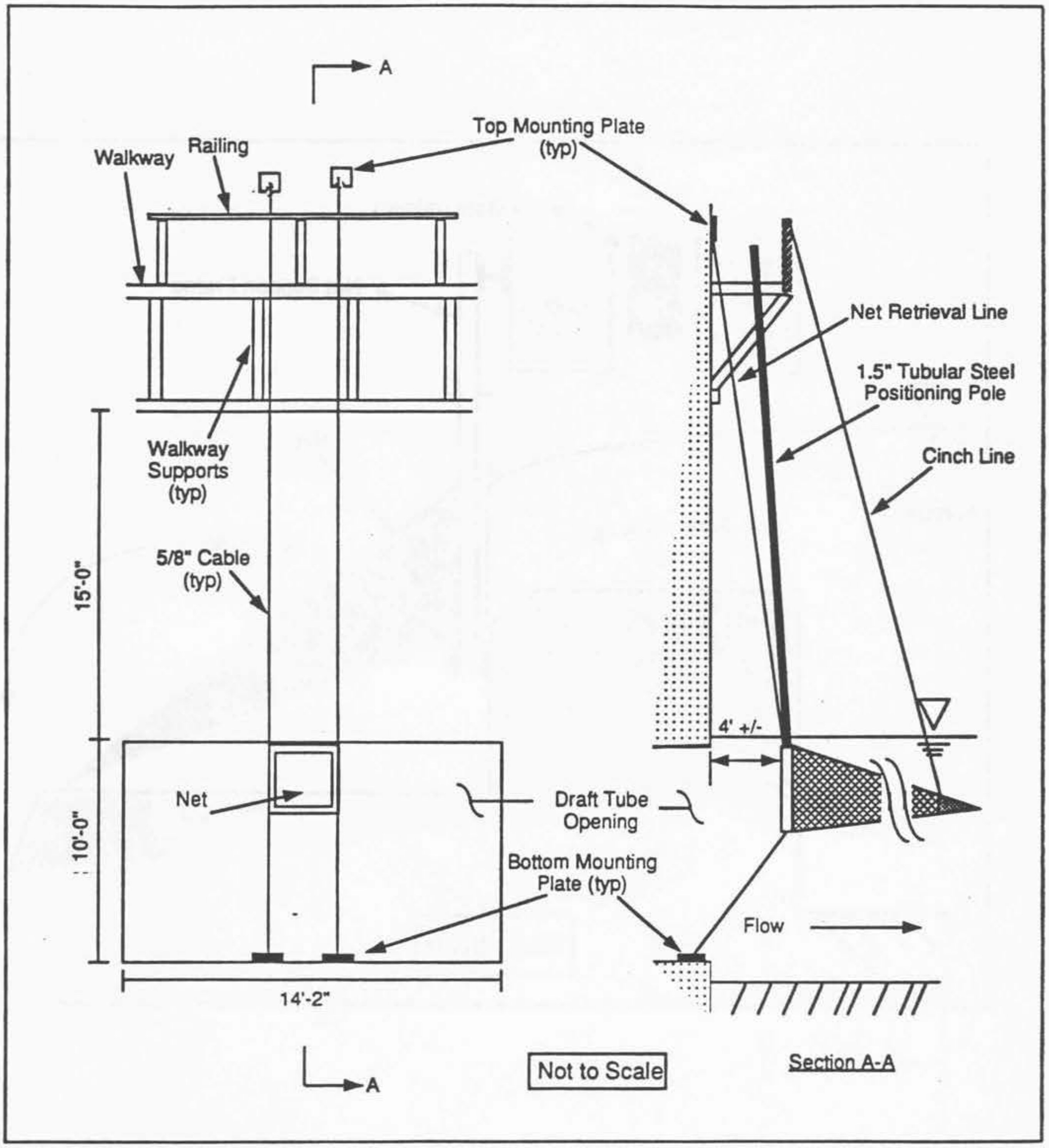


FIGURE 3-4
Schematic Drawing of the Tailrace Net
in Sampling Position

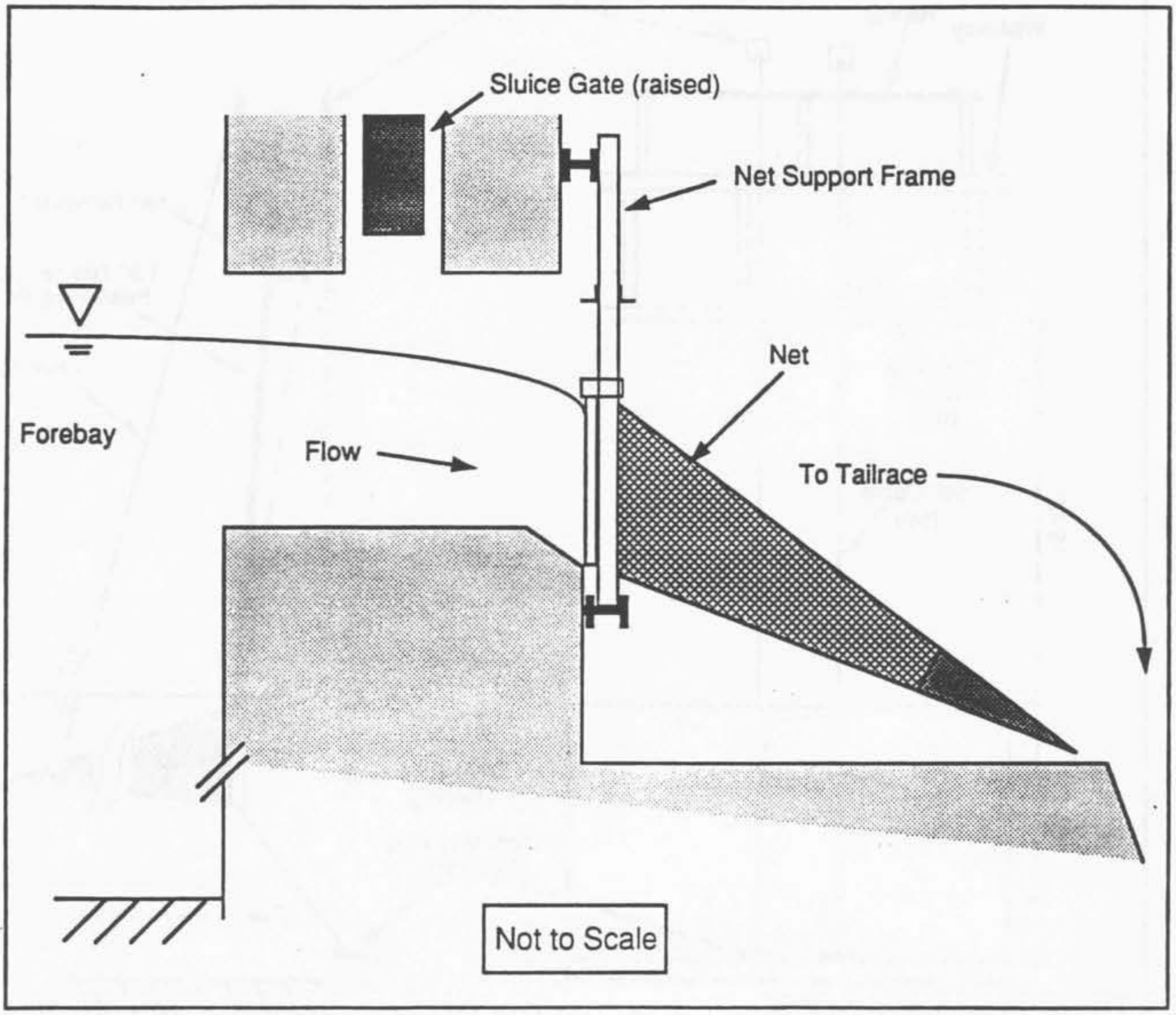
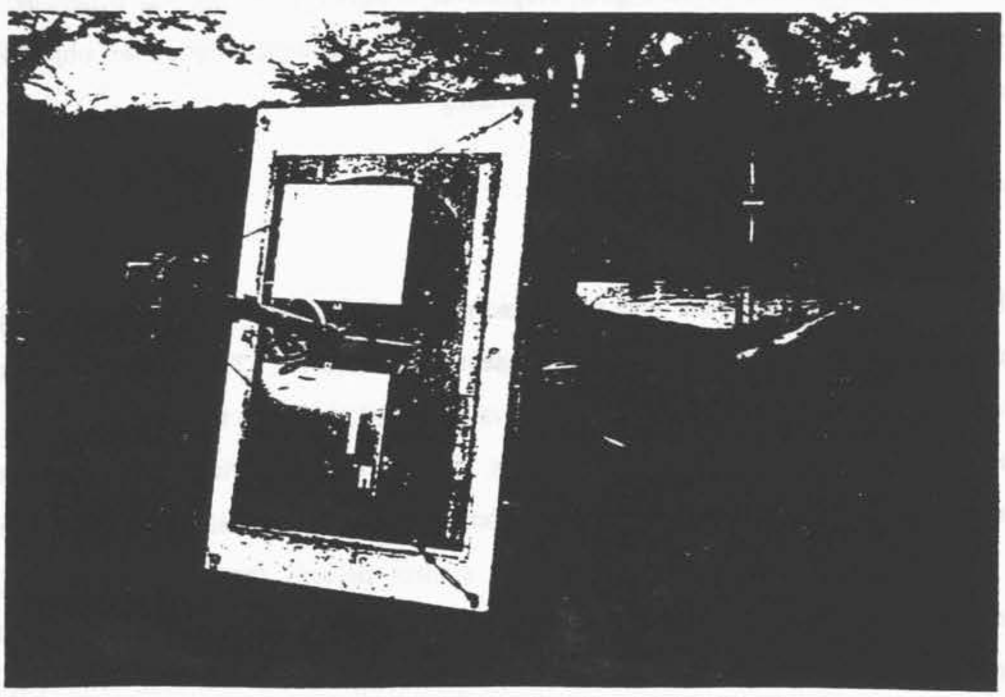


FIGURE 3-5
Schematic Drawing of the Sluice Net in Sampling Position

Photograph 3-1. Strobe Light Float Deployment



Photograph 3-2. Strobe Light Float

SECTION 4

RESULTS

A total of 40 tests was conducted with strobe lights only (8 tests), high-frequency sound only (17 tests), and combined strobe light and sound (15 tests). Behavioral device testing was conducted between October 25 and November 4. Two preliminary strobe light tests also were conducted on October 22 and one on October 23. These three tests were performed to assure that the strobe lights, the sonar system, and the tailrace and sluiceway nets were all operating as designed and is not included in the total of 40 tests. Therefore, netting data from these tests are not included in the evaluation of the strobe light system. Detailed summary tables of all fish (i.e., for each species that was captured) that were caught during each test at each net location are presented in Appendix B.

The number of tests and testing scenarios varied from night to night based on relative fish abundance and the priority of testing (i.e., strobe lights, high-frequency sound, and the combined device system). When both devices and/or the combined system were tested on the same night, strobe light tests typically were conducted at the beginning of the evening followed by sound and/or combined-device tests. However, on two nights, only sound was tested and on one night only the combined system was tested. Also, strobe light tests were conducted on 5 of the 11 test nights, whereas sound and the combined-device tests were performed on ten and seven nights, respectively. Ambient netting was conducted each test night. The schedule for ambient netting varied among the three units depending on test objectives, relative fish abundance, and whether or not a unit was operating.

4.1 STROBE LIGHT TESTS

A total of eight strobe light tests was conducted during five nights. The actual and adjusted catch for each location and for all tests combined are presented in Table 4-1. The mean adjusted catch of juvenile shad during test periods (i.e., strobe lights activated) was 139 fish in the sluiceway net, 137 in the Unit 1 tailrace net, and 100 in the Unit 2 tailrace net. During control periods, the mean adjusted catch was 15 juvenile shad for the sluiceway net and 0 for both the Unit 1 and 2 tailrace nets (no juvenile shad were caught in the tailrace nets during any of the control periods for strobe light tests). There was considerable variation in the number of fish caught among test periods. The adjusted number of juvenile shad caught in the Unit 1, Unit 2, and sluiceway nets ranged from 0 to 550, 0 to 300, and 26 to 449, respectively. Juvenile shad were captured in the Unit 2 net during only two of the four tests that included netting of the Unit 2 discharge. Also, the two highest juvenile shad net catches for Units 1 and 2 occurred during the same two test periods indicating that there may have been similar hydraulic and/or environmental conditions that led to high turbine passage. A more detailed discussion of local water velocities and water clarity and their influence on test results is presented in the next section.

Turbine passage of juvenile shad exceeded sluiceway passage only once during the eight test periods; once when netting was conducted for both Unit 1 and 2 and once when only the Unit 1 discharge was netted. The percentage of the total catch (i.e., shad catch from all locations combined) that was netted in the sluiceway during test periods ranged from 4 to 100%. When all tests are combined, the percentage of the total catch that was netted in the sluiceway is 43%. However, if the test that was conducted on October 28 is deleted from the calculation this percentage changes to 62%. If the net catch from the test performed on October 26 also is deleted from the total catch, then the percentage of the total shad caught that was netted in the sluiceway is 73%. Although the results from any of the tests should not be ignored, the preceding calculations demonstrate the influence that the catch from these two test periods had on the overall results.

Similar to past years, minimal to no turbine passage of juvenile shad was observed during control periods of strobe light testing. Sluiceway passage also was minimal during control periods compared to strobe light activation periods. It is evident that turbine passage is not increased when the sluiceway is opened under ambient conditions and that fish do not readily pass out the sluiceway in the absence of strobe light.

Because turbine passage during test periods was high compared to past years, two tests were conducted to evaluate the influence of the lights on fish passage by activating two lights at time. Two separate tests were performed; one test with only the strobe lights on floats #1 and #2 activated and the other test with only the strobe lights on floats #3 and #4 activated. Strobe light floats #1 and #2 are positioned opposite the trashracks with the light beams directed at a slight angle towards the sluiceway. Light floats #3 and #4 are positioned closer to the trashracks with the light beams directed straight at the sluiceway. The adjusted number of juvenile shad caught for the test with the strobe lights on floats #1 and #2 was 40 fish in the sluiceway and 0 in the tailrace. For the second test, the adjusted catch was 26 shad in the sluiceway and 25 in the tailrace. Based on these catch numbers (from two tests), it appears that the strobe lights on floats #3 and #4 have a greater effect on the number of fish that pass through the turbines than do the strobe lights on floats #1 and #2.

4.2 HIGH-FREQUENCY SOUND TESTS

A total of 17 high-frequency sound tests was performed with the FishStartle™ system over the 11 days of testing. Because this was the first year that high-frequency sound has been tested at York Haven, several different system configurations (i.e., transducer locations, numbers, and types) were evaluated for their ability to elicit an avoidance response from juvenile shad, as well as to guide fish through the sluiceway without considerable increases in turbine passage. A summary of the results of the sound tests is provided below. A complete report was prepared by Sonalysts specifically for the high-frequency sound testing and is presented in Appendix A.

To assess the response of juvenile American shad to high-frequency sound, several tests were conducted with only sound activation (i.e., no netting of passage routes and sluiceway gate closed). The reaction of fish to the sound system was monitored with the HD600FM sonar and recorded on videotape. Three different sound system configurations were evaluated during these tests (Table 4-2) and each demonstrated the ability to repel juvenile shad downstream along the trashracks and towards the sluiceway. As fish approached the sluiceway, they appeared to sound or turn and move upstream away from the trashracks.

For tests that incorporated netting, the actual and adjusted catch of juvenile shad for each net location and for all tests combined are presented in Table 4-3. A total of nine different sound system configurations were used. The number of tests and the adjusted number of juvenile shad that were caught during test periods conducted with each configuration are reported in Table 4-4. The configurations generally differed in the number, location, and/or types of transducers used. Because the system configurations that were tested varied from night to night and often were not replicated, the netting data cannot be averaged or combined without accepting the potential for significant bias or error that could result from differences in effectiveness among the configurations. However, the percentage of netted fish that passed through the sluiceway and the turbines can be examined and compared among the configurations that were tested. Based on the effectiveness of each configuration, hypotheses can be developed with respect to a sound system design that would maximize fish passage through the sluice and minimize passage through turbines.

The adjusted number of juvenile shad that were caught during test periods ranged from 0 to 89 in the sluiceway, 0 to 200 in the Unit 1 discharge net, 0 to 475 in the Unit 2 net, and 0 to 25 in the Unit 10 net. The percentage of the total adjusted catch that was netted in the sluiceway during test periods varied considerably, ranging from 6.4 to 100%. Although Unit 10 netting was conducted during 5 of the 17 sound tests, the catch data from this unit are not considered representative of turbine passage during periods of sound activation because the transducers that were used for these tests were located and directed downstream of Unit 10 for all but one test conducted on October 25. Also, Unit 2 was brought offline on October 29 for scheduled maintenance and remained offline for the duration of the study. Additionally, Unit 1 was operated at 50% or less gate openings from October 30 through the remainder of the study due to mechanical problems. Without these units operating at full load, turbine passage cannot be accurately estimated for behavioral device tests (i.e., netting ability is severely reduced due to reduced or no discharge). Due to the shutdown of Unit 2 and the low gate openings for Unit 1, netting was not conducted for these two units during tests conducted November 2, 3, and 4. Although it is evident that the sound system pushed more fish through the sluiceway during the test periods than during the control periods on these dates, its ability to do this without increasing turbine passage is unknown. Tests that were conducted when both Units 1 and 2 were operating at full generation also demonstrated that the sound system could move fish through the sluiceway but passage through the turbines was increased as well. During three of the six tests with netting of the Unit 1 and 2 discharge, more juvenile shad were captured in the tailrace (both nets combined) than in the sluiceway net based on the adjusted catch numbers.

4.3 COMBINED-DEVICE TESTS

A total of fifteen combined-device tests was performed during seven nights of testing. Three different sound system configurations and two sequences of behavioral device operation were used for combined-device tests (Table 4-5). Comparing the adjusted numbers of juvenile shad caught in the sluiceway net during test periods (18,091 fish) and control (112 fish) periods reveals that the combined-device tests were very successful in repelling shad through the sluiceway. Also, comparison of the number of juvenile shad captured in the sluiceway net (18,091) to the numbers captured in the Unit 1 (250) and Unit 2 (100) nets during combined-device tests demonstrate that few fish were pushed through turbines relative to the sluiceway. However, during most of the combined device tests Unit 2 was offline and the wicket gates to Unit 1 were only 50% open.

The adjusted number of juvenile shad caught in the tailrace nets never exceeded the sluiceway catch during combined-device tests. The percentage of the total catch of juvenile shad that was netted in the sluiceway typically exceeded 97% and was often 100%. However, although the Unit 1 discharge was netted on October 31 and November 1, the flow through the turbine was greatly reduced (wicket gates were about 50% open) because the unit was experiencing mechanical problems. If Unit 1 was operating at full load, more fish might have passed through the turbine during the behavioral device tests conducted on these dates. Also, the combined device test that was performed on October 26 did not incorporate netting in the tailrace, thus it is not known if turbine passage was considerably increased during this test or remained at a low level.

Similar to tests conducted with high-frequency sound alone, several different sound system configurations were used during testing of the combined-device (Table 4-2). Unlike the sound tests, multiple replicates were conducted for several of the configurations that were used for combined-device tests. Three replicates were performed with three of the five configurations and one replicate was performed with each of the other two configurations (Table 4-6). Large numbers of juvenile shad were repelled through the sluiceway during most tests with the combined-device system with the exception of three tests that were conducted on the nights of November 2, 3, and 4 (one test per night). The adjusted number of juvenile shad caught in the sluiceway for these three nights combined was 10 fish. It is likely that the outmigration of juvenile shad had peaked on October 31 and November 1 and/or large numbers of fish were passing over the dam, resulting in few fish congregating in the forebay on these nights.

For tests performed on October 26, 27, and 31 and November 2, 3, and 4 the sound was activated for 1 to 2 minutes prior to activating the strobe lights and both devices were turned off simultaneously. On November 1, the sound was turned on for 1 to 2 minutes then turned off immediately before activation of the strobe lights. The difference in the testing protocols may have been responsible for the large numbers of juvenile shad caught in the sluiceway net on November 1 compared to the numbers of fish caught on the other nights that combined-device testing was performed, but the abundance of juvenile shad in the forebay varied from night to night and may have peaked on November 1.

4.4 AMBIENT NETTING

Ambient netting of Units 1, 2, and 10 occurred between October 23 and November 4. Because of unit outages, data were not collected for all units on all nights. A summary of ambient net collection data for each tailrace location is presented in Table 4-7. The adjusted number of shad captured in tailrace nets varied from 0 to 1,100 shad per hour, although only once (Unit 10 on Nov. 1) did the capture rate exceed 250 juvenile shad per hour. If the netting data from the ambient period that exceeded 250 fish per hour are excluded from the calculation of the hourly rate for all ambient periods combined, the number of fish netted per hour is reduced from 82.4 to 17.6 for Unit 10 and the hourly rate for all units combined is reduced from 51.1 to 26.1 fish per hour. Even with the exclusion of the one test that the hourly rate exceeded 250 fish, the Unit 10 net had the highest hourly capture rate for all ambient periods combined.

4.5 AUTOMATED CONTROL SYSTEM

The automated control system was only partially investigated due to limited time during the testing period. The manipulation of the sonar fish detection box and the triggering of the relay switch functioned as designed. Since the ability to select a threshold value and detect a certain biomass of fish that would exceed the threshold value, thereby triggering the relay closure, is the heart of the system, it was determined that an automated system is feasible for the York Haven site. The remaining components of an automated control system would consist of a series of electrical timers and connections to the motorized gate hoist, warning lights and sirens, etc. In addition, the detection values of fish biomass within the detection box are displayed on the sonar image for each rastor sweep and recorded on the VCR tape.

4.6 SUPPLEMENTAL SAMPLING

4.6.1 Daily Photometry, Secchi Disc, and Turbidity Measurements

Daily light penetration measurements were made to document changes in water clarity. The Li-Cor photometer was used to obtain light penetration information from the surface to depths near the bottom. A second measure of light penetration was obtained using a secchi disk, which provided a simple and quick assessment of changes in water clarity. Additionally, water turbidity information was obtained as a quantitative measure of the amount of suspended material in the water. The photometry data are presented in Figure 4-1. The corresponding secchi disk and turbidity readings shown on each graph. Generally, water clarity was high with light penetration extending to depths near the bottom of the forebay in front of the sluiceway. The greatest secchi depth was 3.9 m measured on October 29. The lowest recorded turbidity value of 1.82 NTU occurred on October 31.

4.6.2 Strobe Light Mapping

In order to determine the light penetration of the strobe lights and to map the light field, photometry measurements were recorded on several nights. Results of the mapping efforts are shown in Tables 4-8a through e. Strobe light penetration extended farther through the water than it had in any of the previous years during which strobe light tests were conducted at York Haven. Strobe light penetration reached

33 feet from float #4 on October 31. This is roughly 15 feet further than it had been recorded in 1992.

4.6.3 Water Velocities

Velocity measurements were recorded to assess the flow fields in front of the trash rack as well as along three transects that extended across the forebay. The measurements along the trash rack were performed on October 26, 27, and November 4 to assess changes in the approach velocities under different plant operation regimes (i.e., units being brought on and offline). Because of high river levels, the plant operated throughout the study with all available units operating at full load (usually fifteen units were operating each night).

Water velocities in front of the trashrack are shown in Figure 4-2. As shown, velocities of 2.5 fps are fairly uniform along the rack except where units are out and then the velocity drops to around 1.5 fps. Velocities along the transects show a similar pattern to previous years where an eddy line extends from near the exciter bays out towards the pontoon boats and then towards the corner of the office building (Figures 4-3, 4-4, 4-5). Observation of floating debris indicates that a slow upstream flow occurs behind the eddy line on the side adjacent to the cableway. Directional measurements obtained with the Swoffer meter show the approximate location of flow vectors in surface waters (Figures 4-3, 4-4, 4-5). In Figure 4-5, the eddy and an area of low velocity flow is shown extending farther upstream, the result of outages of downstream units.

Table 4-1
Data Summary for Strobe Light Tests Conducted at the York Haven Hydroelectric Project.

Test Date	Test Condition	Number of American Shad Collected			Amercian Shad Collection Adjusted for Flow Sampled		
		Sluice	Unit 1	Unit 2	Sluice	Unit 1	Unit 2
10 / 26	test	136	13	4	449	325	100
	control	16	0	0	53	0	0
10 / 27	test	54	2	0	178	50	0
	control	1	0	0	3	0	0
	test	17	2	0	56	50	0
	control	18	0	0	59	0	0
Total	test	71	4	0	234	100	0
	control	19	0	0	63	0	0
10 / 28	test	12	22	12	40	550	300
	control	1	0	0	3	0	0
10 / 29	test	8	1	--	26	25	--
	control	0	0	--	0	0	--
	test	12	0	--	40	0	--
	control	0	0	--	0	0	--
Total	test	20	1	--	66	25	--
	control	0	0	--	0	0	--
10 / 31	test	86	2	--	284	50	--
	control	1	0	--	3	0	--
	test	12	2	--	40	50	--
	control	0	0	--	0	0	--
Total	test	98	4	--	323	100	--
	control	1	0	--	3	0	--
Total	test	337	44	16	1112	1100	400
	control	37	0	0	122	0	0

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Table 4-2
Testing Configurations of the High-Frequency Sound System Used During Behavioral Device Tests Conducted at the York Haven Hydroelectric Project in 1993

Test Device and Objective	Configurations Tested
High-Frequency Sound Observe fish response	1. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 10; all three transducers activated simultaneously. 2. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 7; only the deepest narrow-beam transducer activated. 3. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 9; all three transducers activated simultaneously
High-Frequency Sound Observe fish response/determine passage route	1. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 10; all three transducers activated simultaneously.
	2. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 7; all three transducers activated simultaneously.
	3. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; all three transducers activated simultaneously.
	4. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and # 2; five transducers activated simultaneously.
	5. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and # 2; one wide-beam (8 ft deep) on boat located at Unit 8; wide-beam on boat activated first for one minute, then remaining five transducers activated simultaneously.
	6. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and #2; all six transducers activated simultaneously.
	7. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 8; all three transducers activated simultaneously.
	8. Two narrow-beam (5 and 15 ft deep) on sound barge located about 10 ft off trashracks at Unit 8; both transducers activated simultaneoulsy.
	9. Two narrow-beam (5 and 15 ft deep) on sound barge located about 8 ft off trashracks at Unit 4; one narrow-beam (8 ft deep) on light float #1 and #2; one wide-beam (8 ft deep) on boat located at Unit 8; all five transducers activated simultaneously.
High-Frequency Sound and Strobe Lights Combined Observe fish response/determine passage route	1. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 7; all three transducers activated simultaneously and for entire duration of test, strobe lights activated one minute after sound was turned on.
	2. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 9; all three transducers activated simultaneously and for entire duration of test, strobe lights activated one minute after sound was turned on.
	3. Two narrow-beam (5 and 15 ft deep) on sound barge located about 10 ft off trashracks at Unit 8; both transducers activated simultaneoulsy and for entire duration of test, strobe lights activated one minute after sound was turned on.
	4. Two narrow-beam (5 and 15 ft deep) on sound barge located at Unit 8; one wide-beam (8 ft deep) on boat located at Unit 12; all three transducers activated simultaneously for one minute, then all three deactivated and strobe lights activated.
	5. Two narrow-beam (5 and 15 ft deep) on sound barge located at Unit 4; one wide-beam (8 ft deep) on boat located at Unit 8; one narrow-beam (8 ft deep) on light floats #1 and #2; all five transducers activated simultaneously for one minute, then all three deactivated and strobe lights activated.

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Table 4-3
Data Summary for High-Frequency Sound Tests Conducted at the York Haven Hydroelectric Project in 1993
(sound sytem configuration for each test is described in Table 4-4)

		Number of American Shad Collected				Amercian Shad Collection Adjusted for Proportion of Flow Sampled			
Test Date	Test Condition	Sluice	Unit 1	Unit 2	Unit 10	Sluice	Unit 1	Unit 2	Unit 10
10 / 25	test	14	8	19	0	46	200	475	0
	control	1	1	4	0	3	25	100	0
10 / 26	test	5	5	3	--	17	125	75	--
	control	25	0	0	--	83	0	0	--
	test	1	0	0	--	3	0	0	--
	control	0	0	0	--	0	0	0	--
Totals	test	6	5	3	--	20	125	75	--
	control	25	0	0	--	83	0	0	--
10 / 27	test	2	0	0	--	7	0	0	--
	control	2	0	0	--	7	0	0	--
10 / 28	test	7	1	1	--	23	25	25	--
	control	0	1	1	--	0	25	25	--
	test	13	0	1	--	43	0	25	--
	control	0	0	0	--	0	0	0	--
Totals	test	20	1	2	--	66	25	50	--
	control	0	1	1	--	0	25	25	--
10 / 29	test	1	0	--	--	3	0	--	--
	control	0	0	--	--	0	0	--	--
	test	0	0	--	--	0	0	--	--
	control	0	--	--	--	0	--	--	--
Totals	test	1	0	--	--	3	0	--	--
	control	0	0	--	--	0	0	--	--
10 / 30	test	1	0	--	--	3	0	--	--
	control	0	0	--	--	0	0	--	--
10 / 31	test	12	0	--	--	40	0	--	--
	control	0	0	--	--	0	0	--	--
11 / 2	test	7	--	--	0	23	--	--	0
	control	1	--	--	0	3	--	--	0
	test	6	--	--	0	20	--	--	0
	control	0	--	--	0	0	--	--	0
Total	test	13	--	--	0	43	--	--	0
	control	1	--	--	0	3	--	--	0
11 / 3	test	27	--	--	0	89	--	--	0
	control	0	--	--	0	0	--	--	0
	test	11	--	--	1	36	--	--	25
	control	0	--	--	0	0	--	--	0
	test	2	--	--	--	7	--	--	--
	control	0	--	--	--	0	--	--	--
Total	test	40	--	--	1	132	--	--	25
	control	0	--	--	0	0	--	--	0
11 / 4	test	4	--	--	--	13	--	--	--
	control	1	--	--	--	3	--	--	--
	test	0	--	--	--	0	--	--	--
	control	0	--	--	--	0	--	--	--
Total	test	4	--	--	--	13	--	--	--
	control	1	--	--	--	3	--	--	--
Total	test	113	14	24	1	373	350	600	25
	control	30	2	5	0	99	50	125	0

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Table 4-4
Testing Configuration Summary for High-Frequency Sound Tests Conducted at the York Haven Hydroelectric Project in 1993

Configuration	Number of Tests Conducted											Adjusted American Shad Catch During Test Periods		
	Oct 25	Oct 26	Oct 27	Oct 28	Oct 29	Oct 30	Oct 31	Nov 2	Nov 3	Nov 4	Total	Sluiceway	Unit 1	Unit 2
1. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 10; all three transducers activated simultaneously.	1	--	--	--	--	--	--	--	--	--	1	46	200	475
2. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 7; all three transducers activated simultaneously.	--	1	--	--	--	--	--	--	--	--	1	17	125	75
3. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; all three transducers activated simultaneously.	--	1	1	--	--	--	--	--	--	--	2	10	0	0
4. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and # 2; five transducers activated simultaneously.	--	--	--	2	--	--	--	--	--	--	2	66	25	75
5. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and # 2; one wide-beam (8 ft deep) on boat located at Unit 8; wide-beam on boat activated first for one minute, then remaining five transducers activated simultaneously.	--	--	--	--	1	--	--	--	--	--	1	3	0	--
6. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 4; one narrow-beam (8 ft deep) on light float #1 and #2; all six transducers activated simultaneously.	--	--	--	--	1	--	--	--	--	--	1	0	0	--
7. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 8; all three transducers activated simultaneously.	--	--	--	--	--	1	--	--	--	--	1	3	0	--
8. Two narrow-beam (5 and 15 ft deep) on sound barge located about 10 ft off trashracks at Unit 8; both transducers activated simultaneoulsy.	--	--	--	--	--	--	1	--	--	--	1	40	0	--
9. Two narrow-beam (5 and 15 ft deep) on sound barge located about 8 ft off trashracks at Unit 4; one narrow-beam (8 ft deep) on light float #1 and #2; one wide-beam (8 ft deep) on boat located at Unit 8; all five transducers activated simultaneously.	--	--	--	--	--	--	--	2	3	2	7	188	--	--
Totals	1	2	1	2	2	1	1	2	3	2	17	373	350	625

Table 4-5

Data Summary for Combined-Device (strobe light and high-frequency sound) Tests Conducted at the York Haven Hydroelectric Project in 1993 (sound system configuration for each test is described in Table 4-6)

	Test	Number of American Shad Collected				Amercian Shad Collection Adjusted for Proportion of Flow Sampled			
Test Date	Condition	Sluice	Unit 1	Unit 2	Unit 10	Sluice	Unit 1	Unit 2	Unit 10
10 / 26	test	404	--	--	--	1333	--	--	--
	control	0	--	--	--	0	--	--	--
10 / 27	test	73	5	4	--	241	125	100	--
	control	0	0	0	--	0	0	0	--
10 / 31	test	305	3	--	0	1007	75	--	0
	control	0	0	--	1	0	0	--	25
	test	1040	1	--	--	3432	25	--	--
	control	1	0	--	--	3	0	--	--
	test	275	1	--	--	908	25	--	--
	control	0	0	--	--	0	0	--	--
Totals	test	1620	5	--	0	5346	125	--	0
	control	1	0	--	1	3	0	--	25
11 / 1	test	1049	0	--	0	3462	0	--	0
	control	0	0	--	0	0	0	--	0
	test	302	0	--	0	997	0	--	0
	control	1	0	--	0	3	0	--	0
	test	642	0	--	0	2119	0	--	0
	control	19	1	--	0	63	25	--	0
	test	641	0	--	0	2115	0	--	0
	control	5	1	--	0	17	25	--	0
	test	502	0	--	1	1657	0	--	25
	control	5	0	--	0	17	0	--	0
	test	101	0	--	0	333	0	--	0
	control	0	0	--	0	0	0	--	0
	test	145	0	--	0	479	0	--	0
	control	0	0	--	0	0	0	--	0
Total	test	3382	0	--	1	11161	0	--	25
	control	30	2	--	0	99	50	--	0
11 / 2	test	3	--	--	--	10	--	--	--
	control	3	--	--	--	10	--	--	--
11 / 3	test	0	--	--	0	0	--	--	0
	control	0	--	--	0	0	--	--	0
11 / 4	test	0	--	--	--	0	--	--	--
	control	0	--	--	--	0	--	--	--
Total	test	5482	10	4	1	18091	250	100	25
	control	34	2	0	1	112	50	0	25

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Table 4-6

Testing configuration summary for combined-device (strobe light and high-frequency sound) tests conducted at York Haven Hydroelectric Project in 1993

Configuration	Number of Tests Conducted								Adjusted American Shad Catch During Test Periods		
	Oct 26	Oct 27	Oct 31	Nov 1	Nov 2	Nov 3	Nov 4	Total	Sluiceway	Unit 1	Unit 2
1. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 7; all three transducers activated simultaneously and for entire duration of test, strobe lights activated one minute after sound was turned on.	1	--	--	--	--	--	--	1	1333	--	--
2. Two narrow-beam (5 and 15 ft deep) and one wide-beam (11.5 ft deep) on sound barge located at Unit 9; all three transducers activated simultaneously and for entire duration of test, strobe lights activated one minute after sound was turned on.	--	1	--	--	--	--	--	1	241	125	100
3. Two narrow-beam (5 and 15 ft deep) on sound barge located about 10 ft off trashracks at Unit 8; both transducers activated simultaneoulsy and for entire duration of test, strobe lights activated one minute after sound was turned on.	--	--	3	--	--	--	--	3	5346	125	--
4. Two narrow-beam (5 and 15 ft deep) on sound barge located at Unit 8; one wide-beam (8 ft deep) on boat located at Unit 12; all three transducers activated simultaneously for one minute, then all three deactivated and strobe lights activated.	--	--	--	7	--	--	--	7	11161	0	--
5. Two narrow-beam (5 and 15 ft deep) on sound barge located at Unit 4; one wide-beam (8 ft deep) on boat located at Unit 8; one narrow-beam (8 ft deep) on light floats #1 and #2; all five transducers activated simultaneously for one minute, then all three deactivated and strobe lights activated.	--	--	--	--	1	1	1	3	10	--	--
Totals	1	1	3	7	1	1	1	15	18091	250	100

Table 4-7
Data Summary for Tailrace Ambient Net Collections Conducted at the York Haven Hydroelectric Project in 1993

	Number of American Shad Collected								American Shad Collection Adjusted for Proportion of Flow Sampled (1 hr sampling period)			
	Unit 1		Unit 2		Unit 10		Combined					
Date	Catch	Time (hr)	Catch	Time (hr)	Catch	Time (hr)	Catch	Time (hr)	Unit 1	Unit 2	Unit 10	Combined
10/23	1	1.0	2	1.0	0	1.0	3	3.0	25	50	0	75
10/23	0	1.0	5	1.0	2	1.0	7	3.0	0	125	50	175
10/25	0	1.0	0	1.0	0	1.0	0	3.0	0	0	0	0
10/26	0	1.0	0	1.0	0	1.0	0	3.0	0	0	0	0
10/26	--	--	--	--	0	1.0	0	1.0	--	--	0	0
10/26	2	0.5	3	0.5	0	0.5	5	1.5	50	75	0	125
10/26	0	0.5	0	0.5	0	0.5	0	1.5	0	0	0	0
10/27	0	0.5	1	0.5	1	0.5	2	1.5	0	25	25	50
10/27	1	0.5	0	0.5	0	0.5	1	1.5	25	0	0	25
10/27	0	1.0	1	1.0	--	--	1	2.0	0	25	--	25
10/28	0	1.0	10	1.0	0	1.0	10	3.0	0	250	0	250
10/28	0	1.0	1	1.0	1	1.0	2	3.0	0	25	25	50
10/28	0	0.5	1	0.5	--	--	1	1.0	0	25	--	25
10/29	0	1.0	--	--	2	1.0	2	2.0	0	--	50	50
10/29	0	0.5	--	--	--	--	0	0.5	0	--	--	0
10/29	0	0.5	--	--	0	0.5	0	1.0	0	--	0	0
10/30	0	0.5	--	--	--	--	0	0.5	0	--	--	0
10/31	0	1.0	--	--	0	1.0	0	2.0	0	--	0	0
10/31	1	0.5	--	--	--	--	1	0.5	25	--	--	25
10/31	1	1.0	--	--	1	1.0	2	2.0	25	--	25	50
10/31	0	1.0	--	--	--	--	0	1.0	0	--	--	0
10/31	0	0.5	--	--	--	--	0	0.5	0	--	--	0
11/1	0	1.0	--	--	44	1.0	44	2.0	0	--	1100	1100
11/1	4	0.5	--	--	1	0.5	5	1.0	100	--	25	125
11/2	--	--	--	--	4	1.0	4	1.0	--	--	100	100
11/3	--	--	--	--	0	1.0	0	1.0	--	--	0	0
11/4	--	--	--	--	0	1.0	0	1.0	--	--	0	0
Total	10	17.5	24	9.5	56	17.0	90	44.0	250	600	1400	2250
Fish / Hour	0.6		2.5		3.3		2.0		14.3	63.2	82.4	51.1

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Table 4-8a

Strobe light mapping on 10/29/93 with all lights on.

Transect is along centerline of strobe float #2 towards sluice gate

	Depth	Distance From Strobe Light (ft)						
	(ft)	3	6	9	12	15	18	21
	1	2.00	4.00	1.80	1.20	0.72	0.48	0.33
	2	5.00	5.00	1.70	1.20	0.75	0.45	0.30
Top Light	3	5.50	5.00	2.20	1.30	0.75	0.42	0.30
	4	5.00	3.00	1.90	1.10	0.69	0.39	0.27
	5	5.00	3.00	1.30	1.00	0.69	0.36	0.24
	6	7.00	2.10	1.20	0.90	0.66	0.36	0.24
	7	6.00	3.00	1.30	0.80	0.54	0.36	0.21
	8	5.00	2.10	1.00	0.70	0.45	0.33	0.18
Bottom Light	9	4.00	1.70	0.80	0.60	0.39	0.30	0.15
	10	3.00	1.30	0.70	0.50	0.33	0.24	0.15
	11	2.50	1.10	0.50	0.40	0.27	0.21	0.12
	12	2.00	0.70	0.40	0.30	0.24	0.15	0.12
	13	1.00	0.60	0.30	0.26	0.18	0.12	0.09
	14	0.60	0.50	0.30	0.24	0.15	0.12	0.06
	15	0.30	0.40	0.20	0.21	0.12	0.09	0.06

Table 4-8b

Strobe light mapping on 10/29/93 with floats 1+2 on.

Transect is along centerline of strobe float #2 towards sluice gate

	Depth	Distance From Strobe Light (ft)						
	(ft)	3	6	9	12	15	18	21
	1	3.70	2.80	1.30	0.75	0.42	0.21	0.12
	2	3.60	1.80	1.10	0.36	0.39	0.27	0.15
Top Light	3	4.50	2.50	1.40	0.84	0.36	0.21	0.15
	4	4.80	2.00	1.00	0.69	0.36	0.18	0.15
	5	4.50	2.20	0.90	0.66	0.33	0.21	0.12
	6	7.50	2.10	1.10	0.75	0.30	0.18	0.12
	7	5.40	1.90	1.20	0.60	0.30	0.18	0.12
	8	5.40	2.30	1.20	0.42	0.27	0.15	0.12
Bottom Light	9	4.80	1.80	0.90	0.42	0.24	0.15	0.12
	10	4.20	1.40	0.80	0.36	0.21	0.12	0.09
	11	3.00	1.00	0.60	0.33	0.18	0.12	0.06
	12	1.70	0.90	0.45	0.30	0.15	0.09	0.06
	13	0.90	0.63	0.39	0.21	0.12	0.09	0.06
	14	0.50	0.45	0.27	0.15	0.12	0.06	0.03
	15	0.30	0.36	0.21	0.12	0.09	0.06	0.03

Table 4-8c

Strobe light mapping on 10/30/93 with all lights on.
Transect is along centerline of strobe float #1 towards the sluice gate

	Depth (ft)	Distance From Strobe Light Float (ft)						
		10	16	22	28	34	40	46
Top Light	3	1.50	0.50	0.30	0.20	0.10	0.00	<0.03

Table 4-8d

Strobe light mapping on 10/31/93 with all lights on.
Transect is along centerline of strobe float #4 towards sluice gate

	Depth (ft)	Distance From Strobe Light Float (ft)											
		3	6	9	12	15	18	21	24	27	30	33	36
Top Light	3	3.60	3.50	3.40	1.30	0.50	0.20	0.2	0.1	0.1	0.1	0.03	0

Table 4-8e

Strobe light mapping on 11/2/93 with all lights on.
Transect is along centerline of strobe float #2 towards sluice gate

	Depth (ft)	Distance From Strobe Light (ft)								
		3	6	9	12	15	18	21	24	27
	1	3.50	3.20	2.10	0.87	0.27	0.15	0.12	0.09	0.06
	2	3.70	3.50	3.30	1.24	0.24	0.12	0.12	0.06	0.06
Top Light	3	3.70	3.60	3.50	1.30	0.30	0.15	0.12	0.09	0.03
	4	3.60	3.60	3.50	1.10	0.24	0.18	0.12	0.06	0.03
	5	3.50	3.50	2.50	0.90	0.21	0.15	0.09	0.03	0.15
	6	3.50	3.40	2.70	0.75	0.21	0.18	0.06	0.03	0.15
	7	3.60	3.50	2.30	0.48	0.18	0.15	0.06	0.03	0.15
	8	3.70	3.60	1.70	0.57	0.15	0.12	0.06	0.15	0.00
Bottom Light	9	3.70	2.10	0.90	0.54	0.15	0.09	0.06	0.15	0.00
	10	3.50	1.20	0.54	0.30	0.12	0.09	0.03	0.00	0.00
	11	2.30	1.10	0.33	0.21	0.09	0.06	<.03	0.00	0.00
	12	1.60	0.54	0.21	0.15	0.06	0.03	0.00	####	0.00
	13	0.80	0.33	0.15	0.12	0.03	<0.03	0.00	0.00	0.00
	14	0.40	0.24	0.12	0.09	0.03	<0.03	0.00	0.00	0.00
	15	0.20	0.15	0.03	0.06	<0.03	0.00	0.00	0.00	0.00

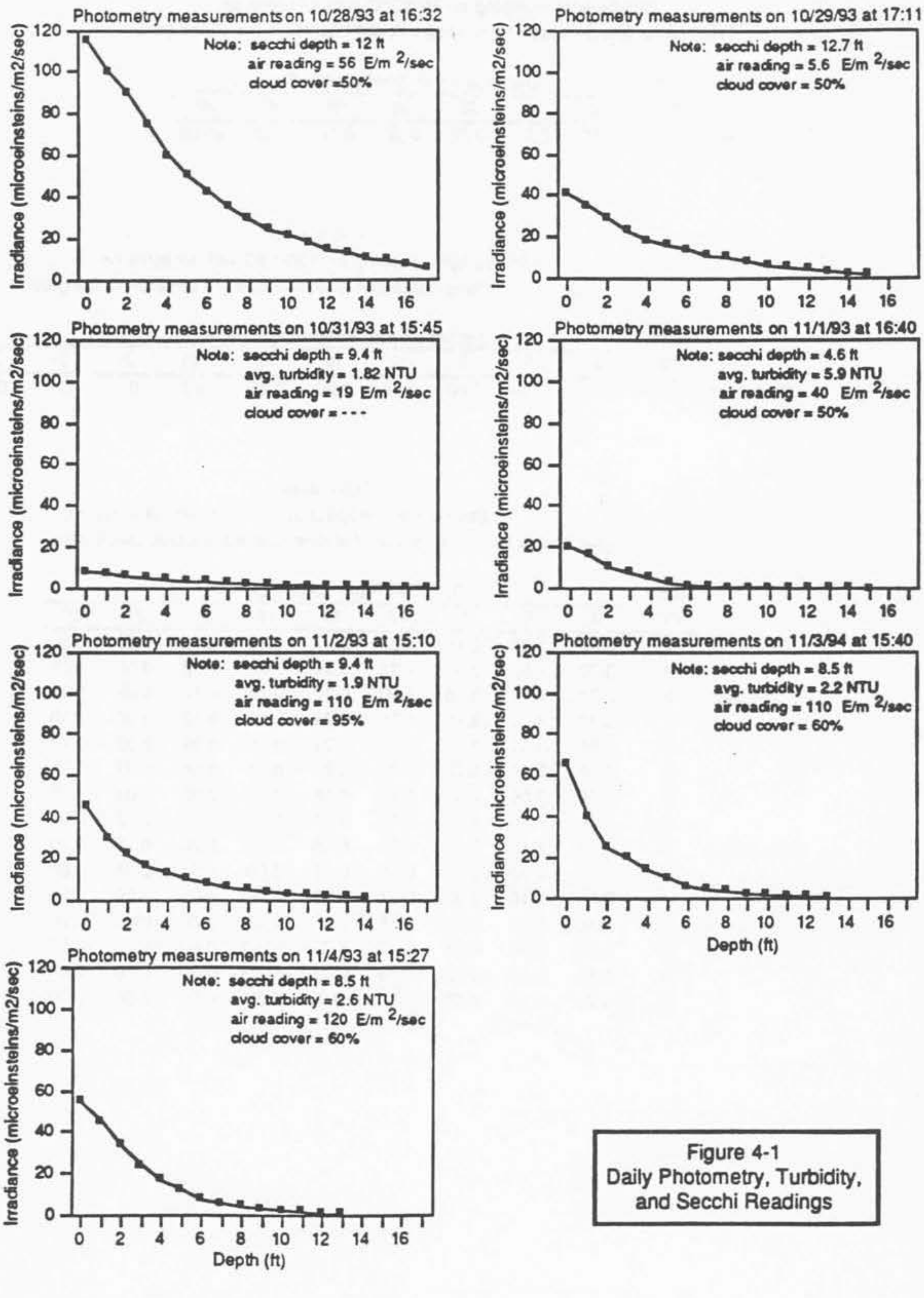
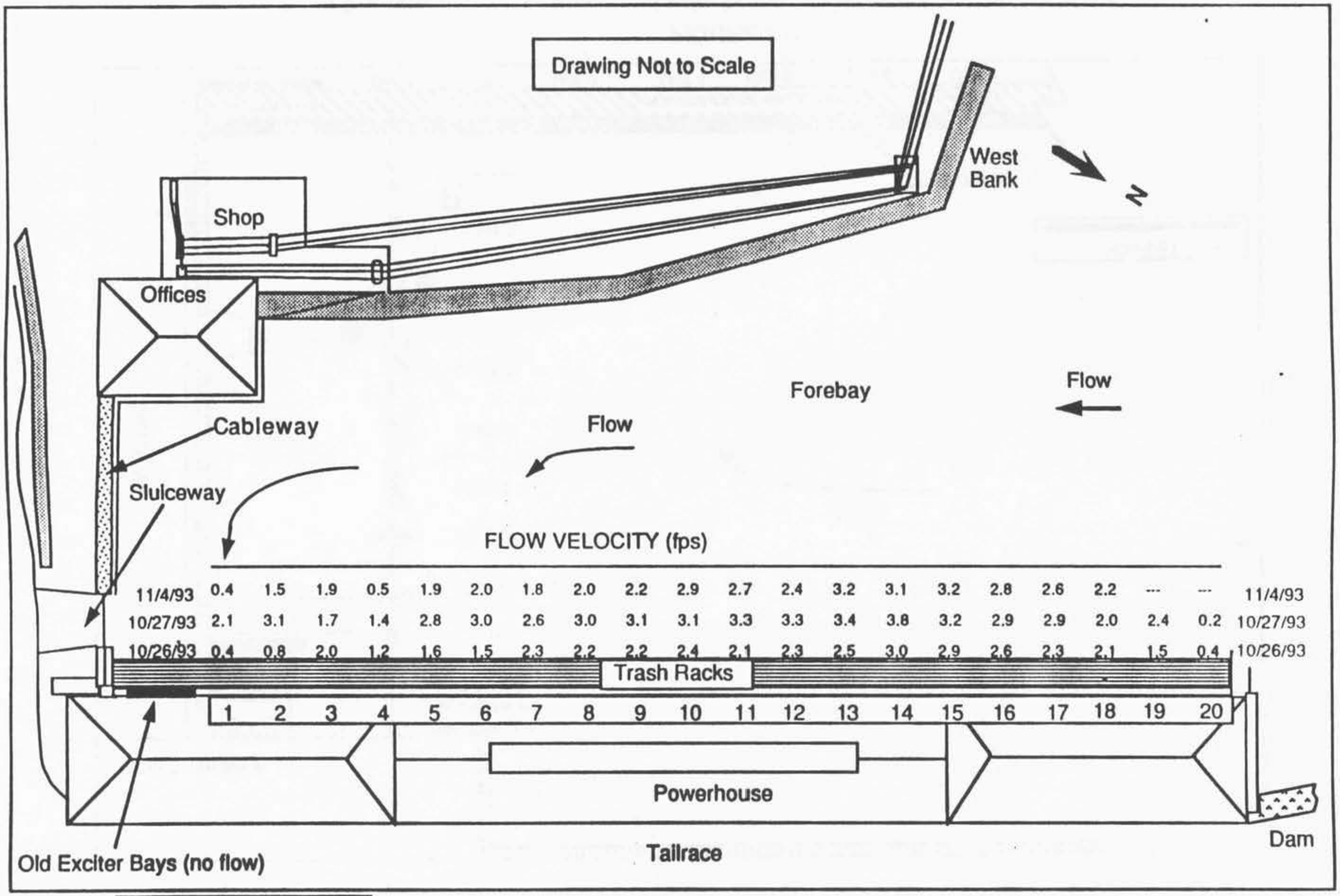


Figure 4-1
Daily Photometry, Turbidity, and Secchi Readings



Date	Unit Outages
10/26	3,4,15,16,18
10/27	3,4,15,16,18
11/4	1(1/2 open),2,15,16,18

FIGURE 4-2
Velocity measurements taken along the trashracks on 10/26, 10/27, and 11/4/93

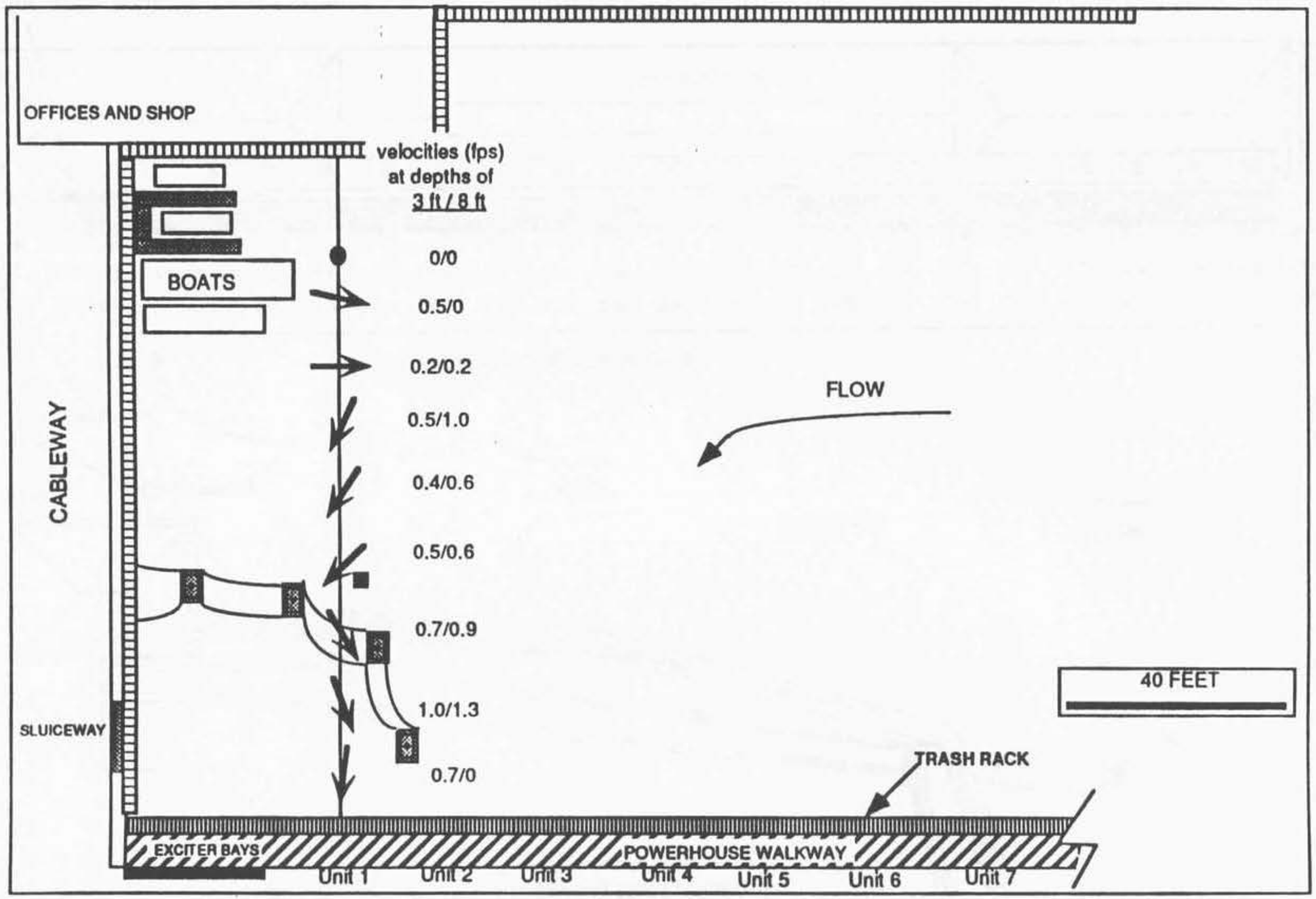


FIGURE 4-3

Flow direction assessment and velocity measurements taken on 10/26/93

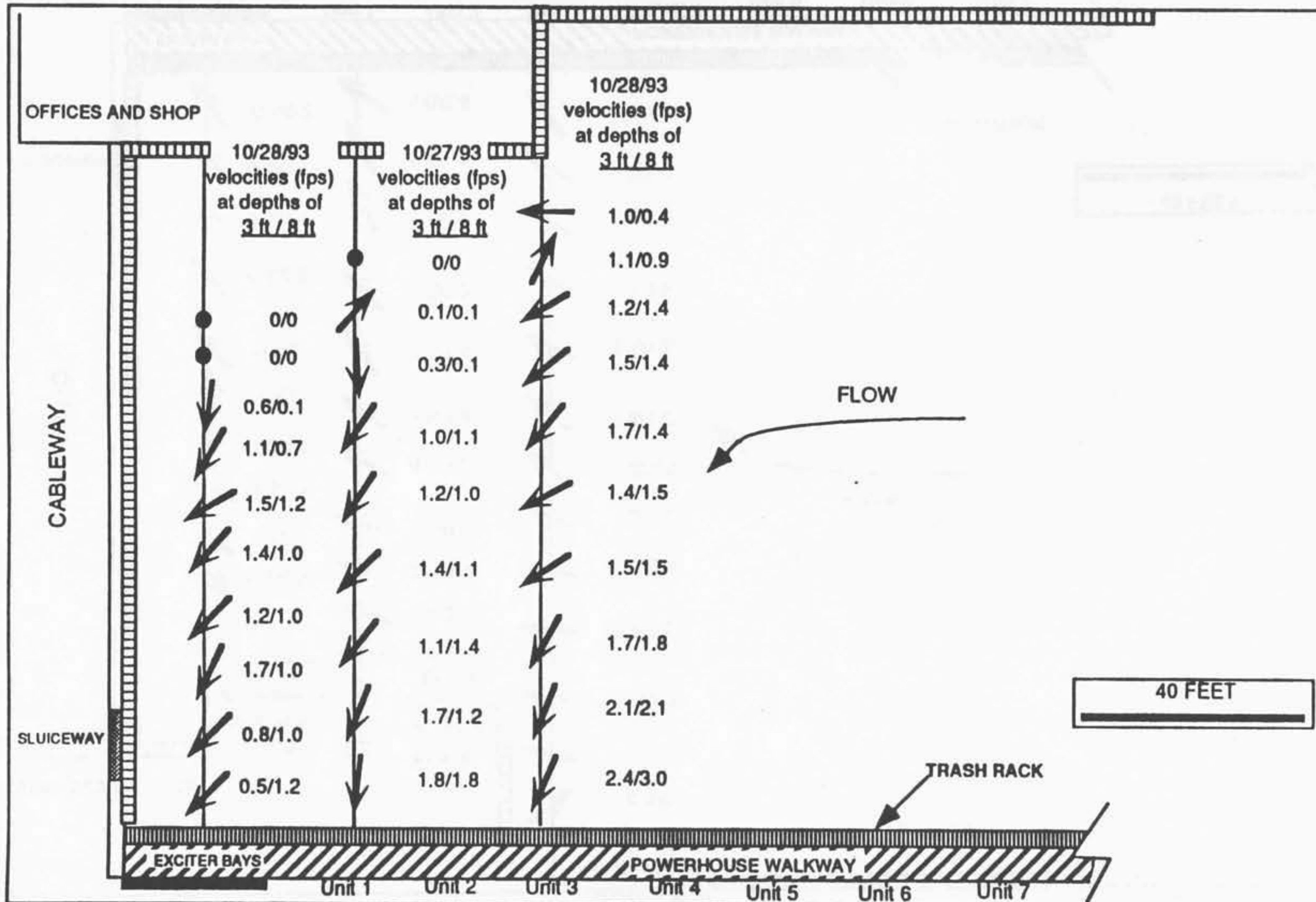


FIGURE 4-4

Flow direction assessment and velocity measurements taken on 10/27-10/28/93

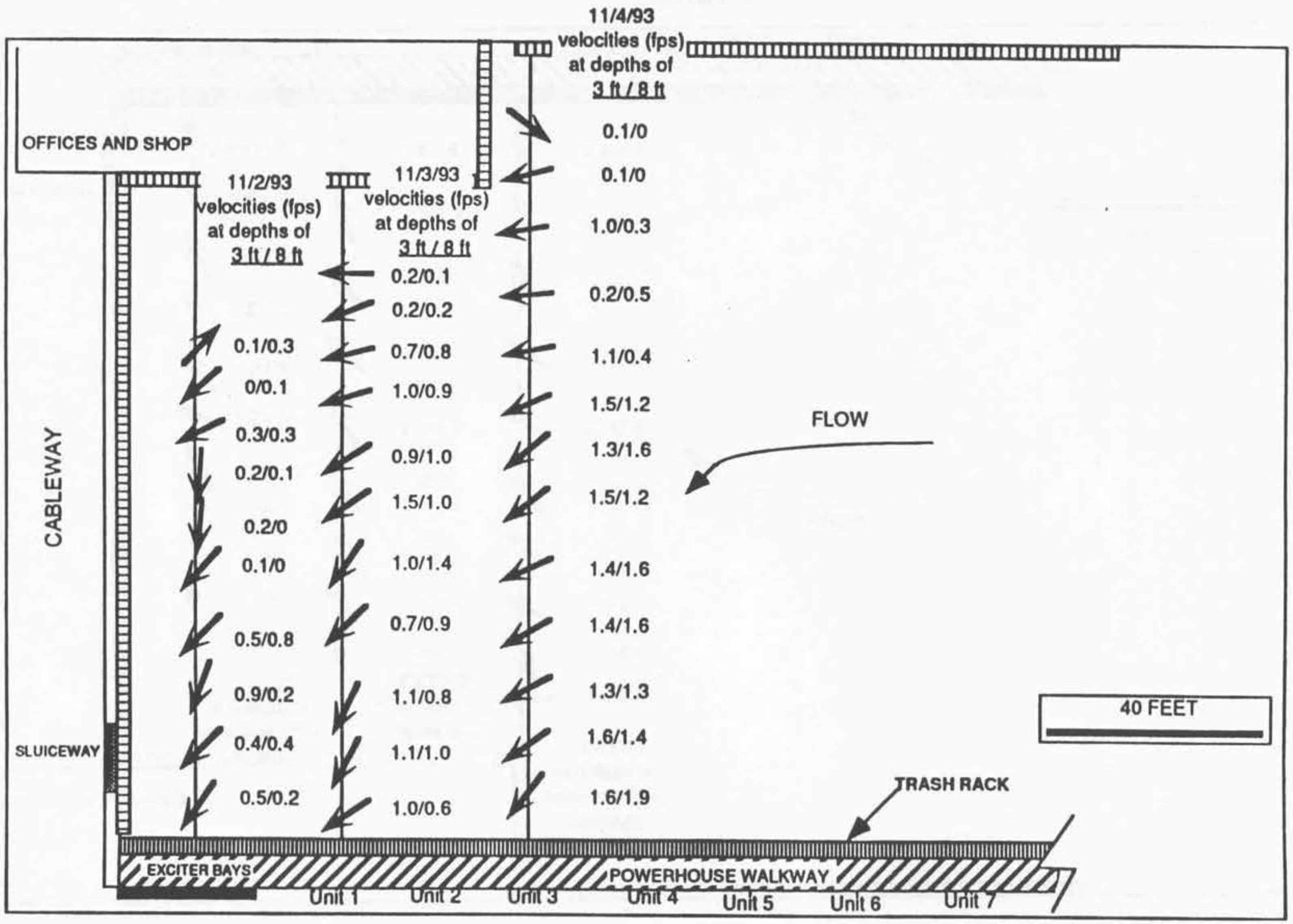


FIGURE 4-5
Flow direction assessment and velocity measurements taken on 11/2-11/4/93

SECTION 5

DISCUSSION AND CONCLUSIONS

Based on the results from the 1993 behavioral device testing, it is evident that strobe lights and high-frequency sound can repel fish through the sluiceway. Additionally, the combined-device system appears to also have the ability to drive juvenile shad through the sluiceway without considerable increases in turbine passage. Although more fish passed through the sluiceway than through the turbines (i.e., Units 1 and 2) during strobe light tests, the difference was not as great as in past years. Several different sound system configurations (i.e., number, location, and type of transducers used) were tested, none of which demonstrated an overwhelming ability to repel fish through the sluiceway without corresponding increases in unit passage. Also, tailrace netting data from the two nights that large numbers of juvenile shad were repelled through the sluiceway by the combined-device system may not have been sufficient for determining the true ratio of sluiceway to unit passage. On both these nights Unit 2 was offline and Unit 1 was operating with the wicket gates 50% open.

5.1 STROBE LIGHTS

Compared to the results from strobe light tests conducted in 1991 and 1992, the ratio of sluiceway to turbine passage during strobe light tests in 1993 was much lower. The interaction between fish behavior and plant operations may have contributed to the lower passage ratio observed in 1993. Water velocities in the forebay and along the trashracks appear to affect fish distributions at the plant. The distribution of water velocities throughout the forebay will be strongly influenced by the combination of unit operations and levels of operation. In 1991, the downstream units near the sluiceway were operating at full load resulting in considerable accumulations of juvenile shad in the area near Units 1 and 2 and the sluiceway. Subsequently, large numbers of juvenile shad were diverted away from the unit intakes and through the sluiceway with a strobe light system. In 1992, many of the lower units were not operating during the test period which resulted in outmigrants accumulating at the upstream units. The result was much lower numbers of shad being repelled through the sluiceway compared to the numbers from 1991. However, similar to 1991, the ratio of sluiceway to turbine passage during 1992 tests was very high.

Hydraulic and environmental factors had the primary influence over the occurrence, distribution and behavior of the shad under both control and test conditions. In most years, shad were observed to arrive at York Haven in the last week of September or the first week of October. In 1993, shad did not start arriving at the site until the second week in October and dense schools did not occur until the third week in October. In general, several factors cause the fish to congregate near the downstream end of the powerhouse in front of Units 1 through 6:

1. The orientation of the powerhouse along the axis of the river causes the flow to move in a downriver direction almost to the cableway wall; therefore, migrants following the flow downriver will move to this area before confronting the physical boundaries of the wall and the trash racks;

2. During the period of migration, river flows tend to be low and Met-Ed operates the downstream units preferentially over the upstream units; therefore, Units 1 through 6 are the most likely to be operating; such operation further enhances the movement of fish to the downstream area;

3. The rapid acceleration of flow through the trash racks creates velocity conditions that the shad clearly avoid; therefore, as they move downstream, they are delayed and accumulate in a dense mass; it is possible that background noise from the operating turbines and water flow contributes to the observed avoidance.

The influence of these factors is considered critical to the successful deployment of strobe lights at this site. In 1993, more fish were observed along the trashrack in front of Units 7 through 20 because more of these Units were in operation than in past years.

It is concluded that a proper combination of physical and hydraulic conditions must exist in the area of a strobe light and bypass system in order to achieve the desired degree of biological effectiveness of this behavioral fish protection system with juvenile American shad.

5.2 SOUND

Studies with sound at York Haven were largely inconclusive because of the frequent changing of transducer operation, the low abundance of shad, and the ongoing strobe light tests. The FishStartle™ system did cause an avoidance response in shad which was clearly apparent to distances of 100 feet. In addition, the fish moved a great distance and did not became acclimated to the sound. The fact that a response was observed, coupled with positive research results recently obtained by others with both low and high frequency sound, would indicate that sound can be a repelling device. Additional research is necessary to determine the feasibility of using sound as part of a directional bypass system.

- Although the maximum range of effectiveness of the sound device was not determined, it appeared that the sound was effective at least to a distance of 100 feet.

- The strong avoidance response indicates good potential for bypassing fish through the sluiceway with a refined sound transducer arrangement.

Based on results with the light and sound combination it can be concluded that:

- A third option for effectively bypassing shad at York Haven under a broad range of environmental and plant operating conditions would combine sound and light devices so that fish along the entire length of the trash rack are bypassed through the sluiceway.

- This combination has the potential to pass fish even in the presence of poor hydraulic conditions.

Based on testing of the automatic control system it can be concluded that:

- It is clearly feasible to automate the fish passage system to periodically pulse fish out the sluiceway in response to their abundance in the forebay.

SECTION 6

LITERATURE CITED

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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 shad present in the upper Chesapeake Bay during the spring spawning season. Besides providing an estimate of spawning adults 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 1993 were nearly identical to those in 1992, the only difference being the elimination of the Bohemia River pound net site and the addition of the Cara Cove site in the Susquehanna Flats (Figure I). 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 1993 was again monitored by project personnel with only the Smith-Root electrofisher. However, changes were made in the 1993 sampling design. The Susquehanna Flats shoreline area was gridded off into 21 separate cells approximately 2,000 feet long instead of 36 cells as in prior years (Figure II). Based on juvenile shad abundance over the previous four years mean catch-per-unit-of-effort (CPUE) for each of these 21 cells was calculated and 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 striped bass survey were also utilized in analysis of the reproductive success of American shad in the upper Bay during 1993.

RESULTS

Pound net tagging for 1993 began on 27 March and continued until 13 May while hook and line effort commenced on 5 May and ended 26 May. Of the 546 adult American shad captured, 412 (75%) were tagged and 120 (22%) subsequently recaptured (Table 1).
Of these 120 recaptures three occurred outside the upper Bay system; two fish off the New Jersey coast and one near Kent Island, MD. All three fish were downrunners captured by pound nets. The 120 total does not reflect the 61 multiple recaptures, five unverifiable tag numbers, and 5 fish tagged prior to 1993 collected by RMC from the two fish lifts.

Recapture data for the 1993 season is summarized as follows:

a. 117 fish recaptured by the Conowingo Fish Lift
   (does not include 61 multiple recaptures, 5 pre-1993 tagged fish, and 5 fish with unverifiable tag numbers)
   0 fish recaptured by pound net
   0 fish recaptured by hook and line from the tailrace
   3 fish recaptured outside the system

b. 101 fish recaptured originally caught by hook and line
   19 fish recaptured originally caught by pound net

c. 98 fish recaptured in the same area as initially tagged
   21 fish recaptured upstream of their initial tagging site (includes two recaptures off the New Jersey coast)
   1 fish recaptured downstream of its initial tagging site

d. shortest period at large: 1 day
   longest period at large: 27 days (1993 fish only)
   mean number days at large: 9.8

e. number of pre-1993 tagged fish recaptured: 8
   number of 1992 tagged fish recaptured: 7
   number of 1991 tagged fish recaptured: 1
   number of pre-1993 multiple recaptures: 3

The population estimate for adult shad in the upper Chesapeake Bay for 1993 using the Petersen Index was 47,563 (Table 2). Since all three fish recaptured outside the upper Bay system were post spawners no emigration factor was calculated for 1993. The 1993 estimate represents a 55% decrease from the previous year (Figure III). However, the overall trend still continues to indicate an increasing population for the upper Bay stock ($r^2 = 0.57$, $p = 0.0019$). Possible reasons for this decline include poor reproduction/larval survival three to six years earlier, continued high exploitation, and/or record flood conditions over the entire Susquehanna River basin during the spring of 1993. Of note is the fact that preliminary results from other east coast states indicate that nearly every American shad run along the Atlantic seaboard also suffered moderate to sharp declines in 1993.

Effort, catch, and catch-per-unit-of-effort (CPUE) by gear type for adult American shad in the upper Bay during 1993 and comparison with previous years is presented in Table 3. Catch per angler hour decreased to 5 1/2 fish in 1993 while the catch per pound net day for all nets combined increased 68% in 1993 over the previous year.

A total of 447 adult American shad (233 hook and line, 214 pound net) were examined for physical characteristics by DNR biologists in 1993. Of the males examined, 77% were ages IV and V with age group IV predominating in both gear types (Table 4). The overall incidence of repeat spawning in male shad increased from 8.2% in 1992 to 14.4% for 1993. Nearly 71% of the 211 female shad examined in 1993 were V and VI year old fish with age group VI slightly predominating. As with their male counterparts, the incidence of repeat spawning in females increased in 1993 with 26.1 % of females being non-virgin recruits as opposed to 9.0% the previous year.

Juvenile Alosa sampling in the upper Bay during 1993 produced substantially greater numbers of young-of-the-year American shad than the previous year. Supplemental haul seine sampling for the Department's juvenile striped bass survey in 1993 captured 36 young-of-the-year American shad as opposed to 0 in 1992. Numbers of juvenile shad collected by electrofisher increased to 31 in 1993, 27 more fish than the previous year. Table 5 provides a breakdown by cell and date of the juvenile shad collected by electrofishing from the upper Bay during 1993.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1993.

GEAR TYPE	LOCATION	CATCH	NUMBER TAGGED
Pound Net	Cherry Tree	255	141
	Cara Cove	26	18
	Total	281	159
Hook and Line	Conowingo Tailrace Susquehanna River	265	253
Fish Lift	Conowingo Tailrace Susquehanna River	13,546	
	TOTALS	14,092	412

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1993 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 1991 survey -

C = 13,995
R = 117
M = 400*

Therefore -

$$N = \frac{(13,995 + 1)\ (400 + 1)}{(117 + 1)}$$

= **47,563**

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):

$$N^* = \frac{(C + 1)\ (M + 1)}{R' + 1}$$ where: R' = tabular value (Ricker p343)

$$\text{Upper } N^* = \frac{(13,995 + 1)\ (400 + 1)}{97.63 + 1} = 56,904$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(13,995 + 1)\ (400 + 1)}{140.21 + 1} = 39,745$$ @ .95 confidence limits

* M adjusted for 3% tag loss

Table 3. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad by hook and line and pound net during the 1980-1993 tagging program in the upper Chesapeake Bay.

YEAR	LOCATION	DAYS FISHED	TOTAL CATCH	CATCH PER POUND NET DAY	POP. EST.
A. Pound Net					
1980	Rocky Pt.	26	50	1.92	5,531
1981	Rocky Pt.	38	50	0.86	9,357
1982	Rocky Pt.	27	62	2.29	37,551
1985	Rocky Pt.	10	30	3.00	14,283
1988	Rocky Pt.	33	87	2.64	
	Cherry Tree	41	75	1.83	
	Romney Cr.	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 R.	54	209	3.87	
	1991 Total	148	1,054	7.12	139,862
1992	Cherry Tree	56	147	2.63	
	Bohemia R.	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

Table 3, continued.

YEAR	HOURS FISHED	TOTAL CATCH	CPUE CPAH*	CPUE HTC**	POP. EST.
B. Hook and Line					
1982	***	88	-	-	37,551
1983	***	11	-	-	12,059
1984	52.0	126	2.42	0.41	8,074
1985	85.0	182	2.14	0.47	14,283
1986	147.5	437	2.96	0.34	22,902
1987	108.8	399	3.67	0.27	27,354
1988	43.0	256	5.95	0.17	38,386
1989	42.3	276	6.52	0.15	75,820
1990	61.8	309	5.00	0.20	123,830
1991	77.0	437	5.68	0.18	139,862
1992	62.8	383	6.10	0.16	105,255
1993	47.6	264	5.55	0.18	47,563

* Catch per angler hour
** Hours to catch 1 shad
*** Hours fished not recorded

Table 4. 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 1993 upper Chesapeake Bay operation.

	MALE				FEMALE			
AGE GROUP	N(%)	RPTS.	MEAN	RANGE	N(%)	RPTS.	MEAN	RANGE
A. Hook & Line								
III	8(3)	0	318	275-344	0	0	-	-
IV	67(29)	0	371	340-420	16(7)	0	397	360-415
V	56(24)	6	416	349-450	27(12)	1	430	391-470
VI	18(8)	9	436	347-457	31(13)	7	459	428-495
VII	2(1)	2	471	466-475	8(3)	3	483	470-504
VIII	0	0	-	-	0	0	-	-
% Repeat Spawners		11.3				13.4		
B. Pound Net								
III	7(3)	0	333	310-355	0	0	-	-
IV	31(15)	0	370	330-410	8(4)	0	404	375-440
V	28(13)	6	410	360-455	43(20)	1	425	390-465
VI	17(8)	10	431	400-465	49(23)	21	451	400-510
VII	2(1)	1	440	-	20(9)	16	473	440-530
VIII	0	0	-	-	9(4)	6	493	460-545
% Repeat Spawners		20.0				34.1		
C. All gears combined								
III	15(3)	0	325	275-355	0	0	-	-
IV	98(22)	0	371	330-420	24(5)	0	399	360-440
V	84(19)	12	414	349-455	70(16)	2	427	390-470
VI	35(8)	19	434	347-465	80(18)	28	454	400-510
VII	4(1)	3	455	440-475	28(6)	19	476	440-530
VIII	0	0	-	-	9(2)	6	493	460-545
% Repeat Spawners		14.4				26.1		

Table 5. Juvenile American shad captured by date and cell and associated catch-per-unit-effort (American shad caught per shock hour) during the 1993 upper Chesapeake Bay electrofishing survey. No sampling at a particular date and cell is represented by a blank space.

CELL	AUGUST				SEPTEMBER				OCTOBER				SHOCK TIME	
NO.	5	10	18	24	2	8	14	22	14	19	26	CATCH	(SEC)	CPUE
1						X	5	1			X	6	2000	10.8
2				X			X	X	X		X	0	2500	0.0
3	X	X		1	X	1		X		X	1	3	4000	2.7
4	X	X	X	X			1					1	2500	1.44
5				X	X						X	0	1500	0.0
6	X	X	X		X	X	X	X	X			0	4000	0.0
7					X				X	X		0	1500	0.0
8			1			X						1	1000	3.6
9	X	X	X		1			X	X	X	X	1	4000	0.9
10		X		X					X			0	1500	0.0
11	X	X						X				0	1500	0.0
12	X			X	1	X	X		1	X	1	3	4000	2.7
13									X	X		0	1000	0.0
14										X	X	0	1000	0.0
15			X			X						0	1000	0.0
16	X	X	X	X	X		2	2	1	X		5	4500	4.0
17							X	X				0	1000	0.0
18	X				X		X					0	1500	0.0
19		X	X	X	X	2	X	5		1	1	9	4500	7.2
20	1		X	X		1	X		X			2	3000	2.4
21		1	X			1	X					2	2000	3.6
TOT	1	1	1	1	2	5	6	8	2	1	3	31	49500	1.87

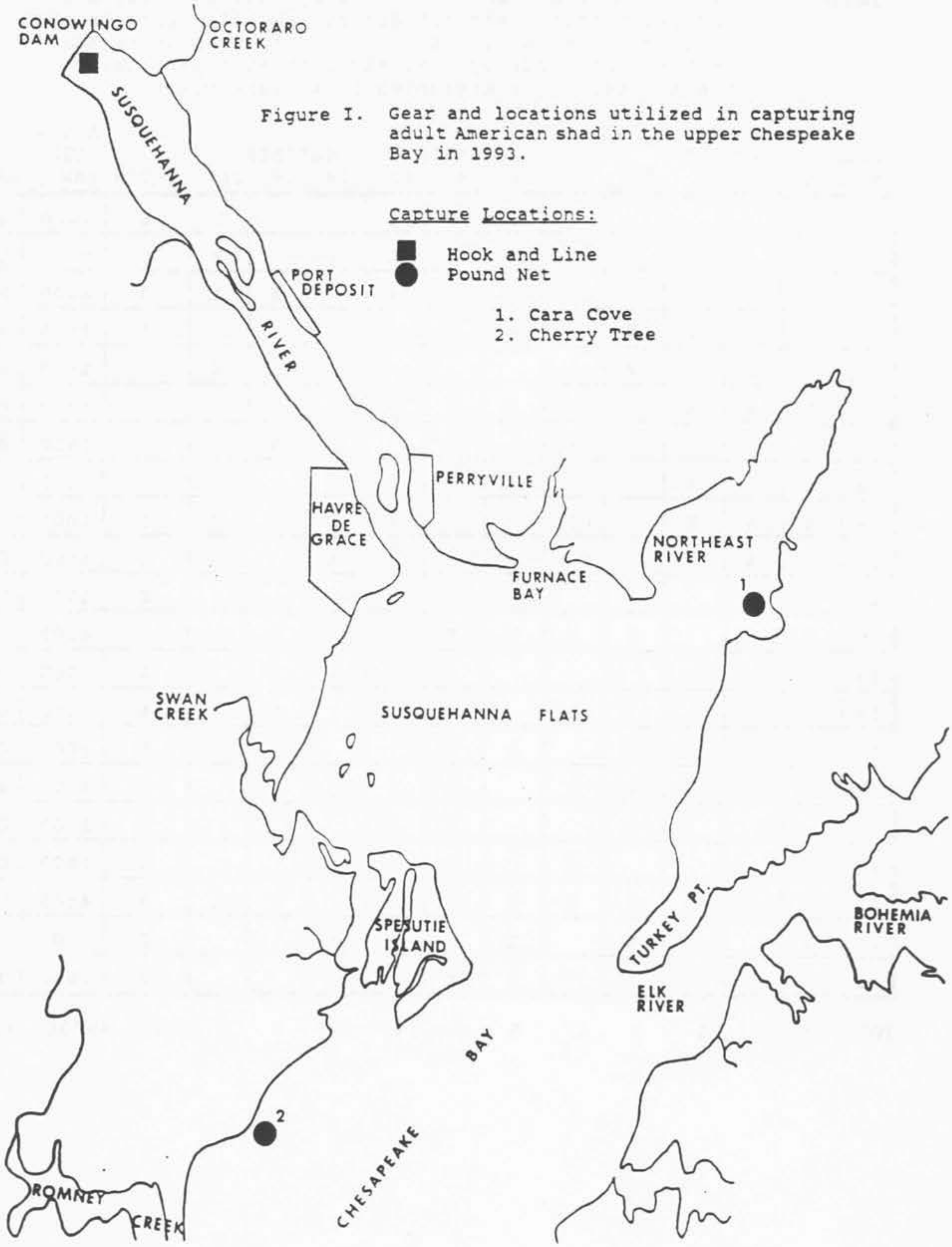


Figure I. Gear and locations utilized in capturing adult American shad in the upper Chespeake Bay in 1993.

Figure II. Upper Chesapeake Bay electrofishing cells sampled during the 1993 juvenile recruitment survey.

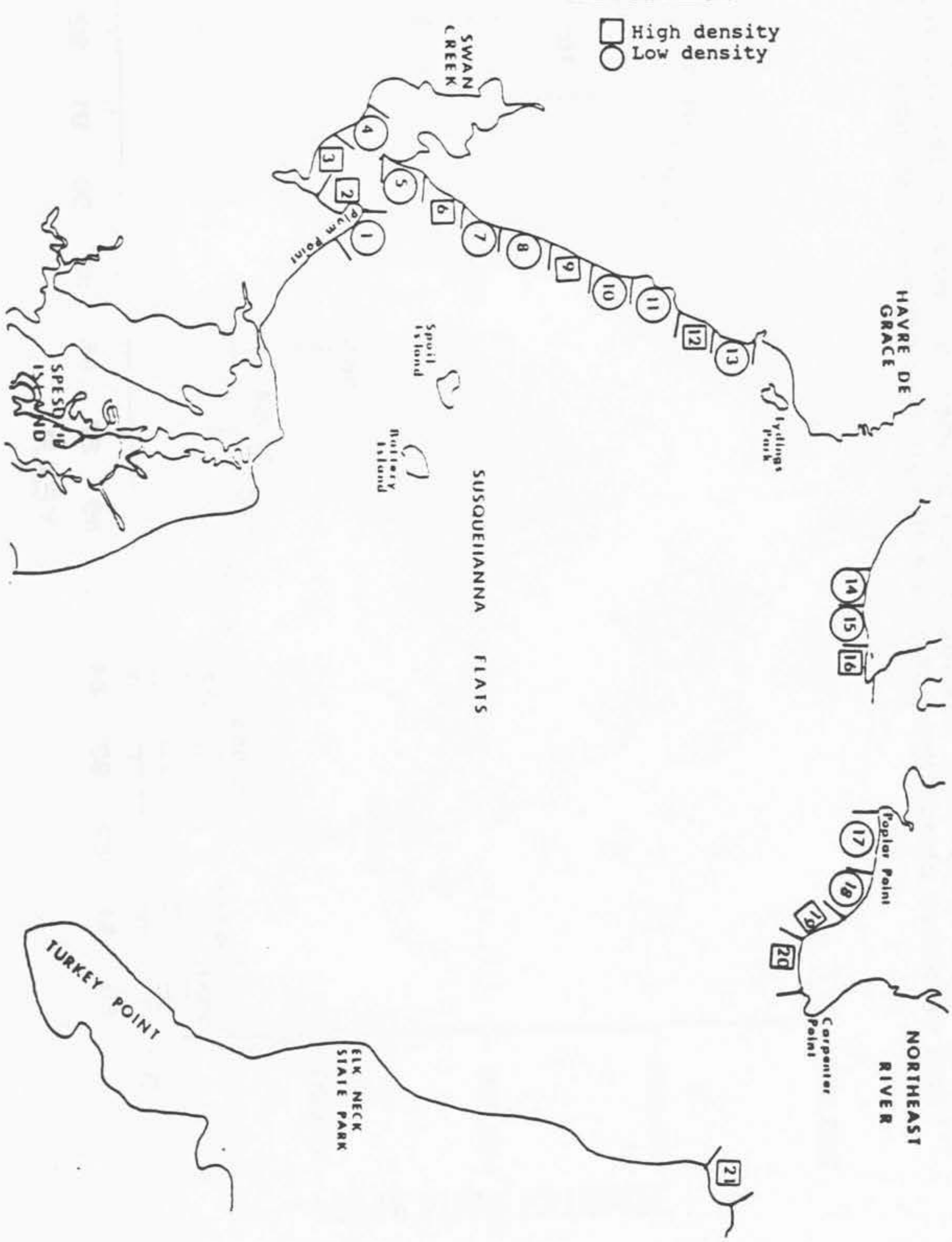
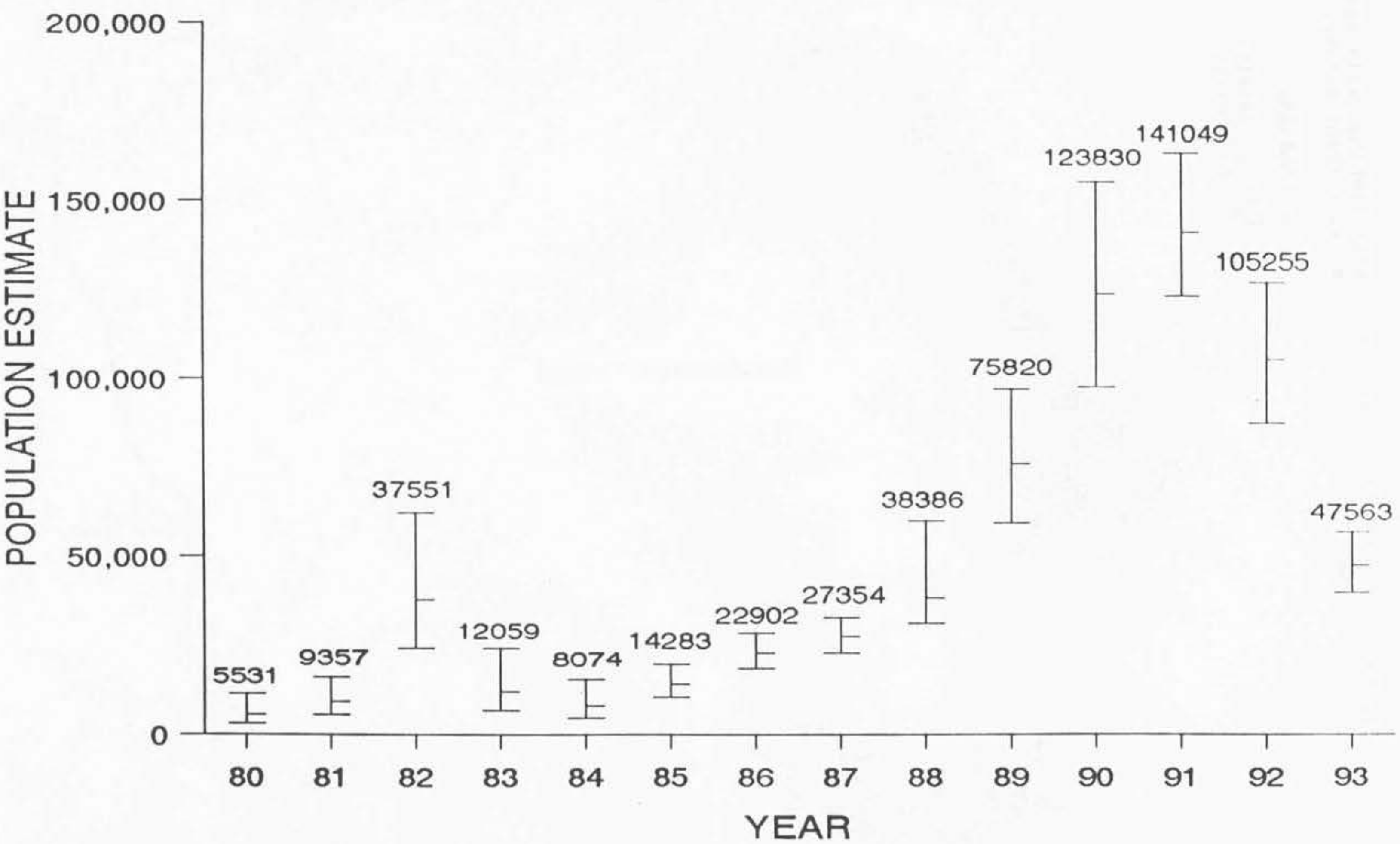


Figure III. Petersen population estimates of adult American shad in the upper Chesapeake Bay, 1980-1993. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.



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