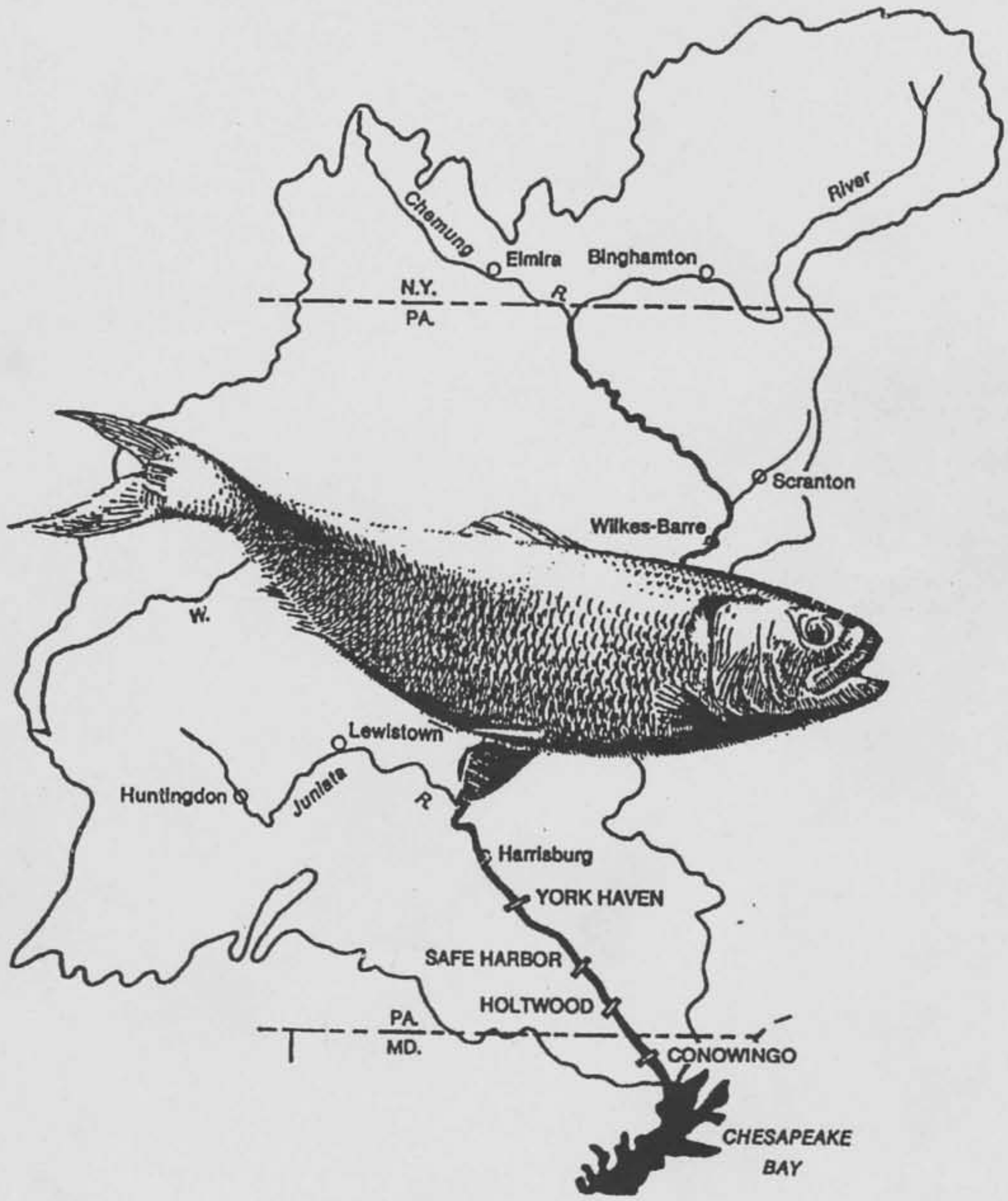
# Restoration of American Shad to the Susequehanna River

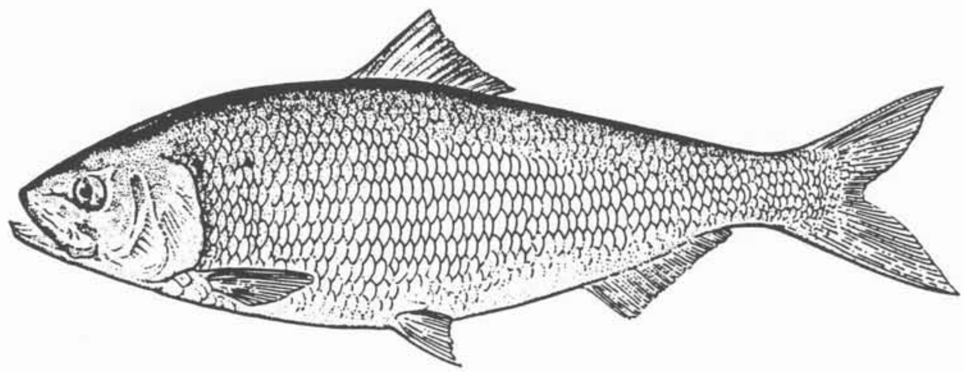
## Annual Progress Report
## 1995




Susquehanna River
Anadromous Fish Restoration Committee

February 1996

# RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



## ANNUAL PROGRESS REPORT

# 1995

## SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE


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


FEBRUARY 1996

## EXECUTIVE SUMMARY

This 1995 Annual Report of the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) presents results from numerous activities and studies directed at restoring American shad to the Susquehanna River. This program, largely funded by hydroelectric project operators, is aimed at rebuilding anadromous shad and herring stocks based on hatchery releases and natural reproduction of adult fish collected at the Conowingo Dam fish lifts and transferred upstream to spawn. Under terms of a 1993 Settlement Agreement with three upstream dam licensees, program funding levels were decreased from prior years and SRAFRC was reorganized to include only state and federal resource agencies and the Susquehanna River Basin Commission. The restoration program represents a continuing commitment among all parties to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1995 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 333,891 fish (Petersen Index). This was based on recapture of 199 marked shad from a tagged population of 1,053 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 but three of the tag returns used in this analysis came from the Conowingo lifts. Estimated stock size in 1995 was the largest recorded since inception of this calculation in 1980. It was 182% larger than in 1994 and a seven-fold increase over 1993. The Conowingo tailrace population estimate for shad in 1995 was also a record at 210,546 fish.

Trapping operations began at both the East and West lifts at Conowingo Dam on 3 April and after 8 April continued daily until 11 June - a total of 68 lift days. Trap operators handled 2,792,000 fish representing 46 taxa. This was considerably more fish than were trapped in 1994, but down from the almost 4 million fish trapped in 1992. Gizzard shad comprised 91% of the total catch. Alosa species included 61,650 American shad, 97,863 blueback herring, 5,575 alewives, and 37 hickory shad.

American shad catch in 1995 was a new high, almost doubling the previous record set in 1994. Blueback herring and alewife numbers were the largest since 1974, reversing a long-term downward trend. Although West lift operations were less than optimal due to the outage of one of the two house units which supplies attraction water, this device accounted for 15,588 American shad, 93,859 bluebacks, 5,405 alewives, and 36 hickory shad. The East lift took 46,062 American shad and all remaining herring. Overall catch per fishing hour for shad at the East lift in 1995 averaged 68.8 fish compared with 51.6 in 1994 and only 19.5 in 1993.

A total of 55,766 American shad was transported to upstream spawning areas with less than 2% observed transport and delayed mortality. Shad were stocked in almost equal numbers at the Tri-County Boat Club above York Haven Dam at Middletown, and at the public boat launch at Columbia. Also, 21,300 river herring (mostly bluebacks) were stocked in mainstem waters above dams and 1,713 alewives were stocked into Muddy Creek and Little Conestoga Creek. Maryland DNR stocked 5,457 bluebacks and 1,951 alewives into the Patapsco River which is undergoing restoration.

Overall sex ratio of shad in lift collections was 1.1 to 1 favoring males. Males ranged in age from III to VII (80% @ IV-V), and females were IV to VII (90% @ V-VI). Based on scale analysis of 598 shad, only 41 (6.9%) were repeat spawners.

Otoliths were successfully examined from 331 adult shad sacrificed at the fish lifts. Of these, 52 (16%) showed wild microstructure and no tetracycline (TC) marks. All remaining samples (84%) were of hatchery origin exhibiting the full range of TC marks including single, double, triple, quadruple, and quintuple immersion treatments. Of all hatchery shad in this collection, 197 (71%) carried triple marks and were most likely of Hudson River egg source. Four otoliths additionally displayed pond-reared fingerling feed tags. A second otolith sample from 114 shad taken in pound nets in the Upper Chesapeake Bay was comprised of 42% wild and 58% hatchery fish. The largest component of the marked cohort (44%) carried double immersion tags, indicating that they were stocked as fry below Conowingo Dam.

The Pennsylvania Fish and Boat Commission (PFBC) operated the intensive shad culture facility at Van Dyke. During the period 4 May to 1 June, 22.61 million shad eggs were delivered to Van Dyke from the Delaware River (10.75 M) and the Hudson River (11.85 M). Overall viability of these eggs was 54%, and production for the Susquehanna amounted to 10.0 million fry. Additionally, Van Dyke stocked 1.04 million Delaware source fry into the Lehigh River.

Most shad produced at Van Dyke in 1995 received a single tetracycline mark on day 5 and were stocked as 7-10 day old larvae into the Juniata River at Thompsontown (1.15 M) and Millerstown (7.19 M), and at Montgomery Ferry on the mainstem (0.73 M). Smaller test lots of between 93,000 and 230,000 fish were either triple or quadruple-tagged and stocked into select tributary waters at 19-22 days of age. Unlike past years, no fingerling shad were reared in ponds in Pennsylvania.

Maryland DNR's Joseph Manning Hatchery received 2.77 million shad eggs from the Delaware and Hudson rivers of which 1.71 million (62%) were viable. A total of 929,000 fry were double TC-marked and stocked at Lapidum below Conowingo Dam in early June. Manning also received 461 adult shad from Conowingo and induced spawning in several tank trials. Ninety-nine females produced 2.7 million fertile eggs and 914,000 larvae. Of these, 308,000 were marked and stocked into the Patuxent River with the remainder being reared to juvenile stage.

As in past years, considerable effort was devoted to assessing relative abundance, growth, instream movements, and source of juvenile shad during summer nursery and autumn outmigration from the river. In 1995, shad were routinely sampled with seines Columbia, PA and several sites were examined above Clarks Ferry and in the upper Juniata River. Lift nets were used to sample shad at Holtwood Dam and cooling water intake strainers and screens at Conowingo and Peach Bottom were examined. Maryland DNR collected shad with electrofisher and seines in the upper Chesapeake Bay.

River flows during summer and early fall were very low generating drought warnings in September. Flows increased substantially by mid-October. Good numbers of shad were collected with seines at Columbia during late July through mid-October and, unlike the past several years, most (87%) were hatchery produced. Outmigration from the river was well documented in Holtwood collections during a 3-week period from mid-October through the first week of November. Analysis of shad otoliths from Holtwood and Peach Bottom collections reaffirmed the dominance of hatchery fish.

Both wild and hatchery shad grew well in the Susquehanna (0.9 mm/day) from an average size (total length) of about 58 mm in late July to 142 mm in late October. Catch per unit effort (CPUE) of juvenile shad with seines at Columbia in 1995 (4.79) was considerably greater than that measured during the prior four years and CPUE with lift nets at Holtwood (21.0) was the highest recorded in the past eleven years. Maryland DNR collected 60 juvenile shad in the upper Chesapeake Bay by electrofisher (24) and seines (36).

A total of 793 juvenile shad from collections at Columbia, Marietta, Holtwood, Peach Bottom, and Conowingo were returned to Benner Spring for tetracycline mark analysis. Otoliths from only 77 fish (9.7%) were unmarked and displayed wild microstructure. This compares to wild fish components of between 39% and 58% in 1992-1994. Eighty percent of fish examined from upper Bay collections were wild compared to 63% in 1994 and 100% in 1993.

Unlike past years, the two hatchery production egg sources (Delaware and Hudson) were not distinctively marked. The 9.07 million single-marked fry stocked upstream produced 87% of all hatchery fish collected during outmigration at Holtwood with a recovery rate of 0.000034 (one in 30,000). Shad stocked in tributaries above Holtwood (Conodoguinet Creek and Conestoga River) comprised only 8.5% of all upstream releases, but 13% of hatchery fish recovered at that site. The overall recapture rate for tributary stockings was 0.000056 (one in 18,000). Most productive among those special stockings was the release of 198,000 fry in the upper Conestoga River with a Holtwood recovery rate of 0.000126 (one in 8,000).

American shad egg collections, hatchery culture and marking in Pennsylvania, and otolith mark analysis were funded from the 1993 settlement agreement with upstream utilities. This source committed $260,000 of which about $252,000 was spent in 1995. The PA Fish and Boat Commission funded juvenile shad net collections above Conowingo Dam. Upstream licensees cooperated with Susquehanna Electric Company (SECO) in separately covering costs associated with Conowingo fish lift operations including collection, sorting, and trucking of shad and herring. SECO and PECO Energy paid for strainer and screen checks for juvenile shad at Conowingo Dam and Peach Bottom. Maryland DNR funded the adult shad population assessment, juvenile shad electrofishing and seining in the upper Chesapeake Bay, and shad culture operations at their Manning hatchery.

Throughout the year, fish passage technical advisory committees for Holtwood, Safe Harbor, and York Haven hydroelectric projects met to discuss fish passage facility development and future evaluation needs at these dams. Construction of fish lifts at Holtwood and Safe Harbor began in 1995 and is expected to be completed by autumn of 1996. York Haven is currently examining an alternative to a powerhouse fish lift - creating a natural passageway for migratory fish using a controlled or gated opening in the East Channel Dam around Three Mile Island.

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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Benner Spring Fish Research Station
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Brian M. Richardson and Steven P. Minkkinen
Maryland Department of Natural Resources
301 Marine Academy Drive
Stevensville, MD 21666



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Maryland Department of Natural Resources
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## JOB I. SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM FISH PASSAGE FACILITIES IN SPRING 1995

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### INTRODUCTION

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

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

Prior to installation and operation of the East lift, SECO had responsibility for funding the trap and transport operations. Completion of the East lift shifted funding responsibility for trap and transport operations to Pennsylvania Power and Light Company, Safe Harbor Water Power Corporation, and Metropolitan Edison Company (collectively termed Upstream Licensees). However, funding for the 1995 operation and maintenance of the East and West lifts remained with SECO.

Objectives of 1995 operation were to: (1) continue to assess the operation of the East lift, (2) continue restoration efforts by the trap and transport of pre-spawned American shad and river herring, (3) monitor species composition and relative abundance of alosids, (4) obtain life history information from selected migratory fishes, (5) assist the Maryland Department of Natural Resources (MD DNR) in assessing the American shad population in the upper Chesapeake Bay, and (6) collect American shad for stock assessment and special studies.

The primary focus of the 1995 report is species targeted for restoration, American shad and river herrings. The report discusses lift operation, catch statistics, and transport of these species. Catch data for most other fishes were collected but are not reported. However, these data are stored on 3½ inch diskette in ASCII format and copies are available upon request from SECO or any of the Upstream Licensees.

## 1.0 METHODS

Personal communications with MD DNR personnel indicated that river herring were present in the upper Chesapeake Bay in March. Four reconnaissance surveys (herring checks) were conducted between 14 and 24 March at Shures Landing below Conowingo Dam, from the bridge over Deer Creek, along Stafford Road south along Deer Creek, and at Octoraro Creek along Route 222. River herring were observed on 24 March at the bridge over Deer Creek. Water temperatures during these surveys varied slightly by area and ranged from 46.6°F to 50.0°F.

Modifications and repairs to both lifts began in the fall of 1994 to ensure efficient and reliable operation during the 1995 season. Preseason work on the East Lift was completed prior to April and included maintenance and repairs of numerous lift components and operating systems. Major tasks undertaken included replacement of the lower hopper sheave blocks and replacement of bearings in the hoist motor, and the addition of a stiffer to spillway gates A and B. In addition, the pneumatic system was inspected and cylinders cleaned, hoses and fittings were inspected and replaced as necessary.

Final preseason preparations to the West lift were completed in late March. Work on the lift included repair of the crowder drive electrical system, installation of a rigging platform to close valves 4 and 5 and repairs to wiring and components in the control and conductor panels.

As in 1994, one of two service units (Service Unit #1), which supplies attraction flow remained inoperable in 1995 due to turbine failure. Attraction water for the West lift was provided from Service Unit #2. Attraction velocities used at the lift were similar to those used in previous years and the volume of attraction water used was at most only 20% less than that used in previous years.

To avoid competition with attraction flow at the West lift, Unit 1 was shut down whenever river flows were less than 65,000 cfs. In 1995, operation of Unit 2 was to be alternated on a daily basis to re-examine the need to shut the unit down as was done in past years. Lift operation was consistent with the 1995 Susquehanna River Technical Committee Work Plan.

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

### 1.1 East and West Lift Operation

Unlike the two previous seasons, natural river flows were low and stable allowing lift operation to commence as scheduled. Half-day lift operation (0700 to 1300 hr) at both lifts occurred from 3 to 7 April and again on 15 April due to small numbers of shad in the catch. Full day lift operation (0700 to 1900 hr) at both lifts commenced on 8 April and continued (except 15 and 16 April) through 11 June. The first American shad was captured at the East lift on 3 April while the West lift captured its first American shad on 8 April. Lift operations were terminated on 11 June.

Work stoppages due to mechanical/electrical failures or maintenance occurred infrequently. The lifts were operated efficiently to maximize the alosid catch. At the East lift outages occurred on 18 and 21 April, totaled 10.5 hours and involved replacement of severed hopper hoses and the re-wrap of the crowder screen hoist cable after the cable reversed on itself. Minor outages occurred at the West lift that involved the crowder or the hopper travel motors. Again, repairs were quickly made and resulted in minimal down time (five hours).

The mechanical aspects of West lift operation in 1995 were similar to that described in RMC (1983), while East lift operation was similar to that described in RMC (1992). Fishing time and/or lift frequency was determined by fish abundance and the time required to process the catch. The hopper was lifted at least hourly throughout the day. Two modifications to normal operation were utilized at both facilities (excepting design differences between the East and West lifts) to reduce the large numbers of gizzard shad and/or common carp attracted to the lifts. First, operation "Fast Fish"[1] (RMC 1986) was employed during periods of high fish density to reduce mechanical delays. Secondly, the weir gate settings were adjusted to increase attraction velocities and operation in the "Fast Fish" mode was continued until fish density was reduced. On rare occasions at the West lift when weir gate modifications proved ineffective, one of the weir gates was closed to prevent overcrowding of fish in the holding channel. As required, mechanical delays at the East lift are reduced by controlling access of fish over the hopper by operation of the crowder screen. Normal lift operation resumed when conditions returned to a level which did not unduly stress the collected fish. These conditions were determined by the lift supervisor.

At the East lift, efforts to improve lift efficiency continued in 1995. Matrix charts, developed during past years, were expanded upon and used during 1995. These matrices contain pond and tailrace elevations, turbine unit operation, and list the various gate settings for efficient lift operation. These settings are changed throughout the day to correspond to changes in hydraulic conditions and fish abundance in an effort to maximize the catch of American shad.

Water velocities at the entrances and within the crowder channel at the East lift were

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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.

maintained to maximize the American shad catch and were within established guidelines. USFWS guidelines recommended water velocities of 0.5 to 1.0 fps in the crowder channel and 3.0 to 8.0 fps at the entrances.

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

Minimum flow releases followed the schedule outlined in the settlement agreement. Minimum flows of 10,000, 7,500 and 5,000 cfs were maintained from 1 through 30 April, 1 through 31 May, and 1 through 11 June, respectively. Generally, units 5 and 6 were used to maintain 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, except for most American shad and some blueback herring, released back to the tailrace. Data (i.e., length, weight, sex, spawning condition, scales and/or otolith) on American shad were taken from those sacrificed, or those that died in handling and transport. Per the 1995 SRTC Work Plan, every 100th shad collected in each Lift was sacrificed to obtain otoliths for stock identification study by the Pennsylvania Fish and Boat Commission (PFBC).

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

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

The primary objective of this project is to trap migratory fish at Conowingo and transport American shad to riverine habitat upstream of the hydroelectric projects on the Susquehanna River. Generally, transport occurred whenever $\geq$ 100 green or gravid shad were collected in a day, or at the supervisor's discretion if fewer shad were collected. As feasible, 5,000 or more river herring were scheduled for transport to Upper Chesapeake Bay tributaries to assist MD DNR with their restoration activities. When possible, river herring were also transported upriver. The primary release site for American shad and river herring was the Tri-County Boat Club Marina (Tri-County) located on the east shore of the Susquehanna River above York Haven Dam (Dauphin County). The PFBC access at Columbia (Lancaster County) was also utilized. Early in the season, the Columbia access was utilized to maximize the number of shad transported based on catch and equipment availability. In addition, late season transport to the Columbia access reduced transport time and stress on fish, particularly during periods of elevated water temperatures (>70°F). The Bainbridge stocking location was utilized one time to release radio tagged American shad for the York Haven telemetry study.

To ensure and enhance transport survival, daily maintenance of all transport equipment was necessary. Due to the record number of shad captured and transported, transport equipment received excessive amounts of wear and tear, particularly that equipment associated with East lift transports. Numerous trailer tires and trailer hitch surge brake bolts were constantly replaced. Trailer brakes and bearings and all trash pumps were serviced on a regular basis. Mechanics from Henkels & McCoy were used on an as needed basis to make repairs to transport equipment that was beyond the scope of routine maintenance, which included replacement of tongues on all trailers.

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

Fish were transported in 1,000 gallon circular truck mounted transfer units from the West lift while those collected at the East lift were transported in 750 gallon circular trailer mounted units. As stated earlier, improvements were made to enhance East lift handling, holding and transport, however, the basic procedures employed at both lifts in 1995 were similar to those used previously (RMC 1986, 1992).

## 2.0 RESULTS

### 2.1 Relative Abundance (East and West Lift)

The relative abundance of fishes at each lift is presented in Table 1. A record number of American shad (61,650) was captured as well as 103,438 river herring (alewife and blueback herring). No new species were collected in 1995 as compared to previous years of operation (RMC 1992).

A combined total of 2,791,907 fish was collected (Table 1). The East lift accounted for 1,796,460 fish of 36 taxa while the West lift collected 995,447 fish of 44 taxa. Some 46,062 and 15,588 American shad were captured at the East and West lifts, respectively. Alosids (American shad, hickory shad, blueback herring, and alewife) comprised 5.9% of the total catch. One hickory shad was captured at the East lift, while 36 were captured at the West lift. Nearly 96% of the river herring were collected at the West lift. Gizzard shad dominated the catch and comprised 91% of the total. Although carp comprised less than 1% of the total combined catch, they were a nuisance species at both lifts during the latter part of the season and interfered with efficient capture and sorting of alosids.

## 2.2 American Shad Catch (East and West Lift)

In 68 days of operation at the East lift, a total of 46,062 American shad was captured (Table 2). The West lift also operated a total of 68 days and captured 15,588 American shad (Table 3). Approximately 90% of the total shad captured were transported. Some 4,478 shad was released back to the tailrace due to advanced maturation of fish, hooking injury, and on a few occasions some were released since all transport equipment and/or holding space was utilized. The remainder consisted of shad released from holding, MD DNR recaptures, holding and lift mortalities, and those sacrificed.

The East lift collected American shad on 3 April it's first day of operation and the West lift collected its first shad on 8 April. About 60% (37,1116 shad) of the shad were collected between 4 May and 25 May. The peak day occurred on 6 May when 2,140 shad were captured at the East lift and the West lift collected 1,578 shad on 12 May. On 10 occasions in May, the East lift captured more than 1,800 American shad in a single day. Some 21.5, 73.4, and 5.1% of the shad catch was collected in April, May, and June.

American shad were collected at water temperatures of 48.2°F to 77.0°F and at natural river flows of 15,600 to 60,400 cfs (Figures 3 and 4). Approximately 59% of the shad were collected at water temperatures <65°F (Table 4). River water temperatures generally were less than 65°F until 16 May.

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

The overall CPE was lower on weekdays (55.3) than on weekends (68.8) (Table 6).

Generally, during both periods, catches were greatest between 1500 and 2000 hr. Some relatively high catch rates were observed prior to 1100 hr for both periods, particularly during minimum flow when discharges ranged from 6,000-10,000 cfs (2 small units operating).

Catch rates were independent of the operation of turbine units 10 and 11 at station discharge of 5,000 to 65,000 cfs (Table 7). The highest average catch rate (135.0) occurred when both large units 10 and 11 were off and generation was between 6,000-10,000 cfs. Catch rates were highest at discharges less than 10,000 cfs and the most shad were captured at this discharge.

**2.3 Sex Ratios (East and West Lifts)**

Sex of American shad was determined by visual macroscopic examination; the resulting data were used to calculate the sex ratios at each lift. The sex ratios are provided in Table 8. Differences in sex ratios between the lifts were minimal and thus were pooled for examining a general trend. Generally, when the daily catch exceeded 100 shad, a minimum subsample of 100 fish per lift was examined; when the daily catch was less than 100 shad all were examined. A total of 11,101 shad was sexed. The combined male/female ratio was 1.1:1. Males comprised 56% of the total catch in April and May and 28% in June.

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

Scale samples of 598 shad were read (Table 9). Males were III to VII years old while females were IV to VII years old. Almost all the males were IV and V years old, while most females were V and VI years old. The 1990 year class was the most abundant year class sampled and comprised 61.5 and 56.5% of the males and females, respectively.

More than 93% of males and females were virgins (Table 9). Of the 359 males, 26 (7.2%) were single repeat spawners while 4 (1.1%) were double repeats. Of the 239 females, 10 (4.1%) were single repeat spawners and one multiple repeat spawner was observed. Overall, repeat spawners comprised 6.8% of the total sample.

Females were larger than males (Table 9). The smallest male measured 295 mm fork length, the smallest female was 321 mm. The average length of males and females were 402 and 454 mm, respectively.

### 2.5 Maryland Tag-Recapture (East and West Lifts)

Including multiple recaptures, 305 MD DNR tagged American shad were recaptured; 191 at the East lift and 114 at the West lift (Table 10). Of the 305 shad recovered, 25 were tagged by MD DNR in previous years. The MD DNR tagged 1,116 shad in 1995; 543 from pound nets in the upper Chesapeake Bay and 573 by hook and line in the Conowingo tailrace. Of the 196 first time verified MD DNR recaptures, 147 were tagged in the tailrace and 49 in the pound nets. The shad averaged 11.9 days free before capture.

### 2.6 Other Alosids (East and West Lifts)

A total of 97,863 blueback herring was collected (Tables 1, 2, and 3). Nearly 96% (93,859) of the blueback herring were captured at the West lift. Of those captured at the East lift, 92% (3,700) were collected on 7 May. Blueback herring were present in West lift catches on 39 of 67 days of operation with the highest catch (39,747) occurring on 6 May. Over 73% (69,117) of the blueback herring were collected at the West lift on 6 and 7 May.

A total of 5,575 alewife was collected, only 170 at the East lift (Tables 1, 2, and 3). Alewife were captured during 19 days of East lift operation and during 25 days of West lift operation. Alewife were captured at water temperatures from 51.8°F to 75.2°F.

The combined catch of river herring (blueback herring, alewife, and hickory shad) from both lifts was 103,475 and was higher than the total catch observed in recent years (RMC 1992, 1993). One hickory shad was captured at the East lift and 36 at the West lift.

### 2.7 Transport of American Shad (East and West Lifts)

Pre-spawned American shad were transported from 8 April through 11 June. Over 91% of the American shad catch was transported to upstream spawning areas with an observed stocking survival of 99.6% (Table 11). A total of 56,370 shad was transported; 37,730 from the East lift, 12,734 from the West lift, and 5,906 in combined transports. Some 27,903 shad were stocked directly to the Susquehanna River at Tri-County Marina. Additionally, 27,803 shad were released at the PFBC Columbia access and 60 shad were stocked at Bainbridge for a radio telemetry study funded by the Upstream Licensees. The MD DNR transported 461 shad to the Manning Hatchery for spawning purposes. In addition, the New Jersey Aquarium acquired 143 shad for use in a public display.

Transportation of shad occurred on 50 and 41 days from the East and West lifts, respectively, while combined transports occurred on 34 days (Table 11). The number of transport trips per day at the East lift ranged from 1 to 12, while West lift transports ranged from 1 to 7 per day. East transport-load size varied from 57 to 140 shad per trip. The load size of transports originating from the West lift ranged from 50 to 202 shad per trip. Transport survival ranged from 99.6 to 100% from the East lift while West lift transport survival ranged from 99.5 to 100%. Shad were transported at water temperatures of 48.2 to 79.0°F.

A total of 5,906 shad was transported upstream in combined transports. The average transport survival for these trips was 99.4%; load size ranged from 50 to 174 shad per trip. More than 56% of the shad from combined transports were released at the Columbia PFBC access.

Holding facilities at both lifts were utilized to reduce stress, maximize transport operations, and release larger schools of fish. A total of 7,410 shad was held over at the East lift with 94 (1.2%) holding mortalities, while 3,318 shad were held over at the West facility with a total of 34 (1.0%) holding mortalities.

### 2.8 River Herring Transport

A total of 29,015 river herring (28.1% of total catch) was transported (Table 12). A total of 21,304 (3,112 alewife and 18,192 blueback herring) were transported and released into the mainstem of the Susquehanna River. Also, some 1,713 alewife were released into Muddy Creek (1,000) and the Little Conestoga Creek (713). Herring were transported between 10 April and 6

June with nearly 100% survival.

The MD DNR transported 1,951 alewife and 5,457 blueback herring to Chesapeake Bay tributaries. All 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 1995. 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 64 days beginning 10 April and continued until after transport ceased from both fish lifts. These efforts resulted in the recovery of 538 dead shad (0.96%) of the total shad transported. When delayed mortalities are included with transport mortalities, the transport survival rate for the season was estimated at 98.6%.

**3.0 DISCUSSION**

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

A record number of American shad (61,650) was captured in 1995. The record catch was due to a combination of factors some of which included an increasing shad population, an increase in the amount of lift operation and record low stable flows in April and May. Over 74% of the total shad catch was collected at the East lift. In 1994, the East lift captured some 86% of the 32,330 shad collected. In previous years (1991 to 1993) 39% to 49% of the season shad catch was captured at the West lift. Although it is not possible to determine the exact cause of the shift in capture rates, West lift efficiency may have been undoubtedly affected by the outage of Service Unit #1 and the resultant reduction in the volume of attraction flow in 1994 and 1995. Even though the volume of attraction flow was reduced it should be noted that the West lift shad catch in 1995 (15,588) was the second highest collected compared to 1990 when a record catch of 15,719 shad was collected. Also, it is anticipated that in 1996 the full volume of attraction water will be available for West lift operation due to completion of the turbine runner installation.

Over 90% of the American shad catch was transported to upstream spawning areas with an overall transport survival rate of 99.6%. Continued improvements to transport procedures combined with modifications to equipment greatly improved efficiency and survival of American shad. Although several improvements were made that enhanced East lift transport operations the trailer units had tire and hitch problems that hampered transport efficiency. These problems have been addressed and are expected to be resolved by post season preventative maintenance and monitoring/lubrication programs to be implemented in 1996.

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Table 1

Comparison of annual catch of fishes at the Conowingo Dam Fish Lifts, 3 April through 11 June, 1995.

| *YEAR* | *1995* | *1995* |
|---|---|---|
| *LOCATION* | *EAST* | *WEST* |
| *NO. OF DAYS* | *68* | *68* |
| *NO. OF LIFTS* | *986* | *1245* |
| *OPERATING TIME (HRS)* | *706.2* | *744.3* |
| *FISHING TIME (HRS)* | *653.3* | *651.9* |
| *NO. OF TAXA* | *36* | *44* |
| American eel | 162 | 204 |
| BLUEBACK HERRING | 4,004 | 93,859 |
| HICKORY SHAD | 1 | 36 |
| ALEWIFE | 170 | 5,405 |
| AMERICAN SHAD | 46,062 | 15,588 |
| GIZZARD SHAD | 1,737,685 | 799,694 |
| Rainbow trout | 10 | 6 |
| Brown trout | 13 | 22 |
| Northern pike | 1 | 2 |
| Common carp | 3,262 | 6,209 |
| Golden shiner | 1 | 87 |
| Comely shiner | 163 | 1,746 |
| Spottail shiner | 37 | 249 |
| Quillback | 2,910 | 981 |
| White sucker | 43 | 105 |
| Shorthead redhorse | 118 | 2,098 |
| Brown bullhead | 2 | 281 |
| Channel catfish | 90 | 2,432 |
| White perch | 528 | 55,719 |
| STRIPED BASS | 505 | 5,467 |
| Rock bass | 2 | 83 |
| Redbreast sunfish | 185 | 1,045 |
| Green sunfish | 2 | 20 |
| Bluegill | 46 | 505 |
| Smallmouth bass | 120 | 362 |
| Largemouth bass | 13 | 174 |
| White crappie | 1 | 33 |
| Tessellated darter | 8 | 5 |
| Yellow perch | 22 | 462 |
| Logperch | 3 | . |
| Walleye | 271 | 1,736 |
| Banded darter | 2 | . |
| Atlantic needlefish | 1 | 1 |
| Sea lamprey | 4 | 7 |
| Striped bass x white bass | 8 | 28 |
| Tiger muskie | 5 | 2 |
| Brook trout | . | 2 |
| Chain pickerel | . | 4 |
| Muskellunge | . | 4 |
| Common shiner | . | 5 |
| Spotfin shiner | . | 279 |
| White catfish | . | 403 |
| Yellow bullhead | . | 16 |
| Pumpkinseed | . | 53 |
| Black crappie | . | 24 |
| Greenside darter | . | 4 |
| TOTAL | 1,796,460 | 995,447 |

Table 2

Daily summary of selected fishes collected at the Conowingo Dam East Lift, 3 April through 11 June, 1995.

| DATE | 3 Apr | 5 Apr | 6 Apr | 7 Apr | 8 Apr | 9 Apr | 10 Apr | 11 Apr | 12 Apr | 13 Apr |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 7 | 8 | 6 | 6 | 11 | 13 | 10 | 13 | 12 | 12 |
| FIRST LIFT | 7:47 | 7:17 | 7:25 | 7:38 | 7:28 | 7:33 | 9:13 | 7:33 | 7:08 | 7:07 |
| LAST LIFT | 12:50 | 13:50 | 13:00 | 12:50 | 18:27 | 18:27 | 18:30 | 18:33 | 18:25 | 18:30 |
| OPERATING TIME (HRS) | 5 | 6.5 | 5.6 | 5.2 | 11 | 10.9 | 9.3 | 11 | 11.3 | 11.4 |
| FISHING TIME (HRS) | 4.6 | 5.9 | 5.1 | 4.8 | 10.3 | 10.5 | 8.6 | 10.6 | 10.7 | 10.5 |
| AVG WATER TEMP (C) | 11.1 | 12 | 11.5 | 10.9 | 11.5 | 12.9 | 12 | 11.5 | 12 | 11.5 |
| BLUEBACK HERRING | | | | | | | | | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | 1 | |
| AMERICAN SHAD | 1 | 5 | 1 | 5 | 524 | 719 | 127 | 32 | 4 | 22 |
| GIZZARD SHAD | 65 | 282 | 555 | 546 | 5,119 | 2,964 | 508 | 2,187 | 1,297 | 8,220 |
| COMMON CARP | | | | | | | | | | 1 |
| STRIPED BASS | | | | | | | | | | |
| OTHER SPP | 8 | 8 | 1 | 3 | 8 | 5 | 23 | 14 | 8 | 24 |
| TOTAL | 74 | 295 | 557 | 554 | 5,651 | 3,688 | 658 | 2,233 | 1,310 | 8,267 |

| DATE | 14 Apr | 15 Apr | 17 Apr | 18 Apr | 19 Apr | 20 Apr | 21 Apr | 22 Apr | 23 Apr | 24 Apr |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 11 | 8 | 11 | 4 | 11 | 15 | 8 | 16 | 13 | 18 |
| FIRST LIFT | 7:28 | 7:03 | 7:38 | 7:38 | 7:13 | 7:03 | 13:28 | 8:03 | 8:17 | 7:25 |
| LAST LIFT | 18:00 | 14:00 | 18:00 | 10:50 | 16:30 | 18:45 | 18:50 | 18:30 | 18:30 | 19:03 |
| OPERATING TIME (HRS) | 10.5 | 7 | 10.4 | 3.2 | 9.3 | 11.7 | 5.4 | 10.5 | 10.2 | 11.6 |
| FISHING TIME (HRS) | 9.8 | 6.4 | 9.6 | 3 | 8.3 | 11 | 5.2 | 9.9 | 9.5 | 10.4 |
| AVG WATER TEMP (C) | 10.6 | 11 | 9 | 10.8 | 12 | 13.1 | 13 | 13.7 | 14.6 | 14.5 |
| BLUEBACK HERRING | | | | | | | | | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | 6 | | 1 | 6 | 2 |
| AMERICAN SHAD | 1 | | 1 | | 1 | 768 | 878 | 1,105 | 936 | 632 |
| GIZZARD SHAD | 998 | 873 | 1,286 | 305 | 2,652 | 19,352 | 9,702 | 11,610 | 31,451 | 13,867 |
| COMMON CARP | | | | | 2 | | | | | 3 |
| STRIPED BASS | | | | | | | | | | 1 |
| OTHER SPP | 19 | 14 | 12 | 25 | 29 | 83 | 9 | 20 | 27 | 67 |
| TOTAL | 1,018 | 887 | 1,299 | 330 | 2,684 | 20,209 | 10,589 | 12,736 | 32,420 | 14,572 |

Table 2

Continued.

| *DATE* | *25 Apr* | *26 Apr* | *27 Apr* | *28 Apr* | *29 Apr* | *30 Apr* | *1 May* | *2 May* | *3 May* | *4 May* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *18* | *16* | *19* | *21* | *18* | *10* | *17* | *13* | *18* | *13* |
| *FIRST LIFT* | *7:33* | *7:17* | *7:17* | *7:43* | *7:00* | *8:25* | *7:43* | *7:08* | *8:42* | *7:28* |
| *LAST LIFT* | *18:53* | *18:45* | *19:30* | *18:32* | *16:45* | *18:45* | *19:05* | *17:55* | *18:45* | *17:30* |
| *OPERATING TIME (HRS)* | *11.3* | *11.5* | *12.2* | *10.8* | *9.8* | *10.3* | *11.4* | *10.8* | *10.1* | *10* |
| *FISHING TIME (HRS)* | *10* | *11* | *11.8* | *9.5* | *9.1* | *10.2* | *10.1* | *9.1* | *8.7* | *9.3* |
| *AVG WATER TEMP (C)* | *15.6* | *15.4* | *15.1* | *15.7* | *16.5* | *16.5* | *16.5* | *16.1* | *16.3* | *16.9* |
| BLUEBACK HERRING | | | | | | 1 | | | 2 | 3 |
| HICKORY SHAD | | | | | 1 | | | | | |
| ALEWIFE | | | | | 4 | 3 | 1 | 1 | | |
| AMERICAN SHAD | 621 | 794 | 771 | 960 | 1,336 | 1,218 | 854 | 992 | 34 | 1,258 |
| GIZZARD SHAD | 11,453 | 27,907 | 28,500 | 177,500 | 281,134 | 1,976 | 119,001 | 41,281 | 19,503 | 20,003 |
| COMMON CARP | | | 1 | | | | 7 | | | |
| STRIPED BASS | | | | | | 2 | | | | |
| OTHER SPP | 48 | 19 | 11 | 52 | 96 | 200 | 102 | 29 | 25 | 31 |
| **TOTAL** | **12,122** | **28,720** | **29,283** | **178,512** | **282,571** | **3,400** | **119,965** | **42,303** | **19,564** | **21,295** |

| *DATE* | *5 May* | *6 May* | *7 May* | *8 May* | *9 May* | *10 May* | *11 May* | *12 May* | *13 May* | *14 May* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *18* | *6* | *8* | *22* | *19* | *11* | *16* | *13* | *12* | *11* |
| *FIRST LIFT* | *7:37* | *7:17* | *8:37* | *8:28* | *7:28* | *8:37* | *8:53* | *7:27* | *7:28* | *8:22* |
| *LAST LIFT* | *18:54* | *17:15* | *18:55* | *19:00* | *18:48* | *18:30* | *18:35* | *19:05* | *19:15* | *18:00* |
| *OPERATING TIME (HRS)* | *11.3* | *10* | *10.3* | *10.5* | *11.3* | *9.9* | *9.7* | *11.6* | *11.8* | *9.6* |
| *FISHING TIME (HRS)* | *10.7* | *9.9* | *10.9* | *8.6* | *10.5* | *9.5* | *9.2* | *11.5* | *11.8* | *9.6* |
| *AVG WATER TEMP (C)* | *16.6* | *17* | *17.4* | *17.8* | *17.3* | *17.2* | *17.8* | *17.5* | *18.6* | *18.5* |
| BLUEBACK HERRING | | 141 | 3,700 | 6 | 5 | 1 | 1 | | 72 | 22 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | 1 | | | | | | | | | |
| AMERICAN SHAD | 1,398 | 2,140 | 1,772 | 632 | 1,468 | 1,590 | 968 | 1,315 | 1,842 | 1,891 |
| GIZZARD SHAD | 144,602 | 48,520 | 20,200 | 28,162 | 9,953 | 11,253 | 27,202 | 13,802 | 19,100 | 19,950 |
| COMMON CARP | 12 | | | 65 | 20 | 6 | 18 | 2 | | 6 |
| STRIPED BASS | 1 | | | 2 | | | 2 | 4 | | |
| OTHER SPP | 50 | 2 | 8 | 132 | 108 | 19 | 90 | 9 | 85 | 140 |
| **TOTAL** | **146,064** | **50,803** | **25,680** | **28,999** | **11,554** | **12,869** | **28,281** | **15,132** | **21,099** | **22,009** |

Table 2

Continued.

| DATE | 15 May | 16 May | 17 May | 18 May | 19 May | 20 May | 21 May | 22 May | 23 May | 24 May |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 21 | 19 | 19 | 19 | 25 | 20 | 15 | 24 | 22 | 18 |
| FIRST LIFT | 7:42 | 7:48 | 7:40 | 7:30 | 7:33 | 7:58 | 7:30 | 7:40 | 7:33 | 7:12 |
| LAST LIFT | 18:56 | 18:55 | 18:35 | 19:42 | 19:00 | 19:20 | 18:42 | 18:25 | 18:45 | 18:55 |
| OPERATING TIME (HRS) | 11.2 | 11.1 | 10.9 | 12.2 | 11.5 | 11.4 | 11.2 | 10.8 | 11.2 | 11.7 |
| FISHING TIME (HRS) | 9.8 | 9.5 | 9.3 | 11.7 | 10 | 11 | 11 | 10.1 | 9.9 | 10.5 |
| AVG WATER TEMP (C) | 19 | 18.8 | 19 | 19 | 19.3 | 19.6 | 19.1 | 20.9 | 20 | 20.6 |
| BLUEBACK HERRING | 4 | 3 | | | | | | 1 | | 2 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | 1 | | | | | 2 | |
| AMERICAN SHAD | 461 | 933 | 733 | 1,238 | 938 | 1,296 | 1,840 | 465 | 890 | 1,018 |
| GIZZARD SHAD | 9,360 | 24,700 | 41,403 | 34,105 | 37,101 | 32,600 | 14,053 | 39,937 | 32,300 | 19,754 |
| COMMON CARP | 205 | 19 | 76 | 80 | 112 | 205 | | 213 | 88 | 10 |
| STRIPED BASS | 1 | 2 | 1 | 21 | 2 | 7 | 12 | 3 | 16 | 16 |
| OTHER SPP | 432 | 34 | 99 | 270 | 275 | 29 | 20 | 266 | 74 | 811 |
| TOTAL | 10,463 | 25,691 | 42,312 | 35,715 | 38,428 | 34,137 | 15,925 | 40,885 | 33,370 | 21,611 |

| DATE | 25 May | 26 May | 27 May | 28 May | 29 May | 30 May | 31 May | 1 Jun | 2 Jun | 3 Jun |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 18 | 21 | 21 | 17 | 21 | 21 | 14 | 15 | 13 | 14 |
| FIRST LIFT | 7:07 | 7:28 | 7:23 | 7:15 | 7:12 | 7:10 | 7:08 | 7:07 | 7:23 | 7:10 |
| LAST LIFT | 18:38 | 18:30 | 18:10 | 18:45 | 18:50 | 18:45 | 18:45 | 18:45 | 18:45 | 18:45 |
| OPERATING TIME (HRS) | 11.5 | 11 | 10.8 | 11.5 | 11.6 | 11.6 | 11.6 | 11.6 | 11.4 | 11.6 |
| FISHING TIME (HRS) | 10.5 | 10.1 | 10.2 | 10.8 | 10.5 | 10.2 | 10.6 | 10.5 | 10.4 | 10.5 |
| AVG WATER TEMP (C) | 21.3 | 21.2 | - | 23.2 | 22.3 | 23 | 22.8 | 22 | 23.6 | 23.3 |
| BLUEBACK HERRING | | 4 | | 1 | | | 9 | | 3 | 10 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | 3 | | 4 | | 1 | 2 | | 2 | | |
| AMERICAN SHAD | 1,020 | 382 | 1,232 | 960 | 772 | 411 | 206 | 344 | 230 | 260 |
| GIZZARD SHAD | 24,730 | 34,051 | 31,100 | 10,050 | 27,800 | 56,410 | 12,909 | 8,028 | 8,270 | 11,095 |
| COMMON CARP | 74 | 29 | 23 | | 68 | 404 | 53 | 30 | 21 | 52 |
| STRIPED BASS | 13 | 18 | 37 | 15 | 23 | 26 | 12 | 21 | 19 | 41 |
| OTHER SPP | 134 | 111 | 58 | 37 | 97 | 54 | 41 | 28 | 32 | 24 |
| TOTAL | 25,974 | 34,595 | 32,454 | 11,063 | 28,761 | 57,307 | 13,230 | 8,453 | 8,575 | 11,482 |

Table 2

Continued.

| DATE | 4 Jun | 5 Jun | 6 Jun | 7 Jun | 8 Jun | 9 Jun | 10 Jun | 11 Jun | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 14 | 14 | 13 | 12 | 12 | 11 | 12 | 9 | 986 |
| FIRST LIFT | 7:07 | 7:23 | 7:23 | 7:07 | 7:07 | 7:28 | 7:03 | 7:39 | - |
| LAST LIFT | 18:45 | 18:45 | 18:45 | 18:45 | 18:30 | 18:30 | 18:30 | 15:30 | - |
| OPERATING TIME (HRS) | 11.6 | 11.4 | 11.4 | 11.6 | 11.4 | 11 | 11.5 | 7.8 | 706.2 |
| FISHING TIME (HRS) | 10.6 | 10.3 | 10.4 | 10.8 | 10.5 | 10.3 | 10.6 | 7.3 | 653.3 |
| AVG WATER TEMP (C) | 23.6 | 23.5 | 24 | 24.6 | 25.5 | 26.1 | 25.8 | 25 | - |
| BLUEBACK HERRING | | 5 | | 8 | | | | | 4,004 |
| HICKORY SHAD | | | | | | | | | 1 |
| ALEWIFE | 128 | | 1 | | | | | | 170 |
| AMERICAN SHAD | 314 | 28 | 64 | 80 | 27 | 57 | 204 | 43 | 46,062 |
| GIZZARD SHAD | 860 | 25,240 | 3,170 | 5,395 | 1,085 | 3,620 | 2,728 | 990 | 1,737,685 |
| COMMON CARP | 280 | 72 | 15 | 618 | 1 | 211 | 62 | 98 | 3,262 |
| STRIPED BASS | 26 | 21 | 31 | 24 | 28 | 28 | 12 | 17 | 505 |
| OTHER SPP | 39 | 7 | 26 | 42 | 18 | 18 | 14 | 18 | 4,771 |
| TOTAL | 1,647 | 25,373 | 3,307 | 6,167 | 1,159 | 3,934 | 3,020 | 1,166 | 1,796,460 |

Table 3

Daily summary of selected fishes collected at the Conowingo Dam West Lift, 3 April through 11 June, 1995.

| *DATE* | *3 Apr* | *5 Apr* | *6 Apr* | *7 Apr* | *8 Apr* | *9 Apr* | *10 Apr* | *11 Apr* | *12 Apr* | *13 Apr* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *7* | *8* | *7* | *7* | *19* | *15* | *12* | *16* | *15* | *18* |
| *FIRST LIFT* | *8:16* | *7:05* | *7:02* | *7:02* | *7:00* | *7:12* | *7:05* | *7:20* | *7:22* | *7:08* |
| *LAST LIFT* | *12:15* | *14:04* | *12:58* | *12:55* | *18:40* | *18:45* | *18:40* | *18:40* | *18:30* | *18:30* |
| *OPERATING TIME (HRS)* | *4* | *7* | *5.9* | *5.9* | *11.7* | *11.6* | *11.6* | *11.3* | *11.1* | *11.4* |
| *FISHING TIME (HRS)* | *3* | *5.8* | *5.5* | *5.4* | *9.9* | *9.9* | *10.7* | *9.3* | *10* | *9.8* |
| *AVG WATER TEMP (C)* | *11.8* | *11.1* | *10* | *11.6* | *11* | *12.2* | *12.2* | *11.9* | *12.5* | *12.2* |
| BLUEBACK HERRING | | | | | | | | | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | 1 | 5 | 1 | 8 | 4 | 2 |
| AMERICAN SHAD | | | | | 25 | 7 | 34 | 13 | 47 | 61 |
| GIZZARD SHAD | 1,001 | 874 | 4,098 | 2,113 | 20,963 | 9,108 | 642 | 15,150 | 1,305 | 8,573 |
| COMMON CARP | 2 | 2 | 1 | 1 | 1 | | 8 | | | 1 |
| STRIPED BASS | | | | | 1 | | 1 | | | |
| OTHER SPP | 131 | 49 | 22 | 17 | 36 | 33 | 119 | 26 | 57 | 113 |
| **TOTAL** | **1,134** | **925** | **4,121** | **2,131** | **21,027** | **9,153** | **805** | **15,197** | **1,413** | **8,750** |

| *DATE* | *14 Apr* | *15 Apr* | *17 Apr* | *18 Apr* | *19 Apr* | *20 Apr* | *21 Apr* | *22 Apr* | *23 Apr* | *24 Apr* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *12* | *10* | *16* | *18* | *13* | *19* | *19* | *29* | *20* | *23* |
| *FIRST LIFT* | *7:00* | *7:00* | *7:00* | *7:00* | *7:00* | *7:05* | *7:00* | *7:00* | *7:00* | *7:02* |
| *LAST LIFT* | *18:00* | *14:05* | *18:00* | *18:00* | *16:30* | *18:25* | *18:50* | *18:50* | *18:48* | *18:50* |
| *OPERATING TIME (HRS)* | *11* | *7.1* | *11* | *11* | *9.5* | *11.3* | *11.8* | *11.8* | *11.8* | *11.8* |
| *FISHING TIME (HRS)* | *10.1* | *6.2* | *9.8* | *9.6* | *8.3* | *9.6* | *10.2* | *9.3* | *10.2* | *10* |
| *AVG WATER TEMP (C)* | *11.1* | *9.8* | *9.8* | *10.6* | *11.9* | *12* | *13* | *14.4* | *14* | *13.8* |
| BLUEBACK HERRING | | | | | | | | | | |
| HICKORY SHAD | | | | | | | | 1 | 23 | 3 |
| ALEWIFE | 3 | 9 | 6 | 1 | 7 | 126 | 387 | 549 | 1,021 | 197 |
| AMERICAN SHAD | 11 | | 14 | 9 | 10 | 40 | 52 | 74 | 51 | 60 |
| GIZZARD SHAD | 4,577 | 2,865 | 6,721 | 9,310 | 24,915 | 46,400 | 13,121 | 60,300 | 47,500 | 17,716 |
| COMMON CARP | 4 | 1 | 1 | 2 | | 5 | | 1 | 1 | 1 |
| STRIPED BASS | | | 1 | | | | 2 | 1 | 10 | 11 |
| OTHER SPP | 40 | 26 | 47 | 31 | 36 | 371 | 186 | 579 | 346 | 404 |
| **TOTAL** | **4,635** | **2,901** | **6,790** | **9,353** | **24,968** | **46,942** | **13,748** | **61,505** | **48,952** | **18,392** |

Table 3

Continued.

| DATE | 25 Apr | 26 Apr | 27 Apr | 28 Apr | 29 Apr | 30 Apr | 1 May | 2 May | 3 May | 4 May |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 21 | 21 | 17 | 14 | 23 | 14 | 13 | 23 | 23 | 24 |
| FIRST LIFT | 7:02 | 7:02 | 7:25 | 7:02 | 7:02 | 8:30 | 7:15 | 7:08 | 7:02 | 7:10 |
| LAST LIFT | 18:45 | 18:40 | 18:15 | 18:40 | 18:20 | 18:30 | 18:15 | 18:45 | 18:55 | 18:45 |
| OPERATING TIME (HRS) | 11.7 | 11.6 | 10.8 | 11.6 | 11.3 | 10 | 11 | 11.6 | 11.9 | 11.6 |
| FISHING TIME (HRS) | 9.8 | 9.2 | 9.3 | 5.4 | 9.3 | 7.2 | 10.2 | 10.8 | 10.9 | 10.1 |
| AVG WATER TEMP (C) | 14.6 | 14.2 | 15.8 | 15.7 | 16 | 13.7 | 15.7 | 16.4 | 15.8 | 15.8 |
| BLUEBACK HERRING | | | | | | 757 | 6,274 | 1,583 | 2,764 | 3,901 |
| HICKORY SHAD | 1 | | | | | 6 | 1 | | 1 | |
| ALEWIFE | 91 | 27 | 77 | 456 | 940 | 95 | 598 | 264 | 530 | |
| AMERICAN SHAD | 148 | 134 | 218 | 178 | 245 | 336 | 293 | 330 | 121 | 275 |
| GIZZARD SHAD | 14,438 | 62,060 | 10,850 | 6,065 | 16,608 | 8,148 | 4,280 | 5,063 | 7,135 | 31,330 |
| COMMON CARP | 4 | 2 | 1 | 1 | | | 1 | | | 2 |
| STRIPED BASS | 8 | 11 | 2 | 13 | 20 | 12 | 12 | 12 | 54 | 3 |
| OTHER SPP | 432 | 191 | 156 | 1,010 | 1,435 | 2,433 | 3,286 | 1,076 | 2,118 | 3,701 |
| TOTAL | 15,122 | 62,425 | 11,304 | 7,723 | 19,248 | 11,787 | 14,745 | 8,328 | 12,723 | 39,212 |

| DATE | 5 May | 6 May | 7 May | 8 May | 9 May | 10 May | 11 May | 12 May | 13 May | 14 May |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 22 | 18 | 11 | 15 | 21 | 26 | 20 | 12 | 20 | 12 |
| FIRST LIFT | 7:10 | 7:05 | 8:15 | 7:15 | 7:10 | 7:05 | 7:10 | 7:02 | 7:21 | 7:30 |
| LAST LIFT | 18:30 | 18:15 | 18:50 | 18:25 | 18:30 | 18:55 | 19:05 | 14:05 | 18:55 | 17:15 |
| OPERATING TIME (HRS) | 11.3 | 11.2 | 10.6 | 11.2 | 11.3 | 11.8 | 11.9 | 7 | 11.6 | 9.8 |
| FISHING TIME (HRS) | 10.6 | 9.5 | 11.2 | 10.4 | 9.9 | 10.2 | 9.5 | 7 | 10.9 | 8.8 |
| AVG WATER TEMP (C) | 16.8 | 16.5 | 16.6 | 17.3 | 17.1 | 17.1 | 18.8 | 17.4 | 17.3 | 17.7 |
| BLUEBACK HERRING | 2,917 | 39,747 | 29,370 | 3,020 | 326 | 10 | 91 | 17 | 93 | 1,323 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | 577 | 553 | 183 | 900 | 605 | 223 | 177 | 1,578 | 839 | 1,099 |
| GIZZARD SHAD | 10,490 | 3,830 | 2,080 | 13,300 | 12,049 | 23,030 | 42,900 | 15,930 | 13,475 | 13,195 |
| COMMON CARP | 1 | | | | 4 | 25 | 2 | 17 | 23 | 9 |
| STRIPED BASS | 65 | 50 | 5 | 53 | 49 | 60 | 30 | 129 | 90 | 47 |
| OTHER SPP | 2,129 | 943 | 2,698 | 4,284 | 2,606 | 2,239 | 5,271 | 3,020 | 4,849 | 2,904 |
| TOTAL | 16,179 | 45,123 | 34,336 | 21,557 | 15,639 | 25,587 | 48,471 | 20,691 | 19,369 | 18,577 |

Table 3

Continued.

| *DATE* | *15 May* | *16 May* | *17 May* | *18 May* | *19 May* | *20 May* | *21 May* | *22 May* | *23 May* | *24 May* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *17* | *24* | *22* | *25* | *25* | *24* | *21* | *18* | *20* | *21* |
| *FIRST LIFT* | *9:35* | *7:10* | *7:00* | *7:00* | *7:07* | *7:24* | *7:17* | *7:00* | *7:07* | *6:57* |
| *LAST LIFT* | *18:50* | *18:48* | *18:50* | *18:53* | *18:55* | *18:55* | *18:56* | *18:45* | *18:55* | *19:00* |
| *OPERATING TIME (HRS)* | *9.3* | *11.6* | *11.8* | *11.9* | *11.8* | *11.5* | *11.7* | *11.8* | *11.8* | *12.1* |
| *FISHING TIME (HRS)* | *10.3* | *9.3* | *10.5* | *9.5* | *10.1* | *10.3* | *9.7* | *10.1* | *10.6* | *11* |
| *AVG WATER TEMP (C)* | *17.8* | *18.8* | *18.6* | *18.7* | *19.2* | *19.2* | *18.5* | *20.4* | *20.4* | *21* |
| BLUEBACK HERRING | 607 | 440 | 97 | 20 | 13 | 13 | 3 | 18 | 72 | 12 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | 417 | 138 | 198 | 50 | 57 | 168 | 136 | 363 | 381 | 889 |
| GIZZARD SHAD | 10,090 | 25,063 | 13,513 | 23,895 | 18,985 | 14,428 | 14,021 | 8,026 | 4,672 | 3,169 |
| COMMON CARP | 7 | 67 | 13 | 69 | 7 | 95 | 97 | 978 | 61 | 151 |
| STRIPED BASS | 503 | 211 | 155 | 163 | 237 | 158 | 112 | 233 | 142 | 118 |
| OTHER SPP | 1,826 | 1,219 | 725 | 2,835 | 1,010 | 581 | 1,429 | 630 | 507 | 374 |
| TOTAL | **13,450** | **27,138** | **14,701** | **27,032** | **20,309** | **15,443** | **15,798** | **10,248** | **5,835** | **4,713** |

| *DATE* | *25 May* | *26 May* | *27 May* | *28 May* | *29 May* | *30 May* | *31 May* | *1 Jun* | *2 Jun* | *3 Jun* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *20* | *22* | *24* | *23* | *27* | *20* | *19* | *21* | *19* | *20* |
| *FIRST LIFT* | *7:20* | *7:13* | *7:00* | *7:15* | *7:00* | *7:12* | *7:00* | *6:59* | *7:00* | *7:02* |
| *LAST LIFT* | *18:40* | *18:45* | *18:55* | *18:45* | *18:55* | *18:50* | *19:00* | *19:00* | *18:45* | *18:55* |
| *OPERATING TIME (HRS)* | *11.3* | *11.5* | *11.9* | *11.5* | *11.9* | *11.6* | *12* | *12* | *11.8* | *11.9* |
| *FISHING TIME (HRS)* | *10.3* | *10.4* | *10.4* | *10* | *10.7* | *10.3* | *10.9* | *10.7* | *10.7* | *10.8* |
| *AVG WATER TEMP (C)* | *20.7* | *21.5* | *21.8* | *20.7* | *21.7* | *22.2* | *22.3* | *22.3* | *22.4* | *23* |
| BLUEBACK HERRING | 60 | 33 | 5 | 15 | 12 | 1 | 2 | 2 | 137 | 21 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | 204 | 129 | 233 | 269 | 291 | 144 | 500 | 361 | 153 | 77 |
| GIZZARD SHAD | 6,993 | 8,215 | 5,408 | 7,387 | 6,781 | 2,142 | 1,107 | 927 | 1,535 | 808 |
| COMMON CARP | 3 | 270 | 3 | | 160 | 586 | 83 | 441 | 1 | 42 |
| STRIPED BASS | 134 | 146 | 148 | 91 | 114 | 335 | 130 | 150 | 287 | 89 |
| OTHER SPP | 1,028 | 909 | 233 | 431 | 310 | 438 | 228 | 234 | 404 | 208 |
| TOTAL | **8,422** | **9,702** | **6,030** | **8,193** | **7,668** | **3,646** | **2,050** | **2,115** | **2,517** | **1,245** |

Table 3

Continued.

| DATE | 4 Jun | 5 Jun | 6 Jun | 7 Jun | 8 Jun | 9 Jun | 10 Jun | 11 Jun | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 20 | 22 | 15 | 18 | 18 | 17 | 17 | 13 | 1245 |
| FIRST LIFT | 7:13 | 7:00 | 7:00 | 6:50 | 7:00 | 7:07 | 7:00 | 7:07 | - |
| LAST LIFT | 18:50 | 19:00 | 18:45 | 18:55 | 18:40 | 18:40 | 18:55 | 15:40 | - |
| OPERATING TIME (HRS) | 11.6 | 12 | 11.8 | 12.1 | 11.7 | 11.6 | 11.9 | 8.6 | 744.3 |
| FISHING TIME (HRS) | 10.7 | 10.5 | 11 | 10.9 | 11 | 10.3 | 10.8 | 7.6 | 651.9 |
| AVG WATER TEMP (C) | 23.3 | 23.8 | 24 | 24.8 | 24.6 | 23.3 | 24.2 | 24.3 | - |
| BLUEBACK HERRING | 16 | 51 | 6 | 10 | | | | | 93,859 |
| HICKORY SHAD | | | | | | | | | 36 |
| ALEWIFE | | | | | | | | | 5,405 |
| AMERICAN SHAD | 266 | 143 | 151 | 36 | 146 | 86 | 31 | 51 | 15,588 |
| GIZZARD SHAD | 2,418 | 2,097 | 1,375 | 520 | 696 | 861 | 632 | 422 | 799,694 |
| COMMON CARP | 510 | 728 | 1 | 52 | 184 | 161 | 150 | 1,165 | 6,209 |
| STRIPED BASS | 61 | 151 | 73 | 150 | 177 | 273 | 102 | 72 | 5,467 |
| OTHER SPP | 648 | 308 | 416 | 690 | 687 | 561 | 312 | 558 | 69,189 |
| TOTAL | 3,919 | 3,478 | 2,022 | 1,458 | 1,890 | 1,942 | 1,227 | 2,268 | 995,447 |

Table 4

Catch of American shad by water temperature at the Conowingo Dam Fish Lifts (East and West), 3 April through 11 June, 1995. Clean-out lifts excluded.

| WATER TEMP. (F) | HOURS FISHING | NUMBER | CATCH/ EFFORT | PERCENT |
|---|---|---|---|---|
| < 65 | 707.42 | 34837 | 49.25 | 58.8 |
| > 65 | 587.57 | 24416 | 41.55 | 41.2 |
| TOTAL | 1294.98 | 59253 | 45.76 | 100 |

Table 5

**Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam East Fish Lift, 1995.**

| Date | | Weir Gates | | | | |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | TOTAL |
| 3 Apr | # Shad | - | | - | 1 | 1 |
| | Hrs Fishing | 1 | | 1.6 | 2 | 4.6 |
| | Catch / Hr Fishing | - | | - | 0.5 | 0.2 |
| 5 Apr | # Shad | - | | - | 5 | 5 |
| | Hrs Fishing | 0.8 | | 2 | 3.1 | 5.9 |
| | Catch / Hr Fishing | - | | - | 1.6 | 0.8 |
| 6 Apr | # Shad | | | | - | - |
| | Hrs Fishing | | | | 5.1 | 5.1 |
| | Catch / Hr Fishing | | | | - | - |
| 7 Apr | # Shad | | | 5 | - | 5 |
| | Hrs Fishing | | | 2 | 2.8 | 4.8 |
| | Catch / Hr Fishing | | | 2.5 | - | 1 |
| 8 Apr | # Shad | 488 | | 1 | 35 | 524 |
| | Hrs Fishing | 5.3 | | 3 | 2 | 10.3 |
| | Catch / Hr Fishing | 92.4 | | 0.3 | 17.6 | 51 |
| 9 Apr | # Shad | 589 | | | 130 | 719 |
| | Hrs Fishing | 8.3 | | | 2.2 | 10.5 |
| | Catch / Hr Fishing | 71.4 | | | 57.8 | 68.5 |
| 10 Apr | # Shad | | | 62 | 64 | 126 |
| | Hrs Fishing | | | 6.5 | 2.1 | 8.6 |
| | Catch / Hr Fishing | | | 9.5 | 30.7 | 14.7 |
| 11 Apr | # Shad | 23 | | 2 | 7 | 32 |
| | Hrs Fishing | 3.7 | | 3.2 | 3.7 | 10.6 |
| | Catch / Hr Fishing | 6.1 | | 0.6 | 1.9 | 3 |
| 12 Apr | # Shad | | | 4 | - | 4 |
| | Hrs Fishing | | | 8.2 | 2.5 | 10.7 |
| | Catch / Hr Fishing | | | 0.5 | - | 0.4 |
| 13 Apr | # Shad | | | 15 | 7 | 22 |
| | Hrs Fishing | | | 6.5 | 4 | 10.5 |
| | Catch / Hr Fishing | | | 2.3 | 1.8 | 2.1 |
| 14 Apr | # Shad | | | 1 | - | 1 |
| | Hrs Fishing | | | 8.8 | 1 | 9.8 |
| | Catch / Hr Fishing | | | 0.1 | - | 0.1 |
| 15 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 4.7 | 1.7 | 6.4 |
| | Catch / Hr Fishing | | | - | - | - |
| 17 Apr | # Shad | | | - | 1 | 1 |
| | Hrs Fishing | | | 7.6 | 2 | 9.6 |
| | Catch / Hr Fishing | | | - | 0.5 | 0.1 |
| 18 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 2 | 1 | 3 |
| | Catch / Hr Fishing | | | - | - | - |
| 19 Apr | # Shad | | | 1 | - | 1 |
| | Hrs Fishing | | | 4.7 | 3.7 | 8.3 |
| | Catch / Hr Fishing | | | 0.2 | - | 0.1 |

Table 5

Continued.

| Date | | Weir Gates | | | | TOTAL |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | |
| 20 Apr | # Shad | 108 | | 308 | 352 | 768 |
| | Hrs Fishing | 0.5 | | 5.1 | 5.4 | 11 |
| | Catch / Hr Fishing | 216 | | 60.2 | 65 | 69.6 |
| 21 Apr | # Shad | 532 | | 202 | 144 | 878 |
| | Hrs Fishing | 2.8 | | 1.8 | 0.6 | 5.2 |
| | Catch / Hr Fishing | 191.1 | | 115.4 | 227.4 | 169.9 |
| 22 Apr | # Shad | | | 888 | 217 | 1105 |
| | Hrs Fishing | | | 6.5 | 3.3 | 9.9 |
| | Catch / Hr Fishing | | | 135.9 | 65.1 | 112 |
| 23 Apr | # Shad | 607 | | | 325 | 932 |
| | Hrs Fishing | 6.4 | | | 3.1 | 9.5 |
| | Catch / Hr Fishing | 94.6 | | | 105.4 | 98.1 |
| 24 Apr | # Shad | 549 | | 14 | 69 | 632 |
| | Hrs Fishing | 4.1 | | 3.2 | 3 | 10.4 |
| | Catch / Hr Fishing | 132.8 | | 4.3 | 23 | 60.9 |
| 25 Apr | # Shad | 418 | | 80 | 120 | 618 |
| | Hrs Fishing | 3.2 | | 4.5 | 2.2 | 10 |
| | Catch / Hr Fishing | 129.9 | | 17.8 | 53.3 | 62 |
| 26 Apr | # Shad | 502 | | 77 | 215 | 794 |
| | Hrs Fishing | 3.5 | | 3.7 | 3.8 | 11 |
| | Catch / Hr Fishing | 143.4 | | 21 | 56.1 | 72.2 |
| 27 Apr | # Shad | 251 | | 128 | 392 | 771 |
| | Hrs Fishing | 2.6 | | 3.7 | 5.5 | 11.8 |
| | Catch / Hr Fishing | 97.2 | | 34.9 | 70.6 | 65.3 |
| 28 Apr | # Shad | | | 542 | 418 | 960 |
| | Hrs Fishing | | | 6.3 | 3.2 | 9.5 |
| | Catch / Hr Fishing | | | 85.6 | 130.6 | 100.7 |
| 29 Apr | # Shad | 798 | | 318 | 220 | 1336 |
| | Hrs Fishing | 3.3 | | 3.9 | 1.9 | 9.1 |
| | Catch / Hr Fishing | 244.3 | | 81.2 | 114.8 | 146.8 |
| 30 Apr | # Shad | 882 | | | 336 | 1218 |
| | Hrs Fishing | 8 | | | 2.2 | 10.2 |
| | Catch / Hr Fishing | 110.7 | | | 152.7 | 119.8 |
| 1 May | # Shad | 436 | | 89 | 329 | 854 |
| | Hrs Fishing | 2.6 | | 4.3 | 3.2 | 10.1 |
| | Catch / Hr Fishing | 168.8 | | 20.7 | 101.2 | 84.3 |
| 2 May | # Shad | 822 | | 115 | 53 | 990 |
| | Hrs Fishing | 3 | | 3.5 | 2.6 | 9.1 |
| | Catch / Hr Fishing | 275.5 | | 32.9 | 20.5 | 109.2 |
| 3 May | # Shad | 3 | | 19 | 12 | 34 |
| | Hrs Fishing | 2.4 | | 3.2 | 3 | 8.7 |
| | Catch / Hr Fishing | 1.2 | | 5.8 | 4 | 3.9 |
| 4 May | # Shad | | | 307 | 951 | 1258 |
| | Hrs Fishing | | | 4.2 | 5 | 9.3 |
| | Catch / Hr Fishing | | | 72.2 | 190.2 | 136 |

Table 5

Continued.

| Date | | Weir Gates | | | | TOTAL |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | |
| 5 May | # Shad | | | 952 | 438 | 1390 |
| | Hrs Fishing | | | 9.2 | 1.6 | 10.7 |
| | Catch / Hr Fishing | | | 104 | 282.6 | 129.9 |
| 6 May | # Shad | 1067 | | | 931 | 1998 |
| | Hrs Fishing | 5.6 | | | 4.3 | 9.9 |
| | Catch / Hr Fishing | 191.7 | | | 214 | 201.5 |
| 7 May | # Shad | 1020 | | | 627 | 1647 |
| | Hrs Fishing | 5.3 | | | 4.9 | 10.3 |
| | Catch / Hr Fishing | 191.2 | | | 127.5 | 160.7 |
| 8 May | # Shad | 207 | | 329 | 77 | 613 |
| | Hrs Fishing | 1.3 | | 6 | 1.3 | 8.6 |
| | Catch / Hr Fishing | 163.4 | | 54.8 | 57.7 | 71.3 |
| 9 May | # Shad | 475 | | 388 | 605 | 1468 |
| | Hrs Fishing | 3.5 | | 2.7 | 4.3 | 10.5 |
| | Catch / Hr Fishing | 135.7 | | 145.5 | 140.7 | 140.3 |
| 10 May | # Shad | 15 | | 368 | 1187 | 1570 |
| | Hrs Fishing | 0.6 | | 3.6 | 5.3 | 9.6 |
| | Catch / Hr Fishing | 23.7 | | 102.7 | 222.6 | 164.4 |
| 11 May | # Shad | 548 | | 35 | 39 | 622 |
| | Hrs Fishing | 3.9 | | 2.5 | 2.7 | 9.2 |
| | Catch / Hr Fishing | 139.3 | | 14 | 14.2 | 67.7 |
| 12 May | # Shad | 383 | | 182 | 647 | 1212 |
| | Hrs Fishing | 4.1 | | 1.3 | 6 | 11.5 |
| | Catch / Hr Fishing | 92.7 | | 136.5 | 107.8 | 105.7 |
| 13 May | # Shad | 1290 | | 113 | 419 | 1822 |
| | Hrs Fishing | 7.9 | | 0.2 | 3.6 | 11.8 |
| | Catch / Hr Fishing | 164 | | 452 | 115.3 | 155.1 |
| 14 May | # Shad | 1354 | | | 504 | 1858 |
| | Hrs Fishing | 6.1 | | | 3.5 | 9.6 |
| | Catch / Hr Fishing | 220.8 | | | 146.1 | 193.9 |
| 15 May | # Shad | 222 | | 40 | 58 | 320 |
| | Hrs Fishing | 3.4 | | 3 | 3.3 | 9.8 |
| | Catch / Hr Fishing | 65.3 | | 13.3 | 17.3 | 32.8 |
| 16 May | # Shad | 628 | | 131 | 174 | 933 |
| | Hrs Fishing | 3.5 | | 3.5 | 2.5 | 9.6 |
| | Catch / Hr Fishing | 179.4 | | 36.9 | 69.6 | 97.7 |
| 17 May | # Shad | 20 | | 540 | 123 | 683 |
| | Hrs Fishing | 0.5 | | 6.8 | 2 | 9.3 |
| | Catch / Hr Fishing | 40 | | 79 | 61.5 | 73.2 |
| 18 May | # Shad | 144 | | 662 | 415 | 1221 |
| | Hrs Fishing | 1.8 | | 6.6 | 3.4 | 11.8 |
| | Catch / Hr Fishing | 82.3 | | 100.1 | 122.7 | 103.9 |
| 19 May | # Shad | 601 | | 119 | 128 | 848 |
| | Hrs Fishing | 2.7 | | 3.7 | 3.7 | 10 |
| | Catch / Hr Fishing | 225.4 | | 32.2 | 34.9 | 84.5 |

Table 5

Continued.

| Date | | Weir Gates | | | | TOTAL |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | |
| 20 May | # Shad | 691 | | 325 | 280 | 1296 |
| | Hrs Fishing | 5 | | 1.8 | 4.2 | 11 |
| | Catch / Hr Fishing | 136.8 | | 182.2 | 67.2 | 117.8 |
| 21 May | # Shad | 758 | | | 1082 | 1840 |
| | Hrs Fishing | 5.6 | | | 5.5 | 11 |
| | Catch / Hr Fishing | 136.6 | | | 197.3 | 166.8 |
| 22 May | # Shad | 44 | | 356 | 65 | 465 |
| | Hrs Fishing | 0.2 | | 6.7 | 3.1 | 10.1 |
| | Catch / Hr Fishing | 176 | | 52.7 | 21.1 | 46.1 |
| 23 May | # Shad | | | 764 | 123 | 887 |
| | Hrs Fishing | | | 8.1 | 1.8 | 9.9 |
| | Catch / Hr Fishing | | | 94.5 | 67.1 | 89.4 |
| 24 May | # Shad | 258 | | 473 | 287 | 1018 |
| | Hrs Fishing | 1.8 | | 5.2 | 3.5 | 10.5 |
| | Catch / Hr Fishing | 140.7 | | 91.5 | 82 | 97 |
| 25 May | # Shad | 317 | | 381 | 322 | 1020 |
| | Hrs Fishing | 2.3 | | 2.8 | 5.4 | 10.5 |
| | Catch / Hr Fishing | 137.8 | | 136.9 | 59.3 | 97 |
| 26 May | # Shad | 98 | | 44 | 240 | 382 |
| | Hrs Fishing | 2.3 | | 3.5 | 4.2 | 10.1 |
| | Catch / Hr Fishing | 42 | | 12.6 | 56.5 | 37.9 |
| 27 May | # Shad | 585 | | 415 | 232 | 1232 |
| | Hrs Fishing | 4.8 | | 3.7 | 1.7 | 10.3 |
| | Catch / Hr Fishing | 121 | | 110.7 | 139.2 | 120.2 |
| 28 May | # Shad | 834 | | | 126 | 960 |
| | Hrs Fishing | 8.7 | | | 2 | 10.8 |
| | Catch / Hr Fishing | 95.9 | | | 61.5 | 89.3 |
| 29 May | # Shad | 313 | | 122 | 337 | 772 |
| | Hrs Fishing | 3.7 | | 3.2 | 3.6 | 10.5 |
| | Catch / Hr Fishing | 85.4 | | 37.5 | 94 | 73.5 |
| 30 May | # Shad | 135 | | 193 | 83 | 411 |
| | Hrs Fishing | 1.8 | | 6.1 | 2.2 | 10.2 |
| | Catch / Hr Fishing | 73.6 | | 31.7 | 36.9 | 40.4 |
| 31 May | # Shad | 31 | | 39 | 136 | 206 |
| | Hrs Fishing | 1 | | 5 | 4.6 | 10.6 |
| | Catch / Hr Fishing | 31 | | 7.8 | 29.7 | 19.5 |
| 1 Jun | # Shad | 164 | | 22 | 158 | 344 |
| | Hrs Fishing | 1.8 | | 1 | 7.7 | 10.5 |
| | Catch / Hr Fishing | 89.5 | | 22 | 20.6 | 32.8 |
| 2 Jun | # Shad | 117 | | 22 | 91 | 230 |
| | Hrs Fishing | 1.6 | | 4 | 4.8 | 10.4 |
| | Catch / Hr Fishing | 73.9 | | 5.5 | 18.8 | 22.1 |
| 3 Jun | # Shad | 118 | | 85 | 57 | 260 |
| | Hrs Fishing | 2.3 | | 6 | 2.2 | 10.5 |
| | Catch / Hr Fishing | 50.6 | | 14.2 | 26.3 | 24.8 |

Table 5

Continued.

| Date | | Weir Gates | | | | TOTAL |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | |
| 4 Jun | # Shad | 240 | | 9 | 65 | 314 |
| | Hrs Fishing | 7.4 | | 0.2 | 3 | 10.6 |
| | Catch / Hr Fishing | 32.4 | | 54 | 21.7 | 29.7 |
| 5 Jun | # Shad | | | 17 | 11 | 28 |
| | Hrs Fishing | | | 4.2 | 6.1 | 10.3 |
| | Catch / Hr Fishing | | | 4 | 1.8 | 2.7 |
| 6 Jun | # Shad | 14 | | 25 | 25 | 64 |
| | Hrs Fishing | 0.9 | | 5 | 4.5 | 10.4 |
| | Catch / Hr Fishing | 15.3 | | 5 | 5.6 | 6.1 |
| 7 Jun | # Shad | 41 | | 14 | 25 | 80 |
| | Hrs Fishing | 3.7 | | 3 | 4 | 10.8 |
| | Catch / Hr Fishing | 10.9 | | 4.7 | 6.2 | 7.4 |
| 8 Jun | # Shad | 10 | | - | 17 | 27 |
| | Hrs Fishing | 3.5 | | 1 | 6 | 10.5 |
| | Catch / Hr Fishing | 2.9 | | - | 2.8 | 2.6 |
| 9 Jun | # Shad | 12 | | 8 | 37 | 57 |
| | Hrs Fishing | 3.1 | | 2 | 5.2 | 10.3 |
| | Catch / Hr Fishing | 3.9 | | 4 | 7.2 | 5.6 |
| 10 Jun | # Shad | 107 | | | 97 | 204 |
| | Hrs Fishing | 6.6 | | | 4 | 10.6 |
| | Catch / Hr Fishing | 16.3 | | | 24.3 | 19.3 |
| 11 Jun | # Shad | 38 | | | 5 | 43 |
| | Hrs Fishing | 5.7 | | | 1.6 | 7.3 |
| | Catch / Hr Fishing | 6.6 | | | 3.2 | 5.9 |
| **TOTAL** | **# Shad*** | **19907** | | **10351** | **14676** | **44934** |
| | **Hrs Fishing** | **185.8** | | **236.4** | **230.5** | **652.7** |
| | **Catch / Hr Fishing** | **107.2** | | **43.8** | **63.7** | **68.8** |

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

Table 6

Comparison of catch per effort (hr) of American shad on weekdays versus weekend days by generation (cfs) at the Conowingo Dam East Fish Lift, 3 April through 11 June 1995.

| | | CATCH/HOUR | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | LIFT TIME | 5,000 CFS | 6-10,000 CFS | 11-20,000 CFS | 21-40,000 CFS | > 40,000 CFS | VARYING CFS | CATCH/HOUR |
| WEEKDAYS | 07:00-11:00 | 20.8 | 102.8 | 27.0 | 57.5 | 8.4 | 39.3 | 29.6 |
| WEEKDAYS | 11:01-15:00 | - | 57.4 | 95.2 | 42.2 | 36.6 | 37.7 | 46.9 |
| WEEKDAYS | 15:01-19:00 | 73.9 | 177.0 | 111.6 | 101.2 | 37.9 | 86.5 | 99.5 |
| MEAN | | **26.6** | **144.7** | **70.7** | **63.4** | **27.2** | **54.6** | **55.3** |
| WEEKEND | 07:00-11:00 | 21.5 | 114.7 | 142.9 | 14.9 | 31.3 | 19.3 | 78.4 |
| WEEKEND | 11:01-15:00 | 33.8 | 136.5 | 93.0 | 97.0 | 67.1 | 73.8 | 107.0 |
| WEEKEND | 15:01-19:00 | 49.7 | 142.2 | 78.2 | 108.4 | 4087.5 | 129.5 | 129.7 |
| MEAN | | 26.3 | 129.7 | 105.1 | 85.2 | 97.0 | 74.0 | 102.0 |
| TOTAL | | **26.4** | **135.0** | **79.7** | **70.9** | **31.0** | **57.6** | **68.8** |

Table 7

**Summary of American shad catch by constant generation levels (varying generation during a lift was grouped separately) at the Conowingo Dam East Fish Lift, 3 April through 11 June 1995.**

| Total Discharge | Unit 11 | Unit 10 | Number of Lifts | Time (hours) | Total Shad | Shad/Hour |
|---|---|---|---|---|---|---|
| 5,000 cfs | OFF | OFF | 43 | 34.1 | 901 | 26.4 |
| **TOTAL** | | | **43** | **34.1** | **901** | **26.4** |
| 6-10,000 cfs | OFF | OFF | 171 | 133.9 | 18,071 | 135.0 |
| **TOTAL** | | | **171** | **133.9** | **18,071** | **135.0** |
| 11-20,000 cfs | CHG | OFF | 2 | 1.2 | 117 | 98.9 |
| 11-20,000 cfs | OFF | OFF | 59 | 46.5 | 5,019 | 108.0 |
| **TOTAL** | | | **61** | **47.7** | **5,136** | **107.7** |
| 21-40,000 cfs | OFF | OFF | 76 | 43.9 | 3,286 | 74.8 |
| 21-40,000 cfs | ON | OFF | 70 | 42.3 | 3,356 | 79.4 |
| 21-40,000 cfs | ON | ON | 1 | 0.2 | 113 | 452.0 |
| **TOTAL** | | | **147** | **86.5** | **6,755** | **78.1** |
| > 40,000 cfs | CHG | CHG | 1 | 0.5 | 18 | 36.0 |
| > 40,000 cfs | CHG | OFF | 1 | 1.0 | 27 | 27.0 |
| > 40,000 cfs | ON | OFF | 32 | 14.8 | 1,434 | 96.7 |
| > 40,000 cfs | ON | ON | 267 | 185.9 | 4,781 | 25.7 |
| **TOTAL** | | | **301** | **202.2** | **6,260** | **31.0** |
| VARYING | CHG | CHG | 47 | 37.7 | 1,469 | 38.9 |
| VARYING | CHG | OFF | 38 | 27.6 | 1,970 | 71.3 |
| VARYING | OFF | CHG | 1 | 0.5 | - | - |
| VARYING | OFF | OFF | 54 | 38.7 | 3,164 | 81.8 |
| VARYING | ON | CHG | 35 | 26.7 | 739 | 27.7 |
| VARYING | ON | OFF | 5 | 3.9 | 158 | 40.7 |
| VARYING | ON | ON | 15 | 13.4 | 311 | 23.2 |
| **TOTAL** | | | **195** | **148.5** | **7,811** | **52.6** |
| **GRAND TOTAL** | | | **918** | **652.7** | **44,934** | **68.8** |

Table 8

Daily sex ratio of American shad at the Conowingo Dam Fish Lifts for 1995.

| Date | Daily Catch | Sexed | No. of Males | No. of Females | Ratio (M/F) | Date | Daily Catch | Sexed | No. of Males | No. of Females | Ratio (M/F) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 Apr | 1 | 1 | 1 | 0 | - to 1 | 9 May | 2,073 | 217 | 125 | 92 | 1.4 to 1 |
| 5 Apr | 5 | 5 | 4 | 1 | 4 to 1 | 10 May | 1,813 | 206 | 126 | 80 | 1.6 to 1 |
| 6 Apr | 1 | 2 | 2 | 0 | - to 1 | 11 May | 1,145 | 203 | 120 | 83 | 1.4 to 1 |
| 7 Apr | 5 | 6 | 6 | 0 | - to 1 | 12 May | 2,893 | 250 | 139 | 111 | 1.3 to 1 |
| 8 Apr | 549 | 130 | 98 | 32 | 3.1 to 1 | 13 May | 2,681 | 234 | 127 | 107 | 1.2 to 1 |
| 9 Apr | 726 | 107 | 70 | 37 | 1.9 to 1 | 14 May | 2,990 | 201 | 96 | 105 | 0.9 to 1 |
| 10 Apr | 161 | 133 | 97 | 36 | 2.7 to 1 | 15 May | 878 | 223 | 108 | 115 | 0.9 to 1 |
| 11 Apr | 45 | 44 | 26 | 18 | 1.4 to 1 | 16 May | 1,071 | 200 | 121 | 79 | 1.5 to 1 |
| 12 Apr | 51 | 51 | 34 | 17 | 2 to 1 | 17 May | 931 | 212 | 109 | 103 | 1.1 to 1 |
| 13 Apr | 83 | 83 | 50 | 33 | 1.5 to 1 | 18 May | 1,288 | 170 | 89 | 81 | 1.1 to 1 |
| 14 Apr | 12 | 11 | 9 | 2 | 4.5 to 1 | 19 May | 995 | 157 | 86 | 71 | 1.2 to 1 |
| 15 Apr | 0 | 0 | 0 | 0 | - to 1 | 20 May | 1,464 | 212 | 106 | 106 | 1 to 1 |
| 17 Apr | 15 | 15 | 13 | 2 | 6.5 to 1 | 21 May | 1,976 | 205 | 82 | 123 | 0.7 to 1 |
| 18 Apr | 9 | 9 | 6 | 3 | 2 to 1 | 22 May | 828 | 226 | 113 | 113 | 1 to 1 |
| 19 Apr | 11 | 11 | 10 | 1 | 10 to 1 | 23 May | 1,271 | 248 | 81 | 167 | 0.5 to 1 |
| 20 Apr | 808 | 140 | 92 | 48 | 1.9 to 1 | 24 May | 1,907 | 287 | 91 | 196 | 0.5 to 1 |
| 21 Apr | 930 | 152 | 119 | 33 | 3.6 to 1 | 25 May | 1,224 | 211 | 73 | 138 | 0.5 to 1 |
| 22 Apr | 1,179 | 174 | 117 | 57 | 2.1 to 1 | 26 May | 511 | 212 | 81 | 131 | 0.6 to 1 |
| 23 Apr | 987 | 151 | 109 | 42 | 2.6 to 1 | 27 May | 1,465 | 203 | 63 | 140 | 0.5 to 1 |
| 24 Apr | 692 | 161 | 112 | 49 | 2.3 to 1 | 28 May | 1,229 | 200 | 71 | 129 | 0.6 to 1 |
| 25 Apr | 769 | 220 | 169 | 51 | 3.3 to 1 | 29 May | 1,063 | 205 | 45 | 160 | 0.3 to 1 |
| 26 Apr | 928 | 204 | 149 | 55 | 2.7 to 1 | 30 May | 555 | 207 | 77 | 130 | 0.6 to 1 |
| 27 Apr | 989 | 207 | 161 | 46 | 3.5 to 1 | 31 May | 706 | 301 | 85 | 216 | 0.4 to 1 |
| 28 Apr | 1,138 | 236 | 181 | 55 | 3.3 to 1 | 1 Jun | 705 | 242 | 71 | 171 | 0.4 to 1 |
| 29 Apr | 1,581 | 234 | 155 | 79 | 2 to 1 | 2 Jun | 383 | 200 | 71 | 129 | 0.6 to 1 |
| 30 Apr | 1,554 | 246 | 150 | 96 | 1.6 to 1 | 3 Jun | 337 | 177 | 40 | 137 | 0.3 to 1 |
| 1 May | 1,147 | 209 | 148 | 61 | 2.4 to 1 | 4 Jun | 580 | 200 | 68 | 132 | 0.5 to 1 |
| 2 May | 1,322 | 216 | 161 | 55 | 2.9 to 1 | 5 Jun | 171 | 132 | 45 | 87 | 0.5 to 1 |
| 3 May | 155 | 136 | 104 | 32 | 3.2 to 1 | 6 Jun | 215 | 190 | 56 | 134 | 0.4 to 1 |
| 4 May | 1,533 | 205 | 138 | 67 | 2.1 to 1 | 7 Jun | 116 | 116 | 29 | 87 | 0.3 to 1 |
| 5 May | 1,975 | 209 | 139 | 70 | 2 to 1 | 8 Jun | 173 | 164 | 40 | 124 | 0.3 to 1 |
| 6 May | 2,693 | 203 | 130 | 73 | 1.8 to 1 | 9 Jun | 143 | 143 | 34 | 109 | 0.3 to 1 |
| 7 May | 1,955 | 200 | 106 | 94 | 1.1 to 1 | 10 Jun | 235 | 131 | 30 | 101 | 0.3 to 1 |
| 8 May | 1,532 | 213 | 116 | 97 | 1.2 to 1 | 11 Jun | 94 | 92 | 22 | 70 | 0.3 to 1 |
| | | | | | | TOTAL | 61,650 | 11,101 | 5,702 | 5,399 | |

Table 9

**Age and spawning history of American shad collected and sacrificed at the Conowingo Dam Fish Lifts in 1995.**

| | | | Spawning History | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Repeats | Repeats | Fork Length (mm) | | |
| Sex | Age | N | Virgins | Once | Twice | Mean | Min | Max |
| Male | III | 9 | 9 | - | - | 341 | 295 | 362 |
| | IV | 59 | 59 | - | - | 373 | 328 | 424 |
| | V | 221 | 205 | 13 | 3 | 403 | 344 | 448 |
| | VI | 67 | 54 | 12 | 1 | 431 | 385 | 495 |
| | VII | 3 | 2 | 1 | - | 474 | 453 | 488 |
| | **TOTAL** | **359** | **329** | **26** | **4** | **402** | **295** | **495** |
| Female | IV | 7 | 7 | - | - | 412 | 381 | 437 |
| | V | 135 | 132 | 3 | - | 443 | 321 | 490 |
| | VI | 81 | 73 | 7 | 1 | 467 | 430 | 519 |
| | VII | 16 | 16 | - | - | 510 | 451 | 558 |
| | **TOTAL** | **239** | **228** | **10** | **1** | **454** | **321** | **558** |
| **GRAND TOTAL** | | **598** | **557** | **36** | **5** | **423** | **295** | **558** |

Table 10

Summary of American shad tagged by Maryland DNR and recaptured at the Conowingo Fish Lifts, 1995.

| | DAILY CATCH | | NUMBER OF MD DNR RECAPTURES | | | DAILY CATCH | | NUMBER OF MD DNR RECAPTURES | |
|---|---|---|---|---|---|---|---|---|---|
| DATE | EAST | WEST | EAST | WEST | DATE | EAST | WEST | EAST | WEST |
| 3 Apr | 1 | 0 | - | - | 9 May | 1,468 | 605 | 6 | 1 |
| 5 Apr | 5 | 0 | - | - | 10 May | 1,590 | 223 | 8 | 1 |
| 6 Apr | 1 | 0 | - | - | 11 May | 968 | 177 | 2 | 2 |
| 7 Apr | 5 | 0 | - | - | 12 May | 1,315 | 1,578 | 5 | 10 |
| 8 Apr | 524 | 25 | - | - | 13 May | 1,842 | 839 | 11 | 7 |
| 9 Apr | 719 | 7 | - | - | 14 May | 1,891 | 1,099 | 6 | 4 |
| 10 Apr | 127 | 34 | - | - | 15 May | 461 | 417 | 2 | 1 |
| 11 Apr | 32 | 13 | - | - | 16 May | 933 | 138 | 3 | 2 |
| 12 Apr | 4 | 47 | - | - | 17 May | 733 | 198 | 8 | 3 |
| 13 Apr | 22 | 61 | - | - | 18 May | 1,238 | 50 | 4 | 1 |
| 14 Apr | 1 | 11 | - | - | 19 May | 938 | 57 | 4 | - |
| 15 Apr | 0 | 0 | - | - | 20 May | 1,296 | 168 | 8 | 1 |
| 17 Apr | 1 | 14 | - | - | 21 May | 1,840 | 136 | 11 | 1 |
| 18 Apr | 0 | 9 | - | - | 22 May | 465 | 363 | 3 | 3 |
| 19 Apr | 1 | 10 | - | - | 23 May | 890 | 381 | 6 | 2 |
| 20 Apr | 768 | 40 | - | - | 24 May | 1,018 | 889 | 6 | 8 |
| 21 Apr | 878 | 52 | 1 | - | 25 May | 1,020 | 204 | 9 | 1 |
| 22 Apr | 1,105 | 74 | - | - | 26 May | 382 | 129 | 1 | 1 |
| 23 Apr | 936 | 51 | 1 | - | 27 May | 1,232 | 233 | 14 | 8 |
| 24 Apr | 632 | 60 | 1 | - | 28 May | 960 | 269 | 7 | 6 |
| 25 Apr | 621 | 148 | - | 1 | 29 May | 772 | 291 | 9 | 4 |
| 26 Apr | 794 | 134 | 3 | - | 30 May | 411 | 144 | 10 | 1 |
| 27 Apr | 771 | 218 | 2 | - | 31 May | 206 | 500 | 1 | 8 |
| 28 Apr | 960 | 178 | 1 | - | 1 Jun | 344 | 361 | 2 | 7 |
| 29 Apr | 1,336 | 245 | 1 | - | 2 Jun | 230 | 153 | 2 | 2 |
| 30 Apr | 1,218 | 336 | 5 | - | 3 Jun | 260 | 77 | 1 | 2 |
| 1 May | 854 | 293 | 2 | - | 4 Jun | 314 | 266 | 2 | 5 |
| 2 May | 992 | 330 | 1 | - | 5 Jun | 28 | 143 | - | 4 |
| 3 May | 34 | 121 | - | 2 | 6 Jun | 64 | 151 | - | 2 |
| 4 May | 1,258 | 275 | 3 | 3 | 7 Jun | 80 | 36 | - | - |
| 5 May | 1,398 | 577 | 4 | 2 | 8 Jun | 27 | 146 | - | 1 |
| 6 May | 2,140 | 553 | 5 | 3 | 9 Jun | 57 | 86 | - | - |
| 7 May | 1,772 | 183 | 5 | 1 | 10 Jun | 204 | 31 | 1 | - |
| 8 May | 632 | 900 | 4 | 3 | 11 Jun | 43 | 51 | - | - |
| | | | | | TOTAL | 46,062 | 15,588 | 191 | 114 |

Table 11

Summary of American shad transported from the Conowingo Dam Fish Lifts, 1995.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from both locations* | | | | | |
| 10 Apr | - | 12.8 | 128 | Tri-County Marina | 0 | 100 | 9.2 | 12.4 | 13 |
| 11 Apr | - | 12 | 90 | Tri-County Marina | 0 | 100 | 12 | 13.5 | 12 |
| 13 Apr | - | 11.2 | 123 | Tri-County Marina | 0 | 100 | 13 | 12.6 | 12 |
| 20 Apr | - | 13.5 | 124 | Tri-County Marina | 3 | 97.6 | 12 | 13 | 14 |
| 22 Apr | - | 17 | 132 | Columbia PFC | 0 | 100 | 10 | 11.8 | 16.2 |
| 26 Apr | - | 15.8 | 141 | Tri-County Marina | 0 | 100 | 12.4 | 12.5 | 16.3 |
| 26 Apr | - | 16 | 113 | Tri-County Marina | 0 | 100 | 12.6 | 12 | 16.5 |
| 27 Apr | - | 15.6 | 125 | Tri-County Marina | 0 | 100 | 12.3 | 12.2 | 15.9 |
| 28 Apr | - | 14.2 | 129 | Columbia PFC | 0 | 100 | 12.6 | 12.5 | 14.8 |
| 4 May | - | 15.9 | 93 | Tri-County Marina | 0 | 100 | 12.6 | 9.6 | 13.9 |
| 5 May | - | 15.1 | 99 | Tri-County Marina | 0 | 100 | 9 | 8.3 | 14 |
| 8 May | - | 17.5 | 96 | Tri-County Marina | 0 | 100 | 13 | 10 | 18.2 |
| 11 May | - | 18.2 | 92 | Tri-County Marina | 0 | 100 | 15.2 | 10 | 17.1 |
| 14 May | - | 17.5 | 140 | Columbia PFC | 0 | 100 | 13.2 | 14.2 | 17.5 |
| 15 May | - | 19.6 | 80 | Tri-County Marina | 0 | 100 | 11.8 | 9.6 | 19 |
| 15 May | - | 20 | 131 | Tri-County Marina | 0 | 100 | 9.6 | 7 | 18.2 |
| 16 May | - | 18.2 | 139 | Columbia PFC | 1 | 99.3 | 11.6 | 9.1 | 18.2 |
| 16 May | - | 19.1 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 9.9 | 19.2 |
| 16 May | - | 19 | 125 | Tri-County Marina | 0 | 100 | 11.8 | 10.2 | 19.5 |
| 17 May | - | 19 | 132 | Tri-County Marina | 1 | 99.2 | 11.8 | 7.5 | 18.8 |
| 18 May | - | 20 | 174 | Columbia PFC | 2 | 98.9 | 11 | 9.5 | 19 |
| 19 May | - | 16.5 | 108 | Columbia PFC | 1 | 99.1 | 12.4 | 8.8 | 15.7 |
| 19 May | - | 16 | 124 | Tri-County Marina | 0 | 100 | 11.4 | 9.8 | 15.5 |
| 20 May | - | 19.2 | 136 | Columbia PFC | 0 | 100 | 11.2 | 6.9 | 17.9 |
| 22 May | - | 21 | 125 | Columbia PFC | 0 | 100 | 12.8 | 9.3 | 20.2 |
| 22 May | - | 20.5 | 91 | Columbia PFC | 0 | 100 | 11 | 9 | 20.5 |
| 22 May | - | 21.2 | 91 | Tri-County Marina | 0 | 100 | 12.8 | 8.2 | 21 |
| 22 May | - | 21 | 123 | Tri-County Marina | 5 | 95.9 | 11.2 | 8 | 20.5 |
| 23 May | - | 21 | 118 | Tri-County Marina | 0 | 100 | 12.2 | 9.3 | 22 |
| 23 May | - | 21 | 122 | Tri-County Marina | 2 | 98.4 | 10.8 | 9.8 | 22 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from both locations, continued.* | | | | | |
| 25 May | - | 20.2 | 125 | Columbia PFC | 0 | 100 | 10 | 8.6 | 22.3 |
| 25 May | - | 22.5 | 115 | Columbia PFC | 0 | 100 | 13.5 | 6.5 | 23 |
| 25 May | - | 22.2 | 50 | Columbia PFC | 0 | 100 | 12 | 7.8 | 23 |
| 26 May | - | 22.3 | 132 | Columbia PFC | 0 | 100 | 11.6 | 7.8 | 22.3 |
| 27 May | - | 22.3 | 125 | Columbia PFC | 0 | 100 | 13.2 | 9.6 | 21.8 |
| 27 May | - | 23.5 | 109 | Tri-County Marina | 0 | 100 | 10.6 | 7.8 | 24 |
| 27 May | - | 21.2 | 110 | Columbia PFC | 0 | 100 | 10 | 8.2 | 22 |
| 30 May | - | 22.3 | 105 | Columbia PFC | 0 | 100 | 13.8 | 8 | 20.3 |
| 31 May | - | 24 | 101 | Columbia PFC | 0 | 100 | 12.8 | 8.4 | 23.5 |
| 1 Jun | - | 23.3 | 126 | Columbia PFC | 0 | 100 | 8 | 8 | 23 |
| 1 Jun | - | 21.3 | 110 | Tri-County Marina | 2 | 98.2 | 10.2 | 6.2 | 20.2 |
| 2 Jun | - | 19.8 | 78 | Columbia PFC | 0 | 100 | 11.8 | 9 | 20.1 |
| 3 Jun | - | 24 | 110 | Columbia PFC | 0 | 100 | 11.5 | 6.3 | 24.9 |
| 3 Jun | - | 24.5 | 80 | Columbia PFC | 0 | 100 | 10.8 | 7.4 | 25 |
| 3 Jun | - | 23 | 74 | Columbia PFC | 3 | 95.9 | 10.6 | 8.4 | 23 |
| 4 Jun | - | 25 | 127 | Columbia PFC | 0 | 100 | 10.4 | 6 | 25 |
| 4 Jun | - | 26 | 90 | Columbia PFC | 0 | 100 | 13.2 | 7.8 | 27 |
| 6 Jun | - | 26.7 | 77 | Columbia PFC | 0 | 100 | 10.5 | 8.4 | 27 |
| 9 Jun | - | 25.9 | 95 | Columbia PFC | 2 | 97.9 | 10 | 6.2 | 25.8 |
| 9 Jun | - | 25.1 | 80 | Columbia PFC | 9 | 88.7 | 8.5 | 6 | 25 |
| 10 Jun | - | 25 | 120 | Columbia PFC | 2 | 98.3 | 9 | 7.4 | 23 |
| 10 Jun | - | 24.3 | 105 | Columbia PFC | 0 | 100 | 15 | 6 | 22.8 |
| 11 Jun | - | 25.5 | 83 | Columbia PFC | 0 | 100 | 8.2 | 8.5 | 24.8 |
| TOTAL, COMBINED | | | 5,906 | | 33 | | | | |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift* | | | | | |
| 8 Apr | 524 | 11.5 | 134 | Tri-County Marina | 4 | 97 | 13 | 11.9 | 12 |
| 8 Apr | 524 | 11 | 134 | Tri-County Marina | 0 | 100 | 10.6 | 11.2 | 11.9 |
| 8 Apr | 524 | 11 | 128 | Tri-County Marina | 0 | 100 | 13.4 | 12 | 11 |
| 9 Apr | 719 | 12.1 | 126 | Tri-County Marina | 0 | 100 | 14 | 13 | 11 |
| 9 Apr | 719 | 12 | 135 | Tri-County Marina | 0 | 100 | 9.2 | 12.2 | 12.2 |
| 9 Apr | 719 | 12 | 125 | Tri-County Marina | 0 | 100 | 10.5 | 12.3 | 12 |
| 9 Apr | 719 | 13 | 135 | Tri-County Marina | 0 | 100 | 10 | 12.5 | 13 |
| 10 Apr | 127 | 12 | 135 | Tri-County Marina | 0 | 100 | 10.4 | 13 | 12.2 |
| 10 Apr | 127 | 12 | 135 | Tri-County Marina | 0 | 100 | 11.6 | 12.2 | 12 |
| 20 Apr | 768 | 13 | 125 | Tri-County Marina | 0 | 100 | 12 | 13.4 | 13 |
| 20 Apr | 768 | 12.5 | 117 | Tri-County Marina | 0 | 100 | 12.2 | 12.5 | 13 |
| 20 Apr | 768 | 13 | 134 | Tri-County Marina | 1 | 99.3 | 12.8 | 11.5 | 14 |
| 21 Apr | 878 | 13 | 134 | Tri-County Marina | 0 | 100 | 12.2 | 12 | 13.8 |
| 21 Apr | 878 | 13.5 | 100 | Tri-County Marina | 0 | 100 | 12.2 | 12.8 | 14 |
| 21 Apr | 878 | 14 | 134 | Tri-County Marina | 0 | 100 | 12.4 | 12.6 | 14.7 |
| 21 Apr | 878 | 15.5 | 135 | Tri-County Marina | 0 | 100 | 13.4 | 12.4 | 16 |
| 21 Apr | 878 | 14 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 12.4 | 14.1 |
| 21 Apr | 878 | 13.5 | 135 | Columbia PFC | 0 | 100 | 10 | 12 | 13.8 |
| 21 Apr | 878 | 13.5 | 135 | Columbia PFC | 0 | 100 | 12 | 13 | 13.5 |
| 22 Apr | 1,105 | 14.2 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 12.5 | 15 |
| 22 Apr | 1,105 | 17 | 135 | Tri-County Marina | 0 | 100 | 11.4 | 11.8 | 16 |
| 22 Apr | 1,105 | 15 | 135 | Tri-County Marina | 0 | 100 | 11.5 | 12 | 16 |
| 22 Apr | 1,105 | 14.5 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 12.3 | 15 |
| 22 Apr | 1,105 | 15 | 135 | Tri-County Marina | 2 | 98.5 | 10 | 9.8 | 15 |
| 22 Apr | 1,105 | 14.2 | 134 | Tri-County Marina | 0 | 100 | 11 | 11.2 | 14.5 |
| 23 Apr | 936 | 14 | 135 | Tri-County Marina | 0 | 100 | 8.2 | 11.6 | 14.2 |
| 23 Apr | 936 | 14 | 135 | Tri-County Marina | 1 | 99.3 | 13.2 | 11.5 | 14 |
| 23 Apr | 936 | 15 | 135 | Tri-County Marina | 0 | 100 | 11 | 11.8 | 15 |
| 23 Apr | 936 | 14 | 134 | Tri-County Marina | 0 | 100 | 14.8 | 12 | 15 |
| 23 Apr | 936 | 14.5 | 136 | Tri-County Marina | 4 | 97.1 | 11.1 | 11.2 | 15 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 23 Apr | 936 | 15 | 106 | Tri-County Marina | 0 | 100 | 12 | 11.8 | 15 |
| 23 Apr | 936 | 14.3 | 134 | Tri-County Marina | 0 | 100 | 12.5 | 12.2 | 15 |
| 23 Apr | 936 | 14 | 135 | Tri-County Marina | 0 | 100 | 14.2 | 13 | 14 |
| 24 Apr | 632 | 15.5 | 122 | Tri-County Marina | 0 | 100 | 12.4 | 12.6 | 15.9 |
| 24 Apr | 632 | 16.5 | 135 | Tri-County Marina | 0 | 100 | 11.4 | 12.2 | 17 |
| 24 Apr | 632 | 14.5 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 12.1 | 15.2 |
| 24 Apr | 632 | 15 | 135 | Tri-County Marina | 0 | 100 | 12.2 | 12.4 | 15.1 |
| 24 Apr | 632 | 15 | 135 | Tri-County Marina | 1 | 99.3 | 13 | 10.5 | 14 |
| 25 Apr | 621 | 15.2 | 98 | Tri-County Marina | 0 | 100 | 12.8 | 11.2 | 15 |
| 25 Apr | 621 | 15.8 | 132 | Tri-County Marina | 0 | 100 | 11.2 | 13.4 | 16 |
| 25 Apr | 621 | 16 | 135 | Tri-County Marina | 1 | 99.3 | 10 | 12.7 | 16 |
| 25 Apr | 621 | 15 | 135 | Tri-County Marina | 0 | 100 | 10 | 11 | 13 |
| 26 Apr | 794 | 15.5 | 131 | Tri-County Marina | 0 | 100 | 11 | 11.8 | 16 |
| 26 Apr | 794 | 16 | 135 | Tri-County Marina | 1 | 99.3 | 11 | 11 | 16 |
| 26 Apr | 794 | 16 | 135 | Tri-County Marina | 0 | 100 | 13.2 | 12.8 | 16 |
| 26 Apr | 794 | 15.6 | 135 | Tri-County Marina | 1 | 99.3 | 12.2 | 12.2 | 15.9 |
| 26 Apr | 794 | 15.9 | 135 | Columbia PFC | 0 | 100 | 12.5 | 11.9 | 15 |
| 27 Apr | 771 | 16.5 | 135 | Tri-County Marina | 0 | 100 | 11.2 | 12 | 17 |
| 27 Apr | 771 | 16 | 135 | Tri-County Marina | 0 | 100 | 20 | 12.4 | 16.5 |
| 27 Apr | 771 | 16 | 135 | Tri-County Marina | 0 | 100 | 15.5 | 11 | 16.5 |
| 27 Apr | 771 | 15.9 | 105 | Tri-County Marina | 0 | 100 | 12.2 | 12.4 | 16.4 |
| 28 Apr | 960 | 14 | 128 | Tri-County Marina | 0 | 100 | 11.8 | 12 | 14.6 |
| 28 Apr | 960 | 13.8 | 110 | Tri-County Marina | 0 | 100 | 12 | 12.1 | 14 |
| 28 Apr | 960 | 16 | 125 | Tri-County Marina | 0 | 100 | 12.4 | 12.6 | 16.5 |
| 28 Apr | 960 | 14.5 | 125 | Tri-County Marina | 0 | 100 | 11.8 | 11.8 | 15 |
| 28 Apr | 960 | 16 | 135 | Tri-County Marina | 0 | 100 | 13.5 | 13.5 | 16 |
| 28 Apr | 960 | 15 | 136 | Tri-County Marina | 0 | 100 | 12.5 | 10 | 15 |
| 29 Apr | 1,336 | 16 | 132 | Tri-County Marina | 0 | 100 | 13.1 | 13.6 | 16 |
| 29 Apr | 1,336 | 16 | 134 | Tri-County Marina | 0 | 100 | 11 | 11.5 | 16.5 |
| 29 Apr | 1,336 | 16.5 | 131 | Tri-County Marina | 0 | 100 | 11.5 | 11.2 | 17 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| *Transported from the East Lift, continued.* | | | | | | | | | |
| 29 Apr | 1,336 | 16.8 | 135 | Tri-County Marina | 0 | 100 | 13.2 | 10.3 | 19.3 |
| 29 Apr | 1,336 | 16 | 135 | Tri-County Marina | 2 | 98.5 | 12.2 | 12.8 | 16.5 |
| 29 Apr | 1,336 | 17 | 137 | Tri-County Marina | 0 | 100 | 12.4 | 10.2 | 18.5 |
| 29 Apr | 1,336 | 17 | 135 | Tri-County Marina | 0 | 100 | 10 | 11.9 | 17 |
| 29 Apr | 1,336 | 17 | 135 | Columbia PFC | 0 | 100 | 16 | 12.2 | 17 |
| 30 Apr | 1,218 | 18 | 135 | Tri-County Marina | 0 | 100 | 9.5 | 12.5 | 18.5 |
| 30 Apr | 1,218 | 16.5 | 135 | Tri-County Marina | 1 | 99.3 | 11 | 11.6 | 16.5 |
| 30 Apr | 1,218 | 17.5 | 135 | Columbia PFC | 0 | 100 | 10.4 | 11.4 | 17.8 |
| 30 Apr | 1,218 | 18.2 | 135 | Columbia PFC | 0 | 100 | 13 | 12.6 | 18.2 |
| 30 Apr | 1,218 | 16 | 136 | Tri-County Marina | 0 | 100 | 13.2 | 13.6 | 16 |
| 30 Apr | 1,218 | 16.5 | 135 | Tri-County Marina | 0 | 100 | 11 | 11.8 | 16.5 |
| 30 Apr | 1,218 | 17.5 | 135 | Tri-County Marina | 0 | 100 | 9.2 | 11.8 | 17.8 |
| 30 Apr | 1,218 | 16 | 135 | Tri-County Marina | 0 | 100 | 11.2 | 12.6 | 16 |
| 30 Apr | 1,218 | 18 | 135 | Columbia PFC | 0 | 100 | 12.4 | 12.4 | 18 |
| 1 May | 854 | 16.8 | 134 | Tri-County Marina | 1 | 99.3 | 15.4 | 11.6 | 17.1 |
| 1 May | 854 | 17.2 | 114 | Tri-County Marina | 0 | 100 | 11.2 | 8.6 | 15.1 |
| 1 May | 854 | 17.5 | 108 | Columbia PFC | 0 | 100 | 11.2 | 12 | 18 |
| 1 May | 854 | 16.4 | 111 | Tri-County Marina | 0 | 100 | 12.4 | 10.1 | 15.1 |
| 1 May | 854 | 16 | 123 | Tri-County Marina | 0 | 100 | 14.5 | 11.2 | 14 |
| 1 May | 854 | 16.2 | 136 | Tri-County Marina | 0 | 100 | 14.2 | 10.2 | 14 |
| 1 May | 854 | 18 | 122 | Tri-County Marina | 0 | 100 | 13 | 12 | 18 |
| 1 May | 854 | 16 | 111 | Tri-County Marina | 0 | 100 | 12 | 10 | 14 |
| 2 May | 992 | 16 | 125 | Tri-County Marina | 0 | 100 | 12 | 8.8 | 13 |
| 2 May | 992 | 16 | 127 | Tri-County Marina | 0 | 100 | 11.8 | 8.5 | 13.2 |
| 2 May | 992 | 14 | 112 | Tri-County Marina | 0 | 100 | 12 | 9.1 | 11.1 |
| 2 May | 992 | 16 | 135 | Tri-County Marina | 0 | 100 | 12.5 | 10 | 13 |
| 2 May | 992 | 16 | 135 | Tri-County Marina | 0 | 100 | 14.1 | 9.8 | 13 |
| 2 May | 992 | 16 | 135 | Tri-County Marina | 0 | 100 | 13.2 | 8.9 | 12.5 |
| 3 May | 34 | 16 | 135 | Tri-County Marina | 1 | 99.3 | 12.8 | 13 | 16 |
| 3 May | 34 | 15.5 | 135 | Columbia PFC | 0 | 100 | 16 | 10.1 | 12.2 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 4 May | 1,258 | 16.4 | 135 | Columbia PFC | 0 | 100 | 11.8 | 9 | 15.8 |
| 4 May | 1,258 | 17 | 135 | Columbia PFC | 0 | 100 | 13.2 | 11 | 16.3 |
| 4 May | 1,258 | 16.2 | 135 | Tri-County Marina | 0 | 100 | 12.4 | 9.9 | 14.5 |
| 4 May | 1,258 | 16 | 140 | Tri-County Marina | 0 | 100 | 16 | 7.9 | 15 |
| 4 May | 1,258 | 17 | 135 | Tri-County Marina | 0 | 100 | 11.6 | 9.8 | 15 |
| 4 May | 1,258 | 16.5 | 135 | Tri-County Marina | 0 | 100 | 11.4 | 10 | 15 |
| 5 May | 1,398 | 15.5 | 134 | Tri-County Marina | 1 | 99.3 | 15.2 | 9.4 | 14.2 |
| 5 May | 1,398 | 15.8 | 135 | Tri-County Marina | 0 | 100 | 15.8 | 9.6 | 14.4 |
| 5 May | 1,398 | 16 | 135 | Columbia PFC | 0 | 100 | 11.2 | 9.6 | 16 |
| 5 May | 1,398 | 15.5 | 140 | Tri-County Marina | 0 | 100 | 12.8 | 10.2 | 15 |
| 5 May | 1,398 | 17 | 135 | Columbia PFC | 0 | 100 | 9 | 10.4 | 16 |
| 5 May | 1,398 | 17 | 133 | Columbia PFC | 0 | 100 | 12.6 | 11.8 | 16 |
| 5 May | 1,398 | 17 | 134 | Tri-County Marina | 3 | 97.8 | 11.6 | 10.6 | 16 |
| 5 May | 1,398 | 15 | 133 | Columbia PFC | 0 | 100 | 13.6 | 10.2 | 15 |
| 5 May | 1,398 | 16 | 135 | Columbia PFC | 0 | 100 | 11.4 | 9.8 | 15.2 |
| 5 May | 1,398 | 17 | 135 | Columbia PFC | 0 | 100 | 12.6 | 9.4 | 16.2 |
| 6 May | 2,140 | 17.2 | 135 | Columbia PFC | 0 | 100 | 10.4 | 10.5 | 15.2 |
| 6 May | 2,140 | 17 | 134 | Columbia PFC | 0 | 100 | 12 | 10.8 | 17 |
| 6 May | 2,140 | 18 | 135 | Columbia PFC | 0 | 100 | 10.8 | 10.8 | 17 |
| 6 May | 2,140 | 18 | 135 | Columbia PFC | 0 | 100 | 12 | 11.5 | 16.5 |
| 6 May | 2,140 | 18 | 134 | Columbia PFC | 0 | 100 | 10.4 | 10.8 | 17.2 |
| 6 May | 2,140 | 19.5 | 134 | Columbia PFC | 1 | 99.3 | 10.7 | 11.6 | 18.8 |
| 6 May | 2,140 | 17.5 | 135 | Tri-County Marina | 0 | 100 | 10.5 | 10.6 | 18 |
| 6 May | 2,140 | 18 | 135 | Columbia PFC | 0 | 100 | 11.6 | 10 | 17.5 |
| 6 May | 2,140 | 17.5 | 135 | Columbia PFC | 1 | 99.3 | 12.2 | 10 | 18 |
| 6 May | 2,140 | 17.4 | 135 | Tri-County Marina | 3 | 97.8 | 10.4 | 10.2 | 17.3 |
| 7 May | 1,772 | 17 | 84 | Columbia PFC | 0 | 100 | 10.5 | 9.7 | 15.3 |
| 7 May | 1,772 | 16.5 | 129 | Columbia PFC | 0 | 100 | 11 | 10.4 | 16.5 |
| 7 May | 1,772 | 17.2 | 135 | Columbia PFC | 0 | 100 | 11.8 | 12.4 | 17.2 |
| 7 May | 1,772 | 17.8 | 132 | Columbia PFC | 0 | 100 | 10.4 | 9.6 | 16.8 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 7 May | 1,772 | 17 | 106 | Columbia PFC | 0 | 100 | 14.2 | 10.6 | 17.8 |
| 7 May | 1,772 | 17.5 | 100 | Columbia PFC | 1 | 99 | 10.2 | 11.6 | 18 |
| 7 May | 1,772 | 17.8 | 135 | Columbia PFC | 0 | 100 | 11 | 10.2 | 17.5 |
| 7 May | 1,772 | 18 | 134 | Tri-County Marina | 0 | 100 | 11.8 | 10.2 | 18.2 |
| 7 May | 1,772 | 17.1 | 135 | Tri-County Marina | 0 | 100 | 9.6 | 10.4 | 16.9 |
| 7 May | 1,772 | 17.5 | 135 | Columbia PFC | 0 | 100 | 13.6 | 9.6 | 17.1 |
| 8 May | 632 | 16.8 | 134 | Tri-County Marina | 0 | 100 | 11.8 | 10.4 | 15.4 |
| 8 May | 632 | 17.5 | 133 | Tri-County Marina | 0 | 100 | 13.8 | 9.8 | 16.5 |
| 8 May | 632 | 18 | 135 | Tri-County Marina | 0 | 100 | 10 | 9.8 | 19.5 |
| 8 May | 632 | 17.5 | 133 | Tri-County Marina | 0 | 100 | 12.5 | 10 | 18 |
| 8 May | 632 | 18 | 127 | Tri-County Marina | 0 | 100 | 10.4 | 9.5 | 18 |
| 8 May | 632 | 17 | 108 | Tri-County Marina | 0 | 100 | 13.2 | 9.8 | 17 |
| 9 May | 1,468 | 17.7 | 105 | Tri-County Marina | 0 | 100 | 12.2 | 12 | 17.2 |
| 9 May | 1,468 | 17.2 | 133 | Tri-County Marina | 0 | 100 | 14.8 | 11 | 17.5 |
| 9 May | 1,468 | 17.5 | 114 | Tri-County Marina | 0 | 100 | 9 | 10.2 | 18 |
| 9 May | 1,468 | 18.4 | 135 | Columbia PFC | 0 | 100 | 14.8 | 11.5 | 18 |
| 9 May | 1,468 | 18.5 | 134 | Tri-County Marina | 0 | 100 | 11.5 | 9.8 | 18 |
| 9 May | 1,468 | 17.3 | 137 | Columbia PFC | 0 | 100 | 11.6 | 11.2 | 17 |
| 9 May | 1,468 | 18.4 | 137 | Tri-County Marina | 0 | 100 | 12.8 | 10.4 | 17.1 |
| 9 May | 1,468 | 17.2 | 135 | Columbia PFC | 0 | 100 | 11 | 11 | 17 |
| 9 May | 1,468 | 17.5 | 135 | Tri-County Marina | 3 | 97.8 | 12 | 10.5 | 16.5 |
| 10 May | 1,590 | 17.2 | 134 | Tri-County Marina | 0 | 100 | 11.8 | 10 | 16 |
| 10 May | 1,590 | 17 | 134 | Tri-County Marina | 0 | 100 | 11.6 | 8.8 | 16 |
| 10 May | 1,590 | 18.1 | 135 | Columbia PFC | 0 | 100 | 11.2 | 10.9 | 16.5 |
| 10 May | 1,590 | 18 | 135 | Columbia PFC | 0 | 100 | 12.8 | 8 | 16 |
| 10 May | 1,590 | 17.5 | 139 | Columbia PFC | 0 | 100 | 12.8 | 11.1 | 15.9 |
| 10 May | 1,590 | 17.5 | 135 | Columbia PFC | 0 | 100 | 13.8 | 11.4 | 16 |
| 10 May | 1,590 | 18.5 | 135 | Tri-County Marina | 1 | 99.3 | 13 | 10.4 | 17 |
| 10 May | 1,590 | 18.5 | 123 | Tri-County Marina | 1 | 99.2 | 14 | 9 | 17 |
| 10 May | 1,590 | 17.8 | 135 | Columbia PFC | 0 | 100 | 12 | 9.6 | 15.9 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 10 May | 1,590 | 18 | 135 | Tri-County Marina | 3 | 97.8 | 17 | 8 | 16 |
| 10 May | 1,590 | 17.5 | 135 | Tri-County Marina | 1 | 99.3 | 12.6 | 9.4 | 16.4 |
| 11 May | 968 | 17.5 | 133 | Columbia PFC | 0 | 100 | 11.4 | 8.6 | 16 |
| 11 May | 968 | 17.1 | 135 | Columbia PFC | 0 | 100 | 12.4 | 9 | 15.8 |
| 11 May | 968 | 17.2 | 135 | Columbia PFC | 0 | 100 | 13.4 | 9.2 | 16 |
| 11 May | 968 | 10.5 | 135 | Columbia PFC | 0 | 100 | 11.4 | 9 | 16.5 |
| 11 May | 968 | 18 | 93 | Columbia PFC | 0 | 100 | 12.5 | 12 | 18 |
| 11 May | 968 | 18.5 | 134 | Tri-County Marina | 0 | 100 | 12.4 | 9.2 | 17.2 |
| 11 May | 968 | 17.9 | 134 | Tri-County Marina | 0 | 100 | 10.8 | 8.9 | 16.5 |
| 12 May | 1,315 | 17.1 | 134 | Tri-County Marina | 0 | 100 | 11.8 | 10.8 | 15.5 |
| 12 May | 1,315 | 18 | 135 | Tri-County Marina | 4 | 97 | 9 | 13.2 | 18.2 |
| 12 May | 1,315 | 18 | 135 | Tri-County Marina | 1 | 99.3 | 11.2 | 10 | 15.2 |
| 12 May | 1,315 | 17.9 | 136 | Tri-County Marina | 0 | 100 | 10.1 | 11.2 | 16.1 |
| 12 May | 1,315 | 18 | 140 | Columbia PFC | 0 | 100 | 13 | 11.2 | 17.5 |
| 12 May | 1,315 | 18.6 | 140 | Tri-County Marina | 0 | 100 | 12 | 12.2 | 17.5 |
| 12 May | 1,315 | 17.8 | 135 | Tri-County Marina | 10 | 92.6 | 11.3 | 12.2 | 17 |
| 12 May | 1,315 | 18.5 | 135 | Tri-County Marina | 0 | 100 | 12 | 11.2 | 17 |
| 12 May | 1,315 | 17.5 | 135 | Tri-County Marina | 3 | 97.8 | 11.8 | 9.6 | 17 |
| 13 May | 1,842 | 18 | 135 | Columbia PFC | 0 | 100 | 13 | 13.6 | 18 |
| 13 May | 1,842 | 19 | 134 | Columbia PFC | 0 | 100 | 9 | 8.8 | 19 |
| 13 May | 1,842 | 19 | 135 | Columbia PFC | 1 | 99.3 | 12.4 | 9.4 | 17 |
| 13 May | 1,842 | 19 | 135 | Columbia PFC | 0 | 100 | 12.8 | 13.6 | 19 |
| 13 May | 1,842 | 19.5 | 135 | Columbia PFC | 0 | 100 | 11 | 9.2 | 20 |
| 13 May | 1,842 | 19 | 135 | Columbia PFC | 0 | 100 | 12.2 | 9.2 | 17.5 |
| 13 May | 1,842 | 19 | 135 | Columbia PFC | 0 | 100 | 13 | 14.6 | 19.5 |
| 13 May | 1,842 | 20.5 | 135 | Columbia PFC | 2 | 98.5 | 10 | 9.2 | 20.5 |
| 13 May | 1,842 | 19.8 | 98 | Columbia PFC | 0 | 100 | 12.2 | 9.3 | 17.4 |
| 13 May | 1,842 | 19.5 | 135 | Columbia PFC | 0 | 100 | 13.4 | 14 | 19.5 |
| 13 May | 1,842 | 19.5 | 135 | Columbia PFC | 0 | 100 | 11.6 | 8.8 | 19 |
| 13 May | 1,842 | 19.6 | 133 | Columbia PFC | 0 | 100 | 12.2 | 8.8 | 19.5 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 14 May | 1,891 | 18 | 132 | Columbia PFC | 0 | 100 | 8.4 | 8.4 | 16.8 |
| 14 May | 1,891 | 17.5 | 135 | Columbia PFC | 0 | 100 | 12.2 | 12.2 | 17.5 |
| 14 May | 1,891 | 18 | 134 | Columbia PFC | 0 | 100 | 9.8 | 8.8 | 17.5 |
| 14 May | 1,891 | 18 | 135 | Columbia PFC | 0 | 100 | 14 | 14.2 | 18 |
| 14 May | 1,891 | 17.8 | 140 | Columbia PFC | 0 | 100 | 13 | 7.8 | 16.2 |
| 14 May | 1,891 | 77.5 | 135 | Columbia PFC | 0 | 100 | 10.4 | 12.1 | 17.5 |
| 14 May | 1,891 | 18 | 135 | Columbia PFC | 0 | 100 | 12.3 | 6.8 | 16.8 |
| 14 May | 1,891 | 17.8 | 135 | Columbia PFC | 0 | 100 | 14.6 | 6.6 | 16 |
| 14 May | 1,891 | 18.2 | 135 | Columbia PFC | 0 | 100 | 12 | 7.5 | 16 |
| 14 May | 1,891 | 17.2 | 111 | Columbia PFC | 0 | 100 | 10.2 | 9.4 | 16.2 |
| 14 May | 1,891 | 18.2 | 135 | Columbia PFC | 0 | 100 | 9.2 | 7 | 17 |
| 14 May | 1,891 | 17.8 | 135 | Columbia PFC | 0 | 100 | 12.8 | 6.6 | 16.2 |
| 15 May | 461 | 18.8 | 121 | Columbia PFC | 1 | 99.2 | 10.8 | 7 | 16.8 |
| 15 May | 461 | 18.2 | 135 | Columbia PFC | 0 | 100 | 14 | 10.1 | 16 |
| 15 May | 461 | 18.8 | 135 | Columbia PFC | 0 | 100 | 12.6 | 8.8 | 16.9 |
| 15 May | 461 | 19.1 | 100 | Tri-County Marina | 0 | 100 | 15 | 9.8 | 18 |
| 15 May | 461 | 19.1 | 135 | Tri-County Marina | 0 | 100 | 13.8 | 8.2 | 18.1 |
| 16 May | 933 | 19.2 | 135 | Columbia PFC | 0 | 100 | 12.2 | 9.2 | 18.4 |
| 16 May | 933 | 22 | 135 | Tri-County Marina | 3 | 97.8 | 13.8 | 9.5 | 21 |
| 16 May | 933 | 21.2 | 135 | Tri-County Marina | 1 | 99.3 | 11.8 | 8.6 | 20.5 |
| 17 May | 733 | 19.2 | 134 | Tri-County Marina | 0 | 100 | 11.7 | 7.4 | 18.9 |
| 17 May | 733 | 19 | 128 | Tri-County Marina | 0 | 100 | 14.6 | 8.2 | 19 |
| 17 May | 733 | 19.5 | 135 | Tri-County Marina | 0 | 100 | 14.6 | 8.2 | 19.3 |
| 17 May | 733 | 18 | 129 | Tri-County Marina | 0 | 100 | 14 | 10.5 | 17.5 |
| 18 May | 1,238 | 19 | 129 | Tri-County Marina | 0 | 100 | 9.4 | 8 | 18.5 |
| 18 May | 1,238 | 19 | 135 | Tri-County Marina | 0 | 100 | 9.8 | 7.6 | 18.5 |
| 18 May | 1,238 | 19.5 | 152 | Tri-County Marina | 2 | 98.7 | 13.2 | 7.9 | 18.8 |
| 18 May | 1,238 | 19.5 | 134 | Tri-County Marina | 2 | 98.5 | 12 | 9 | 18.8 |
| 18 May | 1,238 | 19.5 | 134 | Tri-County Marina | 1 | 99.3 | 11.4 | 9.1 | 19.2 |
| 18 May | 1,238 | 19.3 | 135 | Columbia PFC | 0 | 100 | 13.2 | 10.1 | 19.9 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 18 May | 1,238 | 20 | 120 | Columbia PFC | 1 | 99.2 | 13.6 | 8.2 | 20 |
| 18 May | 1,238 | 20 | 135 | Columbia PFC | 1 | 99.3 | 12.2 | 9.4 | 19.8 |
| 18 May | 1,238 | 21 | 135 | Tri-County Marina | 23 | 83 | 11.2 | 8.8 | 20 |
| 19 May | 938 | 19 | 135 | Columbia PFC | 0 | 100 | 11.3 | 9.3 | 18.5 |
| 19 May | 938 | 19.5 | 135 | Columbia PFC | 0 | 100 | 10.8 | 9.8 | 18.2 |
| 19 May | 938 | 18.9 | 135 | Tri-County Marina | 1 | 99.3 | 12.5 | 9.2 | 17.5 |
| 19 May | 938 | 17 | 134 | Columbia PFC | 0 | 100 | 13.4 | 8.6 | 16 |
| 19 May | 938 | 19.9 | 123 | Columbia PFC | 0 | 100 | 12.5 | 8 | 18.5 |
| 20 May | 1,296 | 19 | 131 | Columbia PFC | 0 | 100 | 12 | 7.9 | 17 |
| 20 May | 1,296 | 19.6 | 139 | Columbia PFC | 0 | 100 | 20 | 8.2 | 18.8 |
| 20 May | 1,296 | 19 | 134 | Columbia PFC | 0 | 100 | 13 | 9.8 | 18 |
| 20 May | 1,296 | 21 | 135 | Columbia PFC | 0 | 100 | 12.6 | 8.4 | 20.5 |
| 20 May | 1,296 | 20 | 135 | Columbia PFC | 0 | 100 | 8 | 10.2 | 19 |
| 20 May | 1,296 | 20 | 112 | Columbia PFC | 0 | 100 | 13.6 | 8.7 | 19.5 |
| 20 May | 1,296 | 18 | 134 | Columbia PFC | 0 | 100 | 12.3 | 9.3 | 17.6 |
| 20 May | 1,296 | 19.6 | 138 | Columbia PFC | 0 | 100 | 11.8 | 9.9 | 19 |
| 21 May | 1,840 | 19.8 | 135 | Columbia PFC | 0 | 100 | 10 | 8 | 17 |
| 21 May | 1,840 | 20 | 127 | Columbia PFC | 0 | 100 | 11.8 | 6.2 | 18.2 |
| 21 May | 1,840 | 20 | 130 | Columbia PFC | 3 | 97.7 | 10 | 8.2 | 18.8 |
| 21 May | 1,840 | 19.5 | 119 | Columbia PFC | 0 | 100 | 11 | 8.3 | 18 |
| 21 May | 1,840 | 21 | 125 | Columbia PFC | 0 | 100 | 8.9 | 10.2 | 22 |
| 21 May | 1,840 | 21 | 128 | Columbia PFC | 0 | 100 | 12.6 | 9.2 | 20.3 |
| 21 May | 1,840 | 19.9 | 124 | Columbia PFC | 0 | 100 | 11 | 9.6 | 18.7 |
| 21 May | 1,840 | 19.8 | 125 | Columbia PFC | 0 | 100 | 12.3 | 9 | 18.9 |
| 21 May | 1,840 | 20.5 | 125 | Tri-County Marina | 1 | 99.2 | 12.4 | 8.4 | 19.2 |
| 21 May | 1,840 | 20.5 | 125 | Tri-County Marina | 0 | 100 | 10.8 | 7.9 | 19.5 |
| 21 May | 1,840 | 19 | 125 | Columbia PFC | 0 | 100 | 10.2 | 11.6 | 19 |
| 21 May | 1,840 | 19 | 125 | Columbia PFC | 0 | 100 | 12 | 8.3 | 18.9 |
| 22 May | 465 | 19.9 | 125 | Tri-County Marina | 0 | 100 | 10.8 | 6 | 18.5 |
| 22 May | 465 | 20 | 125 | Tri-County Marina | 0 | 100 | 16.8 | 8.2 | 18 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 22 May | 465 | 21.5 | 125 | Columbia PFC | 0 | 100 | 11.2 | 10 | 20.2 |
| 23 May | 890 | 20.5 | 125 | Columbia PFC | 0 | 100 | 10.8 | 9.6 | 19 |
| 23 May | 890 | 20.9 | 125 | Tri-County Marina | 0 | 100 | 11.4 | 9.5 | 21 |
| 23 May | 890 | 21 | 125 | Tri-County Marina | 0 | 100 | 12.9 | 9.8 | 20.5 |
| 23 May | 890 | 20.7 | 125 | Columbia PFC | 0 | 100 | 17.3 | 10.4 | 21 |
| 23 May | 890 | 20 | 125 | Tri-County Marina | 0 | 100 | 10 | 13 | 20.7 |
| 24 May | 1,018 | 21 | 125 | Tri-County Marina | 3 | 97.6 | 12.1 | 12.1 | 21 |
| 24 May | 1,018 | 20.9 | 125 | Columbia PFC | 0 | 100 | 10.2 | 8 | 20 |
| 24 May | 1,018 | 20.5 | 125 | Columbia PFC | 0 | 100 | 11.8 | 9.8 | 20.5 |
| 24 May | 1,018 | 21 | 125 | Columbia PFC | 0 | 100 | 10.6 | 10 | 23 |
| 24 May | 1,018 | 20.5 | 125 | Columbia PFC | 0 | 100 | 8.8 | 9.4 | 21 |
| 24 May | 1,018 | 21 | 125 | Columbia PFC | 2 | 98.4 | 11.5 | 11 | 22 |
| 24 May | 1,018 | 21 | 115 | Tri-County Marina | 0 | 100 | 10.8 | 7 | 23 |
| 24 May | 1,018 | 21 | 116 | Tri-County Marina | 0 | 100 | 12.2 | 8 | 22 |
| 25 May | 1,020 | 21.5 | 136 | Columbia PFC | 0 | 100 | 10.8 | 8.2 | 22 |
| 25 May | 1,020 | 21 | 125 | Columbia PFC | 0 | 100 | 9.5 | 6.8 | 22 |
| 25 May | 1,020 | 22.1 | 132 | Columbia PFC | 0 | 100 | 10.1 | 8.3 | 23.1 |
| 25 May | 1,020 | 22 | 115 | Columbia PFC | 0 | 100 | 12.2 | 8.8 | 24 |
| 25 May | 1,020 | 22 | 119 | Columbia PFC | 0 | 100 | 9.8 | 9.2 | 23.2 |
| 25 May | 1,020 | 21.2 | 115 | Columbia PFC | 0 | 100 | 10.2 | 8.5 | 22.5 |
| 26 May | 382 | 22 | 125 | Columbia PFC | 1 | 99.2 | 12.6 | 7.8 | 22 |
| 26 May | 382 | 22 | 111 | Columbia PFC | 0 | 100 | 11.4 | 6.5 | 22 |
| 27 May | 1,232 | 22.3 | 126 | Columbia PFC | 1 | 99.2 | 10.8 | 8.2 | 21.8 |
| 27 May | 1,232 | 22 | 124 | Columbia PFC | 0 | 100 | 10 | 8.2 | 21.2 |
| 27 May | 1,232 | 23 | 120 | Columbia PFC | 0 | 100 | 16 | 10 | 22.6 |
| 27 May | 1,232 | 22.2 | 125 | Columbia PFC | 0 | 100 | 8.6 | 10 | 22.5 |
| 27 May | 1,232 | 22 | 124 | Columbia PFC | 0 | 100 | 10 | 7.4 | 22 |
| 27 May | 1,232 | 22.8 | 125 | Tri-County Marina | 21 | 83.2 | 10.1 | 8.8 | 23.8 |
| 27 May | 1,232 | 22 | 125 | Tri-County Marina | 0 | 100 | 9.8 | 7.6 | 22.1 |
| 28 May | 960 | 22 | 125 | Columbia PFC | 0 | 100 | 11 | 7.5 | 21 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued.* | | | | | |
| 28 May | 960 | 22 | 125 | Columbia PFC | 0 | 100 | 7 | 8.4 | 21 |
| 28 May | 960 | 22 | 125 | Columbia PFC | 1 | 99.2 | 14.4 | 8.3 | 21 |
| 28 May | 960 | 24 | 125 | Columbia PFC | 0 | 100 | 10.2 | 8 | 22.2 |
| 28 May | 960 | 22 | 125 | Columbia PFC | 0 | 100 | 8.2 | 8 | 21 |
| 28 May | 960 | 22 | 125 | Columbia PFC | 0 | 100 | 16.2 | 8.6 | 20.8 |
| 28 May | 960 | 23.1 | 117 | Columbia PFC | 0 | 100 | 11 | 7.4 | 22 |
| 28 May | 960 | 21.5 | 65 | Columbia PFC | 0 | 100 | 14.2 | 11 | 22 |
| 29 May | 772 | 23 | 120 | Columbia PFC | 0 | 100 | 12.2 | 8 | 21 |
| 29 May | 772 | 23 | 125 | Columbia PFC | 0 | 100 | 10.8 | 9.8 | 21.5 |
| 29 May | 772 | 23.7 | 97 | Tri-County Marina | 0 | 100 | 17.2 | 10.3 | 22.7 |
| 29 May | 772 | 23.5 | 125 | Columbia PFC | 0 | 100 | 9 | 7.4 | 22.2 |
| 29 May | 772 | 24 | 125 | Columbia PFC | 1 | 99.2 | 9.4 | 7.8 | 22.8 |
| 30 May | 411 | 22 | 123 | Columbia PFC | 0 | 100 | 12.2 | 7.2 | 20 |
| 30 May | 411 | 20.8 | 125 | Columbia PFC | 0 | 100 | 14.4 | 8.5 | 18.2 |
| 30 May | 411 | 22.3 | 121 | Columbia PFC | 1 | 99.2 | 8.4 | 8 | 20.2 |
| 31 May | 206 | 23.6 | 125 | Columbia PFC | 1 | 99.2 | 11 | 8.2 | 21 |
| 1 Jun | 344 | 21.1 | 125 | Columbia PFC | 0 | 100 | 10.8 | 6.3 | 20.2 |
| 2 Jun | 230 | 23.3 | 125 | Columbia PFC | 0 | 100 | 10.6 | 5.8 | 23.7 |
| 2 Jun | 230 | 19 | 93 | Columbia PFC | 1 | 98.9 | 12.2 | 6 | 19.3 |
| 3 Jun | 260 | 23 | 111 | Columbia PFC | 0 | 100 | 13 | 6.4 | 23 |
| 4 Jun | 314 | 14.2 | 125 | Columbia PFC | 3 | 97.6 | 13.8 | 11.8 | 24 |
| 5 Jun | 28 | 24 | 57 | Columbia PFC | 0 | 100 | 9.8 | 8 | 23.5 |
| TOTAL, EAST LIFT | | | 37,648 | | 137 | | | | |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the West Lift* | | | | | |
| 22 Apr | 74 | 12 | 60 | Bainbridge | 0 | 100 | 11 | 12.8 | 12 |
| 23 Apr | 51 | 15.5 | 74 | Tri-County Marina | 1 | 98.6 | 12 | 12.3 | 15.8 |
| 25 Apr | 148 | 15.2 | 93 | Tri-County Marina | 1 | 98.9 | 12.6 | 12 | 15.2 |
| 26 Apr | 134 | 15.5 | 134 | Tri-County Marina | 0 | 100 | 10 | 13 | 15.5 |
| 27 Apr | 218 | 16.5 | 201 | Tri-County Marina | 4 | 98 | 10.5 | 12 | 17 |
| 29 Apr | 245 | 17 | 156 | Columbia PFC | 0 | 100 | 11.8 | 9.4 | 16.2 |
| 30 Apr | 336 | 17.5 | 173 | Tri-County Marina | 0 | 100 | 11 | 11.6 | 18 |
| 30 Apr | 336 | 17 | 168 | Tri-County Marina | 0 | 100 | 20 | 8.8 | 15 |
| 1 May | 293 | 16.5 | 102 | Columbia PFC | 0 | 100 | 8 | 11 | 15 |
| 2 May | 330 | 16.5 | 192 | Tri-County Marina | 0 | 100 | 11 | 12 | 16.5 |
| 2 May | 330 | 18 | 180 | Tri-County Marina | 1 | 99.4 | 11.2 | 14 | 18.5 |
| 3 May | 121 | 16.2 | 169 | Tri-County Marina | 0 | 100 | 11.4 | 13 | 16.5 |
| 4 May | 275 | 16 | 180 | Tri-County Marina | 0 | 100 | 12.5 | 13 | 16.2 |
| 5 May | 577 | 18 | 175 | Tri-County Marina | 0 | 100 | 13 | 12.8 | 18.5 |
| 5 May | 577 | 18.5 | 202 | Tri-County Marina | 2 | 99 | 11.3 | 12 | 13 |
| 6 May | 553 | 17.8 | 176 | Tri-County Marina | 0 | 100 | 12 | 11 | 15 |
| 6 May | 553 | 18 | 180 | Tri-County Marina | 1 | 99.4 | 10.8 | 11.3 | 16.2 |
| 6 May | 553 | 19 | 193 | Tri-County Marina | 4 | 97.9 | 14.2 | 13.6 | 9 |
| 7 May | 183 | 17.5 | 128 | Columbia PFC | 0 | 100 | 11 | 11.4 | 15 |
| 7 May | 183 | 18.5 | 129 | Columbia PFC | 0 | 100 | 15.6 | 13.4 | 17 |
| 8 May | 900 | 17 | 187 | Tri-County Marina | 1 | 99.5 | 14.8 | 11.4 | 16.2 |
| 8 May | 900 | 17.5 | 179 | Tri-County Marina | 0 | 100 | 13.4 | 10.8 | 18 |
| 8 May | 900 | 18.5 | 167 | Columbia PFC | 0 | 100 | 18.6 | 10 | 17 |
| 9 May | 605 | 18 | 194 | Tri-County Marina | 1 | 99.5 | 11.2 | 14.4 | 18.2 |
| 9 May | 605 | 19.5 | 185 | Tri-County Marina | 1 | 99.5 | 10.2 | 10.6 | 18 |
| 9 May | 605 | 19 | 181 | Tri-County Marina | 0 | 100 | 15 | 12 | 19 |
| 10 May | 223 | 19 | 179 | Tri-County Marina | 0 | 100 | 13.8 | 9.6 | 16 |
| 10 May | 223 | 19 | 176 | Tri-County Marina | 2 | 98.9 | 11.9 | 9.7 | 16.4 |
| 11 May | 177 | 19 | 70 | Columbia PFC | 0 | 100 | 14 | 11.2 | 8.3 |
| 11 May | 177 | 18.7 | 114 | Tri-County Marina | 2 | 98.2 | 11.7 | 8.8 | 17.7 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the West Lift, continued.* | | | | | |
| 12 May | 1,578 | 17.5 | 181 | Tri-County Marina | 0 | 100 | 12.8 | 10 | 15.5 |
| 12 May | 1,578 | 19.7 | 178 | Columbia PFC | 1 | 99.4 | 12.8 | 10.1 | 17.5 |
| 12 May | 1,578 | 19 | 178 | Tri-County Marina | 0 | 100 | 10.4 | 10.8 | 17 |
| 12 May | 1,578 | 18.5 | 179 | Tri-County Marina | 0 | 100 | 14.8 | 10.8 | 16 |
| 12 May | 1,578 | 19.9 | 178 | Columbia PFC | 0 | 100 | 13.6 | 9.8 | 18.1 |
| 12 May | 1,578 | 19 | 179 | Columbia PFC | 1 | 99.4 | 13.2 | 12 | 16.9 |
| 12 May | 1,578 | 19 | 170 | Columbia PFC | 1 | 99.4 | 10.9 | 13.5 | 19.5 |
| 13 May | 839 | 20 | 175 | Columbia PFC | 0 | 100 | 14.2 | 8.4 | 17.5 |
| 13 May | 839 | 18.9 | 175 | Columbia PFC | 0 | 100 | 8.8 | 9.4 | 16.9 |
| 13 May | 839 | 19.8 | 188 | Columbia PFC | 0 | 100 | 10 | 10.4 | 17.5 |
| 13 May | 839 | 20.2 | 175 | Columbia PFC | 0 | 100 | 10 | 8.4 | 19 |
| 13 May | 839 | 19 | 174 | Columbia PFC | 1 | 99.4 | 10.7 | 11.2 | 18.9 |
| 13 May | 839 | 18.9 | 169 | Columbia PFC | 0 | 100 | 9.2 | 12.2 | 18.4 |
| 14 May | 1,099 | 18.5 | 184 | Columbia PFC | 1 | 99.5 | 8.4 | 10.4 | 17.5 |
| 14 May | 1,099 | 13.8 | 180 | Columbia PFC | 1 | 99.4 | 14.6 | 7.8 | 11.9 |
| 14 May | 1,099 | 18 | 185 | Columbia PFC | 0 | 100 | 12.2 | 10 | 16.4 |
| 15 May | 417 | 19.4 | 153 | Columbia PFC | 0 | 100 | 11.2 | 9.4 | 16.9 |
| 15 May | 417 | 18.2 | 133 | Columbia PFC | 0 | 100 | 14.2 | 7.8 | 15.3 |
| 15 May | 417 | 19 | 102 | Tri-County Marina | 0 | 100 | 16.8 | 8 | 17.8 |
| 15 May | 417 | 21 | 160 | Tri-County Marina | 0 | 100 | 14 | 9.6 | 19 |
| 17 May | 198 | 20 | 161 | Tri-County Marina | 1 | 99.4 | 11.5 | 9.4 | 10 |
| 20 May | 168 | 20.5 | 121 | Columbia PFC | 0 | 100 | 12.8 | 12.4 | 19.3 |
| 21 May | 136 | 21 | 122 | Columbia PFC | 0 | 100 | 11 | 10 | 20 |
| 22 May | 363 | 19.1 | 162 | Tri-County Marina | 1 | 99.4 | 11.4 | 8.2 | 16.5 |
| 23 May | 381 | 21.2 | 160 | Tri-County Marina | 1 | 99.4 | 9.8 | 7.9 | 19.9 |
| 23 May | 381 | 21 | 160 | Tri-County Marina | 2 | 98.7 | 10 | 13.5 | 21 |
| 24 May | 889 | 21.9 | 150 | Tri-County Marina | 3 | 98 | 13.2 | 11 | 21.7 |
| 24 May | 889 | 21.2 | 155 | Columbia PFC | 1 | 99.4 | 12 | 9.8 | 21.5 |
| 24 May | 889 | 19.9 | 150 | Columbia PFC | 0 | 100 | 12.6 | 10.2 | 19.8 |
| 24 May | 889 | 21 | 158 | Columbia PFC | 0 | 100 | 10 | 11 | 21 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| *Transported from the West Lift, continued.* | | | | | | | | | |
| 24 May | 889 | 22 | 159 | Columbia PFC | 0 | 100 | 11.8 | 15 | 23 |
| 24 May | 889 | 21.2 | 84 | Columbia PFC | 0 | 100 | 10.5 | 10.9 | 22.8 |
| 25 May | 204 | 23.2 | 103 | Columbia PFC | 0 | 100 | 11.2 | 9.2 | 23.1 |
| 26 May | 129 | 22.2 | 114 | Tri-County Marina | 1 | 99.1 | 12.2 | 13.2 | 23 |
| 27 May | 233 | 23.1 | 150 | Tri-County Marina | 2 | 98.7 | 12.7 | 12.7 | 23.4 |
| 28 May | 269 | 23 | 142 | Columbia PFC | 0 | 100 | 11 | 9.6 | 21 |
| 28 May | 269 | 22.2 | 113 | Columbia PFC | 0 | 100 | 11 | 7.2 | 20.5 |
| 29 May | 291 | 24 | 156 | Columbia PFC | 4 | 97.4 | 13.2 | 10 | 21.5 |
| 29 May | 291 | 24.9 | 124 | Columbia PFC | 0 | 100 | 12.4 | 10.2 | 22.5 |
| 30 May | 144 | 22.5 | 138 | Tri-County Marina | 0 | 100 | 10.2 | 12.9 | 22.6 |
| 31 May | 500 | 24 | 135 | Columbia PFC | 0 | 100 | 10.5 | 7.6 | 20 |
| 31 May | 500 | 23.8 | 150 | Columbia PFC | 2 | 98.7 | 11.9 | 9.2 | 20 |
| 31 May | 500 | 24 | 153 | Columbia PFC | 1 | 99.3 | 13.4 | 9.2 | 21 |
| 1 Jun | 361 | 23 | 125 | Columbia PFC | 0 | 100 | 12.3 | 8.4 | 21.9 |
| 1 Jun | 361 | 23.5 | 138 | Columbia PFC | 0 | 100 | 11.2 | 9.8 | 22 |
| 2 Jun | 153 | 24.2 | 94 | Columbia PFC | 2 | 97.9 | 11.7 | 7.3 | 23.2 |
| 4 Jun | 266 | 24 | 149 | Columbia PFC | 5 | 96.6 | 15 | 9 | 23 |
| 5 Jun | 143 | 24 | 125 | Columbia PFC | 0 | 100 | 12.5 | 12 | 24 |
| 6 Jun | 151 | 25.1 | 143 | Columbia PFC | 0 | 100 | 10 | 7.9 | 24.1 |
| 8 Jun | 146 | 25.8 | 125 | Columbia PFC | 0 | 100 | 9.2 | 8.2 | 25.7 |
| TOTAL, WEST LIFT | | | 12,212 | | 53 | | | | |
| | | | 55,766 | | 223 | | | | |

Table 12

Summary of transports of river herring from the Conowingo Dam Fish Lifts, 3 April through 11 June, 1995.

| DATE | SPECIES | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | DO (PPM) START | DO (PPM) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Transported from Location 620* | | | | | |
| 10 Apr | ALEWIFE | - | 12.8 | 8 | Tri-County Marina | 0 | 100 | 9.2 | 12.4 | 13 |
| 11 Apr | ALEWIFE | - | 12 | 8 | Tri-County Marina | 0 | 100 | 12 | 13.5 | 12 |
| 13 Apr | ALEWIFE | - | 11.2 | 5 | Tri-County Marina | 0 | 100 | 13 | 12.6 | 12 |
| 20 Apr | ALEWIFE | - | 13.5 | 111 | Tri-County Marina | 0 | 100 | 12 | 13 | 14 |
| 15 May | BLUEBACK HERRING | - | 20 | 20 | Tri-County Marina | 0 | 100 | 9.6 | 7 | 18.2 |
| 2 Jun | BLUEBACK HERRING | - | 19.8 | 85 | Columbia PFC | 0 | 100 | 11.8 | 9 | 20.1 |
| 3 Jun | BLUEBACK HERRING | - | 24 | 12 | Columbia PFC | 0 | 100 | 11.5 | 6.3 | 24.9 |
| | LOCATION 620 TOTAL | | | 249 | | 0 | | | | |
| | | | | | *Transported from the East Lift* | | | | | |
| 29 Apr | ALEWIFE | 4 | 16.8 | 3 | Tri-County Marina | 0 | 100 | 13.2 | 10.3 | 19.3 |
| | EAST LIFT TOTAL | | | 3 | | 0 | | | | |
| | | | | | *Transported from the West Lift* | | | | | |
| 23 Apr | ALEWIFE | 1,021 | 15.5 | 299 | Tri-County Marina | 0 | 100 | 12 | 12.3 | 15.8 |
| 24 Apr | ALEWIFE | 197 | 14 | 1,000 | Muddy Creek | 3 | 99.7 | 11.2 | 11.8 | 14.5 |
| 26 Apr | ALEWIFE | 27 | 16 | 713 | Little Contestoga Creek | 3 | 99.6 | 10.2 | 10.4 | 16.4 |
| 1 May | BLUEBACK HERRING | 6,274 | 16.5 | 936 | Columbia PFC | 0 | 100 | 12 | 10.4 | 15.4 |
| 1 May | BLUEBACK HERRING | 6,274 | 16.5 | 402 | Columbia PFC | 0 | 100 | 8 | 11 | 15 |
| 1 May | BLUEBACK HERRING | 6,274 | 17.4 | 1,215 | Columbia PFC | 0 | 100 | 9.8 | 11.5 | 15 |
| 1 May | BLUEBACK HERRING | 6,274 | 17.5 | 1,101 | Columbia PFC | 2 | 99.8 | 17 | 14.5 | 10.5 |
| 1 May | ALEWIFE | 598 | 16.5 | 104 | Columbia PFC | 0 | 100 | 12 | 10.4 | 15.4 |
| 1 May | ALEWIFE | 598 | 16.5 | 45 | Columbia PFC | 0 | 100 | 8 | 11 | 15 |
| 1 May | ALEWIFE | 598 | 17.4 | 135 | Columbia PFC | 0 | 100 | 9.8 | 11.5 | 15 |
| 1 May | ALEWIFE | 598 | 17.5 | 122 | Columbia PFC | 0 | 100 | 17 | 14.5 | 10.5 |
| 3 May | BLUEBACK HERRING | 2,764 | 17 | 947 | Columbia PFC | 0 | 100 | 12.8 | 10.9 | 14.9 |
| 3 May | BLUEBACK HERRING | 2,764 | 18 | 700 | Columbia PFC | 0 | 100 | 11.4 | 12 | 18.1 |
| 3 May | BLUEBACK HERRING | 2,764 | 17 | 1,218 | Columbia PFC | 0 | 100 | 15.2 | 11.7 | 15 |
| 3 May | ALEWIFE | 530 | 17 | 223 | Columbia PFC | 0 | 100 | 12.8 | 10.9 | 14.9 |
| 3 May | ALEWIFE | 530 | 18 | 100 | Columbia PFC | 0 | 100 | 11.4 | 12 | 18.1 |
| 3 May | ALEWIFE | 530 | 17 | 239 | Columbia PFC | 0 | 100 | 15.2 | 11.7 | 15 |
| 4 May | BLUEBACK HERRING | 3,901 | 16 | 1,028 | Columbia PFC | 0 | 100 | 12 | 13 | 16.2 |
| 5 May | BLUEBACK HERRING | 2,917 | 17 | 1,036 | Columbia PFC | 0 | 100 | 11.5 | 13.5 | 17 |
| 7 May | BLUEBACK HERRING | 29,370 | 17.5 | 1,277 | Columbia PFC | 0 | 100 | 14 | 12 | 15.5 |
| 7 May | BLUEBACK HERRING | 29,370 | 17.5 | 1,535 | Glen Cove Marina | 0 | 100 | 12 | 12.5 | 18 |
| 7 May | BLUEBACK HERRING | 29,370 | 17.5 | 1,595 | Glen Cove Marina | 0 | 100 | 11.5 | 12.8 | 17.5 |
| 7 May | BLUEBACK HERRING | 29,370 | 18 | 2,000 | Glen Cove Marina | 0 | 100 | 12 | 14 | 17.5 |
| 7 May | BLUEBACK HERRING | 29,370 | 17.5 | 2,000 | Glen Cove Marina | 0 | 100 | 12 | 12.5 | 17.5 |
| 11 May | BLUEBACK HERRING | 91 | 19 | 330 | Columbia PFC | 0 | 100 | 14 | 11.2 | 8.3 |
| 14 May | BLUEBACK HERRING | 1,323 | 18.1 | 400 | Glen Cove Marina | 0 | 100 | 12.2 | 9.4 | 17.9 |
| 15 May | BLUEBACK HERRING | 607 | 19 | 303 | Tri-County Marina | 0 | 100 | 16.8 | 8 | 17.8 |
| 4 Jun | BLUEBACK HERRING | 16 | 24 | 3 | Columbia PFC | 0 | 100 | 15 | 9 | 23 |
| 5 Jun | BLUEBACK HERRING | 51 | 24 | 41 | Columbia PFC | 0 | 100 | 12.5 | 12 | 24 |
| 6 Jun | BLUEBACK HERRING | 6 | 25.1 | 8 | Columbia PFC | 0 | 100 | 10 | 7.9 | 24.1 |
| | WEST LIFT TOTAL | | | 21,055 | | 8 | | | | |
| | COMBINED TOTAL | | | 21,307 | | 8 | | | | |

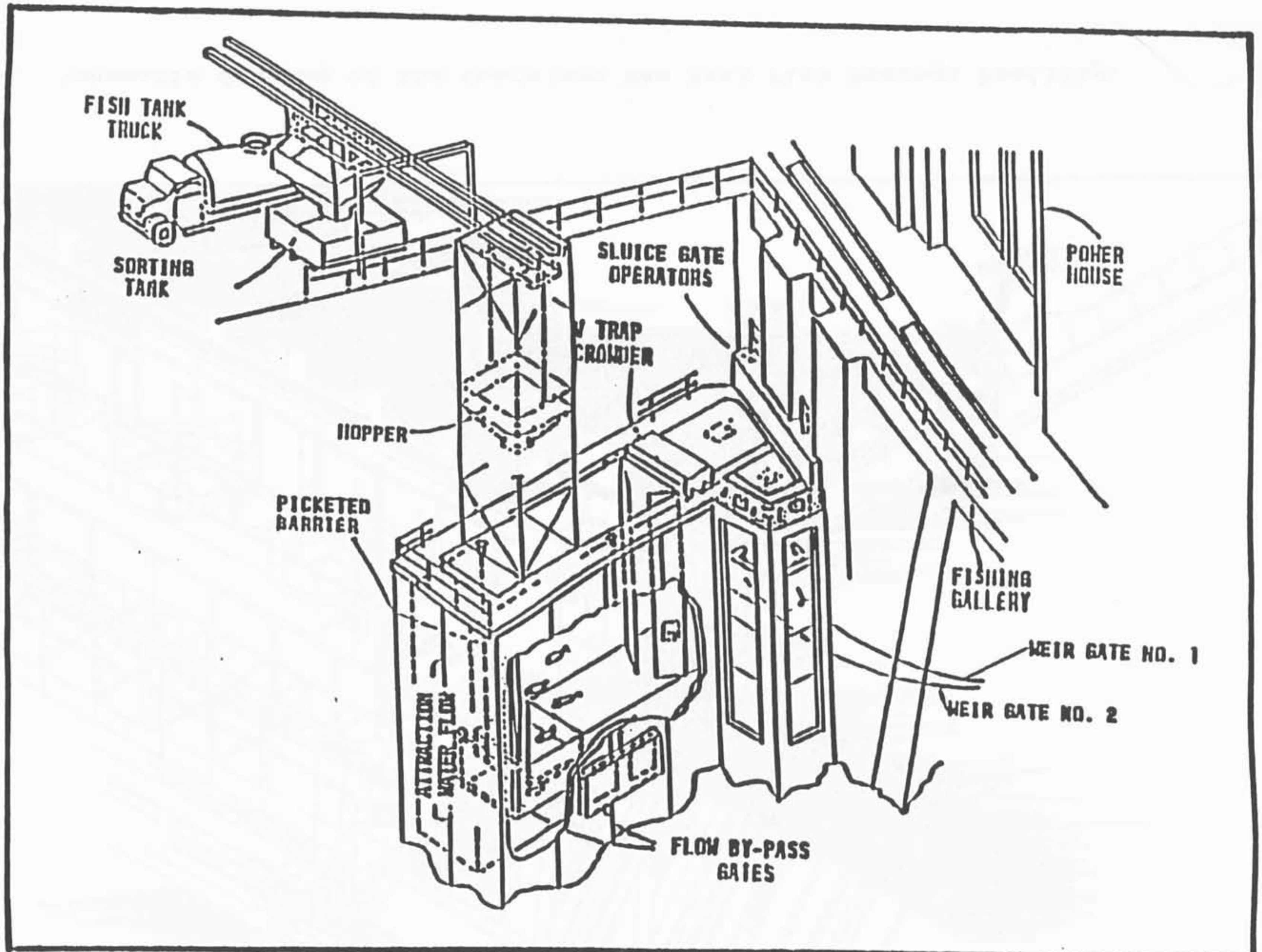



Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

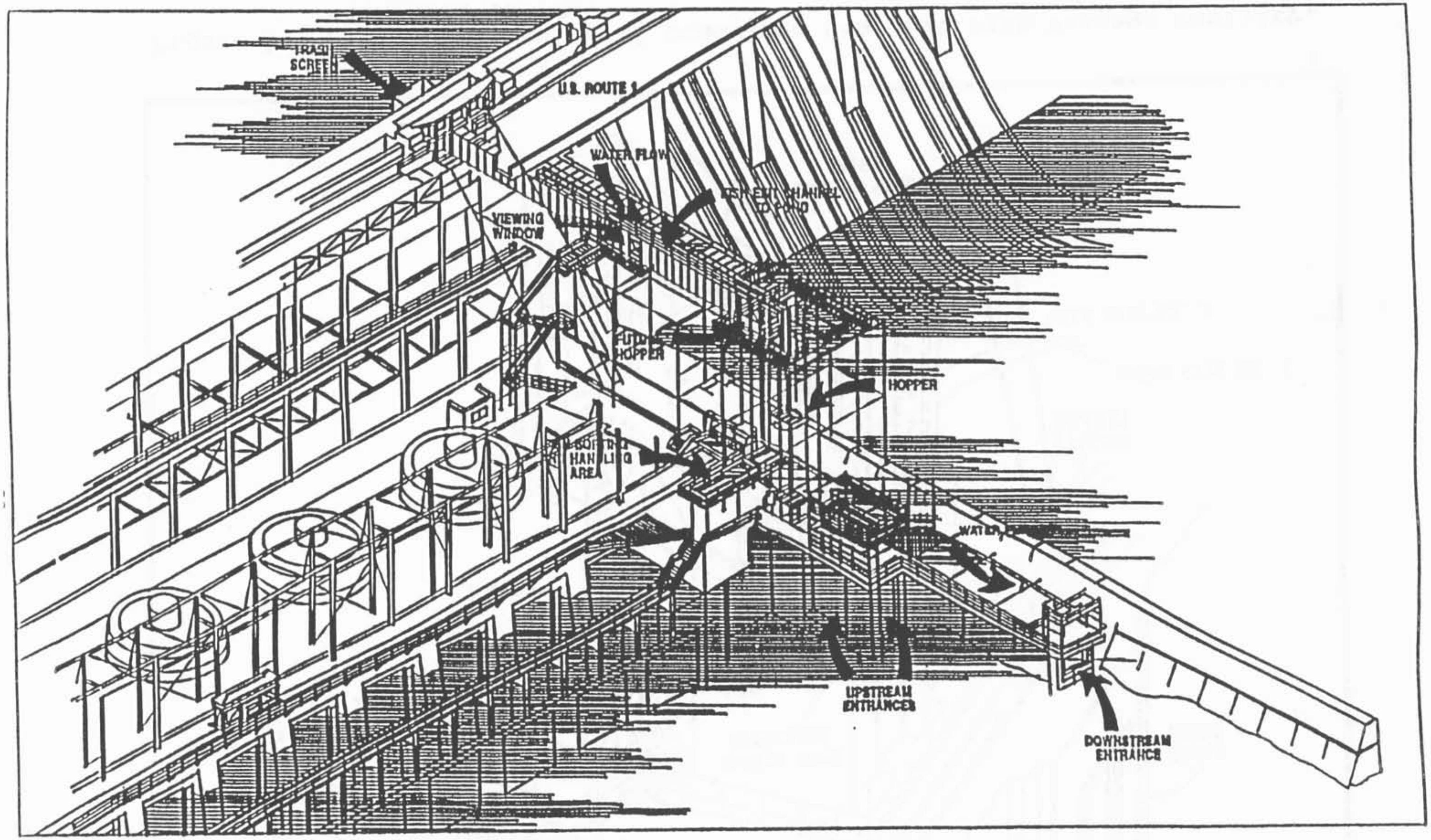



Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

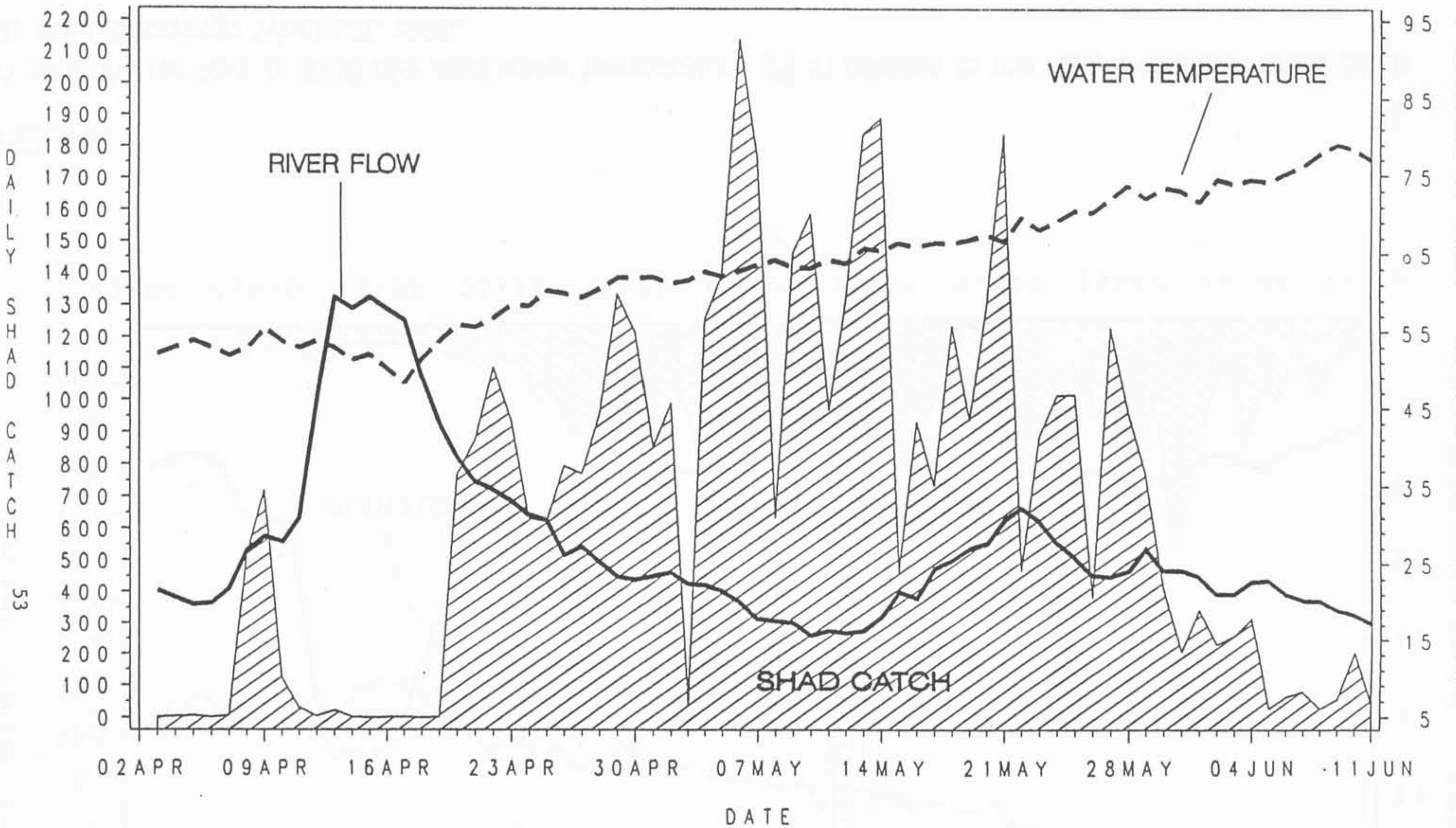



FIGURE 3

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, 1995.

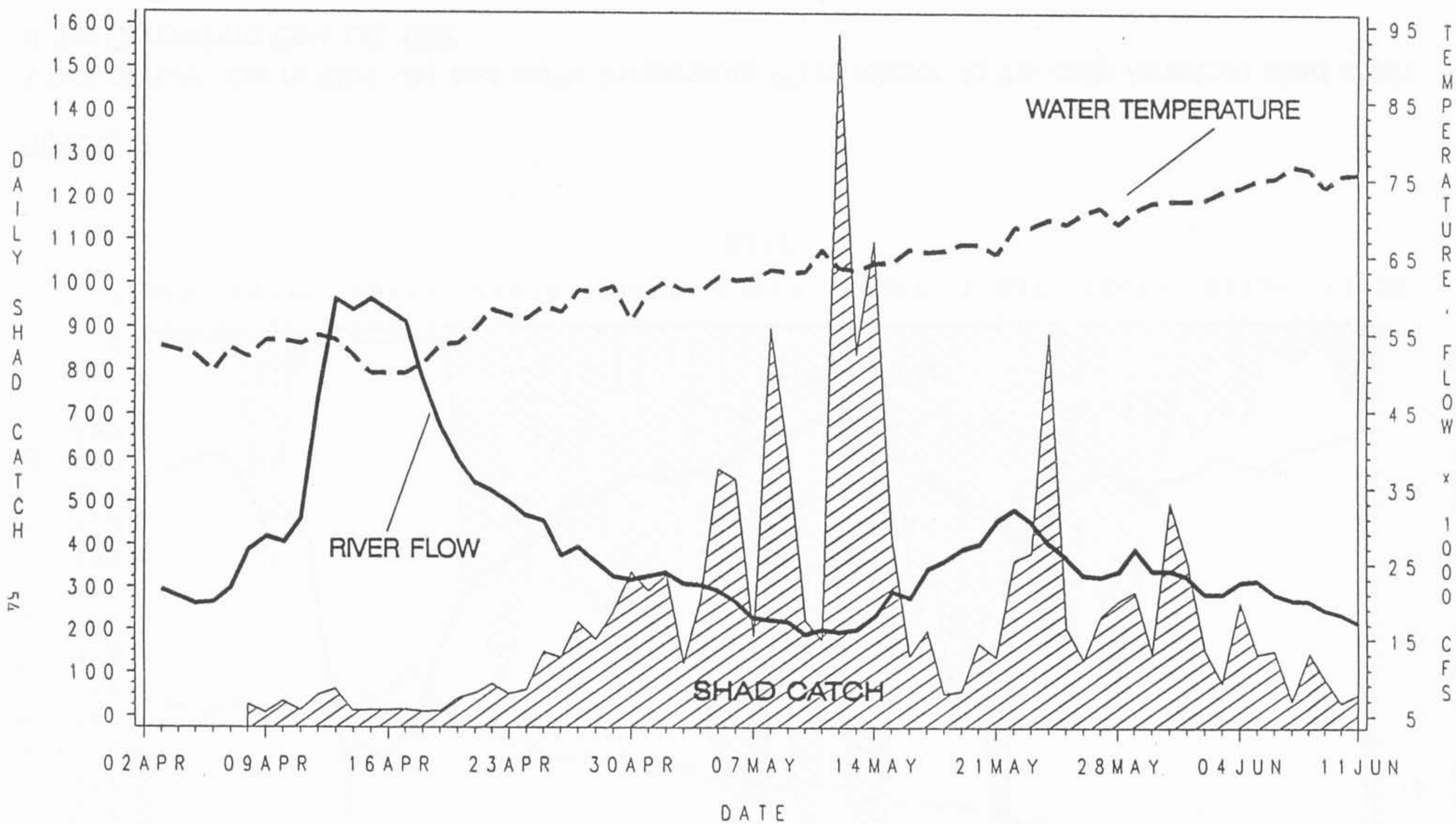



FIGURE 4

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, 1995.

## JOB II.

## AMERICAN SHAD EGG COLLECTION PROGRAM

**THE WYATT GROUP, Inc.**

**Lancaster, Pennsylvania**

## INTRODUCTION

Since 1980 some 453 million eggs have been obtained as part of the Susquehanna River anadromous fish restoration program. Annual production has ranged from 11 to 52 million eggs per year. The Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) goal for 1995 was to obtain a minimum of 30 million shad eggs from the Delaware River and the Hudson River. The 1995 program included an exploratory effort to secure more collection sites on the Hudson River.

Collection began in the last week of May and continued until the last week in June. It terminated when the quantity of eggs (less than five liters per day) did not justify further shipments to the Pennsylvania Fish & Boat Commission, Van Dyke Hatchery, Thompsontown, Pennsylvania. Throughout the sampling program, timely communication was maintained with resource agency biologists to assess the progress of the program and to alert hatchery staff to volume of eggs to be delivered.

## METHODS

### **Delaware River** (Pennsylvania-New Jersey)

SRAFRC secured permission from the Delaware River Basin Fish and Wildlife Management Cooperative (New Jersey), to collect up to 15 million shad eggs from the Delaware River. Biologists from the Pennsylvania Fish and Boat Commission and Ecology

III, Inc.(Berwick, PA) conducted the collection and spawning programs.

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

Shad were captured with gill-nets set parallel to the current between dusk and midnight. Ten to seventeen nets were set each night of sampling. Each net measured 200 x 6-foot with meshes of 4.5 to 5.5 inches.

**Hudson River** (New York)

**Production Program**

Sampling was either for production or exploratory in nature (see below). Production efforts were concentrated primarily at two sites, Rogers Island (River Mile 114) for haul seining and off Cheviot, NY (River Mile 106) for gill-netting. The exploratory work involved searching for new sites to supplement efforts at the latter locations.

Collection of American shad on the Hudson River was by either anchored gill-nets or haul seine. Gill-netting and haul seining alternated with the changing tidal conditions. Sampling at the Rogers Island by haul seine is an effective method at the low slack tide. Gill-netting is influenced by tidal condition because of changes in water depth at sites that have spawning habitat. Traditionally, gill-netting is most effective at high slack tide. It is especially effective after dusk.

Monofilament gill-nets, 600-foot x 6-foot with 4.5 inch to 5.75 inch stretch mesh, were set beginning just before dark, tide permitting. Net lengths of 1,800 - 2400 feet 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 parallel to the shoreline in deeper water at the edge of the main channel where the river was narrow. Water depth for anchored nets ranged from 4-12 feet.

A 500 x 12-foot haul seine with 2-inch stretch mesh was used at Rogers Island. Seine operations were conducted on an ebb tide, between late afternoon and dusk. With this tidal condition, a landing site was avaible where the catch could be beached and processed.

## Exploritory Program

### Background

Since 1988, the effort on the Hudson River has been directed at maximum egg production at primarily two locations (Rogers Island and Cheviot). One boat crew has either engaged in gill-netting or haul seining to capture ripe shad. Only occasionally has sampling been conducted at other locations, usually near the end of the spawning season when catches decreased at traditional sites.

All efforts to capture shad on the Hudson River have provided an understanding of the spawning habits and habitat of the American shad. With declining egg numbers from the primary sites, and the elimination of the Connecticut River as a source of eggs, a goal for 1995 was to examine other areas on the Hudson River for the potential of egg collection. The Wyatt Group, therefore, employed a second crew to mount an expanded sampling effort. Its design was based on previous Hudson River experience.

### Sampling Locations

Various sections of the River between Castleton-on-Hudson (RM 137) and Kingston-Rhinecliff, NY (RM 95) were sampled by gill-net to find areas where spawning shad concentrated (Maps 1-5). Ultimately, sites at Castleton-on-Hudson (RM 137) and Glasco (RM 102) proved to be very productive (see Results). Other areas sampled included: Upper/Green Flats (RM 104), off Inbocht Bay (RM 110) Roeliff Jansen Kill Creek/Catskill Creek area (RM 113), Athens (RM 117) and Coxsackie (RM 123).

### Sampling Schedule

Sampling was conducted before and during the spawning period. The effort was organized by river section in an order of priority that reflected probability of success based on past experience. Sites most similar in character to historic shad spawning grounds were sampled first. Tidal charts were also used as a guide to determine when and where suitable conditions existed to collect spawning shad.

### Sampling Gear

Shad were collected by anchored gill nets. Each net was up to 600 feet long with 4 to 5.5 inch mesh. Up to 2,400 feet of net was used each night. Nets were tended on a continuous basis after an approximately 45-60 minute period of set.

### Sampling Conditions

The expansion program began when water temperature was 49°F. Shad are available in the sections of river sampled about one month previous to the spawning season. The goal was to locate large numbers of pre-spawned shad. Potential sites were sampled again when water temperature exceeded 55°F.

Sampling was conducted between 6:00 P.M. and 4:00 A.M. The most productive time of day to collect spawning shad is usually in a 4-hour period beginning at dusk. On the Hudson, in 1995, it was from 8:00 P.M. to midnight. Efforts were made as late as 4:00 A.M.

## PROCESSING SHAD

The processing methods used to obtain shad eggs have been described in previous reports of SRAFRC (e.g., see SRAFRC, 1994 Annual Report). Briefly, ripe shad are removed from nets, separated by sex, and placed into tubs of water. Eggs are gently stripped into plastic pans and fertilized using sperm from several males. A small amount of water is added and gametes are gently mixed by hand. Following several washings, eggs are placed into containers with clean water and allowed to harden for up to 2 hours. Water-hardened eggs are poured into double plastic bags (5 liters of eggs and 5 liters of water), oxygen is added, and containers are delivered nightly to the Van Dyke Hatchery by vehicle.

## RESULTS

The total number of eggs collected from the Delaware and Hudson rivers was 24.43 million. This represents the highest total since 1991 when 29.81 million were collected (Table 1). The total number of eggs delivered to the Van Dyke Hatchery was 22.13 million. Some 2.3 million eggs were provided to the Maryland Department of Natural Resources, Manning Hatchery through cooperative efforts of SRAFRC and the Pennsylvania Fish and Boat Commission.

### **Delaware River** (Pennsylvania-New Jersey)

Gill netting began on 2 May at a water temperature of 54 °F. No eggs were collected. Sampling was discontinued until 14 May. A shipment of 0.85 million was made on this date. Sampling then continued until 31 May.

A total of 12.1 million eggs was collected on from the Delaware River (Table 2). Some 10.75 million eggs was shipped to the Van Dyke Hatchery and 1.34 million were shipped to Manning Hatchery. More than one million eggs were shipped on 4 of 13 dates.

Overall egg viability was 44.9% (Table 2). In the water temperature range of 61-63°F, it averaged 76.8%. It decreased substantially (to 32.4%) when shad were collected at water temperatures higher than 64 °F.

**Hudson River** (New York)

The Hudson River egg collection program began on 25 April and continued until 25 May. The total effort included 35 days of gill-netting and 6 days of haul seining.

Egg production on the Hudson River was 52% higher than in 1994. A total of 12.94 million eggs was obtained (Table 3). This included 9.13 million eggs from shad captured by gill-net and 2.71 million eggs from shad captured by haul seine. A total of 1.1 million eggs were provided to Manning Hatchery.

Egg viability averaged 62%. Best viability was achieved after water temperature exceeded 55 °F. Average egg viability under these condition was 71.4%.

In the exploritory effort, six new areas of the River (Glasco, Green /Upper Flats, Imbocht Bay/ Roe Jan Creek area, Athens, Castleton-on-Hudson and Coxsackie) were sampled (Table 4). This represented exploritory sampling of a 25 mile stretch of river (RM 102 to RM 137). Gill-netting was conducted from 25 April until 30 April when water temperature was less than 54 °F. During this period sampling was made to find concentrations of pre-spawned shad. Shad were captured at all locations but not in large numbers. On 3 May, gill-netting was conducted at Castleton-on-Hudson (RM 137) when water temperature was

54 °F. A total of 0.86 million eggs were taken on the first effort.

With the onset of water in the range of spawning temperature (54°F), sampling at traditional sites (Cheviot and Rogers Island) commenced. However, exploritory efforts continued through a return to previous sites. Gill-netting at Castleton and Glasco (RM 102) were productive. The success at Castleton warranted a significant sampling effort and it was sampled on 11 days between 3 and 18 May. A total of 7.15 million eggs was collected.

Effort shifted from Castleton to Glasco beginning 20 May, even though Castleton was productive. This strategy was engaged because of the requirements of the exploratory program. From 20 - 25 May, 0.47 million eggs were collected at Glasco..

The exploratory program was effective in finding new sites that could produce relatively large numbers of spawning shad on a consistent basis. Especially important about the site at Castleton is that it can be sampled somewhat regardless of tidal conditions. Unlike the traditional site at Cheviot, water depth at low tide is still suitable for gill netting.

TABLE 1. Total number (millions) of American shad eggs collected from various rivers and delivered to the Van Dyke Hatchery, 1980-1995.

| Year | Delaware | Hudson | Connecticut | Columbia | Other* | Totals |
|---|---|---|---|---|---|---|
| 1980 | - | - | - | - | 13.56 | 13.56 |
| 1981 | - | - | - | 5.78 | 5.84 | 11.62 |
| 1982 | - | - | - | 22.57 | 3.28 | 25.85 |
| 1983 | 2.40 | 1.17 | - | 19.51 | 11.40 | 34.48 |
| 1984 | 2.64 | - | - | 27.88 | 10.57 | 41.09 |
| 1985 | 6.16 | - | - | 12.06 | 7.33 | 25.55 |
| 1986 | 5.86 | - | - | 39.97 | 6.69 | 52.52 |
| 1987 | 5.01 | - | - | 23.53 | 4.46 | 33.00 |
| 1988 | 2.91 | - | - | 26.92 | 1.97 | 31.80 |
| 1989 | 5.96 | 11.18 | - | 23.11 | 2.44 | 42.69 |
| 1990 | 13.15 | 14.53 | - | - | 0.94 | 28.62 |
| 1991 | 10.74 | 17.66 | 1.10 | - | 0.31 | 29.81 |
| 1992 | 9.60 | 3.00 | 5.71 | - | 0.17 | 18.48 |
| 1993 | 9.30 | 2.97 | 7.44 | - | 1.78 | 21.49 |
| 1994 | 10.27 | 6.29 | 4.10 | - | 0.56 | 21.22 |
| 1995 | 10.75 | 11.85 | - | - | - | 22.60 |
| TOTALS | 94.75 | 68.65 | 18.35 | 201.33 | 71.30 | 454.38 |

*Primarily the Pamunkey River and the James River.

TABLE 2. Collection data for American shad eggs taken on the Delaware River, Pennsylvania, 1995.

| Date | Volume Eggs (liters) | Number of Eggs | PFC Shipment Number | Water Temp. (°F) | Percent Viability |
|---|---|---|---|---|---|
| May 14 | 30.0 | 840,554* | 11 | 59 | NA |
| 15 | 27.9 | 860,890 | 13 | 61 | 66.7 |
| 16 | 37.2 | 1,265,606 | 15 | 63 | 78.3 |
| 17 | 23.4 | 813,227 | 18 | 61 | 67.4 |
| 18 | 18.0 | 504,332* | 21 | 61 | NA |
| 21 | 42.9 | 1,398,084 | 25 | 63 | 54.9 |
| 22 | 41.8 | 1,179,301 | 27 | 64 | 48.7 |
| 23 | 38.0 | 1,636,971 | 30 | 66 | 21.0 |
| 24 | 12.0 | 522,056 | 32 | 68 | 28.8 |
| 25 | 25.0 | 878,075 | 33 | 68 | 34.4 |
| 29 | 14.6 | 512,796 | 34 | 66 | 53.3 |
| 30 | 17.5 | 799,392 | 35 | 66 | 45.6 |
| 31 | 14.2 | 886,340 | 36 | 70 | 11.3 |
| Total | 342.5 | 12,097,624* | 13 | $\bar{X}$ = 64 | $\bar{X}$ = 44.9 |
| Van Dyke | 294.5 | 10,752,738 | 11 | $\bar{X}$ = 65 | $\bar{X}$ = 44.9 |
| Manning | 48.0 | 1,344,886 | 2 | $\bar{X}$ = 60 | $\bar{X}$ = NA |

* Shipped to Maryland Department of Natural Resources, Manning Hatchery
NA Not Available

TABLE 3. Collection data for American shad eggs taken on the Hudson River, New York, 1995.

| Date | Volume Eggs (liters) | Number of Eggs | PFC Shipment Number | Water Temp. (°F) | Percent Viability | Gear |
|---|---|---|---|---|---|---|
| May 3 | 30.0 | 865,771 | 1 | 54 | 34.6 | Gill |
| 4 | 32.1 | 936,862 | 2 | 55 | 73.0 | Gill |
| 6 | 32.2 | 898,172 | 3 | 54 | 10.6 | Gill |
| 6 | 7.2 | 194,039 | 4 | 54 | 48.8 | Gill |
| 8 | 31.5 | 1,048,962 | 5 | 55 | 45.2 | Gill |
| 10 | 26.6 | 850,537 | 6 | 56 | 64.3 | Gill |
| 10 | 9.2 | 290,186 | 7 | 57 | 65.7 | Seine |
| 11 | 15.6 | 525,092 | 8 | 56 | 57.9 | Gill |
| 13 | 25.2 | 1,024,177 | 9 | 55 | 76.7 | Seine |
| 13 | 4.1 | 135,069 | 10 | 56 | 62.0 | Gill |
| 14 | 17.0 | 544,072* | 12 | 57 | NA | Seine |
| 15 | 24.6 | 801,699 | 14 | 56 | 73.0 | Seine |
| 16 | 35.4 | 1,104,404 | 16 | 57 | 78.3 | Gill |
| 16 | 17.4 | 598,319 | 17 | 57 | 76.5 | Seine |
| 17 | 25.2 | 786,186 | 19 | 58 | 74.7 | Gill |
| 17 | 1.6 | 50,467 | 20 | 59 | 83.2 | Gill |
| 18 | 17.0 | 544,073* | 22 | 60 | NA | Gill |
| 20 | 5.5 | 173,481 | 23 | 60 | 77.0 | Gill |
| 20 | 4.8 | 163,304 | 24 | 60 | 77.4 | Gill |
| 21 | 5.4 | 183,717 | 26 | 61 | 65.6 | Gill |
| 22 | 14.0 | 446,440 | 28 | 64 | 74.5 | Gill |
| 22 | 9.0 | 309,476 | 29 | 64 | 73.5 | Gill |
| 23 | 13.7 | 466,097 | 31 | 64 | 67.6 | Gill |
| Total | 404.3 | 12,940,601 | 23 | $\bar{x}$ = 58 | $\bar{x}$ = 62.0 | |
| Van Dyke | 370.3 | 11,852,456 | 21 | $\bar{x}$ = 58 | $\bar{x}$ = 62.0 | |
| Manning | 34.0 | 1,088,145 | 2 | $\bar{x}$ = 58 | $\bar{x}$ = NA | |

* Shipped to Maryland Department of Natural Resources, Manning Hatchery
NA Not Available

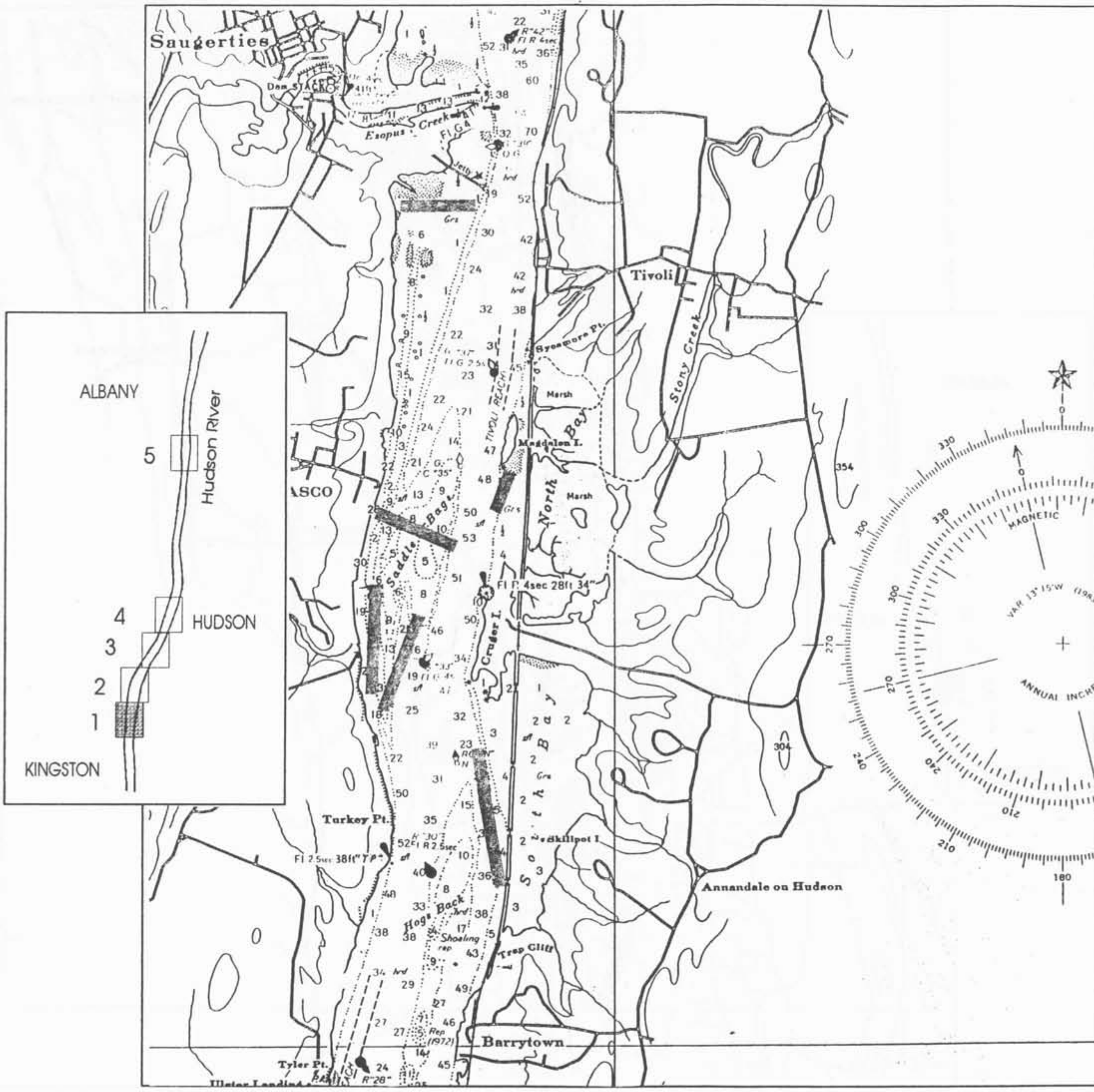
Table 4. Summary of American shad egg collections on the Hudson River ,1995.

| | WATER | | | | EGGS SHIPPED | | | SHAD COLLECTED | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | Date | Temp (F) | Tide | Depth (feet) | Liters | Number | Viability (%) | Roe | Males | Ripe |
| MAP 1 | | | | | | | | | | |
| Glasco | 25 Apr | 49 | High | 4-7 | - | - | - | 2 | 2 | 0 |
| Glasco | 15 May | 56 | Low | 2-7 | - | - | - | 12 | 5 | 0 |
| Glasco | 20 May | 60 | High | 7-10 | 4.80 | 163,304 | 77.40 | 32 | 59 | 6 |
| Glasco | 21 May | 61 | High | 7-10 | - | - | - | 27 | 18 | 0 |
| Glasco | 22 May | 64 | High | 7-12 | 9.00 | 309,476 | 73.50 | 40 | 16 | 14 |
| Glasco | 25 May | 64 | High | 7-12 | - | - | - | 4 | 3 | 1 |
| MAP 2 | | | | | | | | | | |
| Green Flats | 26 Apr | 51 | Low | 4-6 | - | - | - | 9 | 9 | 0 |
| Upper Flats | 30 Apr | 53 | High | 9-12 | - | - | - | 13 | 6 | 2 |
| Upper Flats | 9 May | 55 | High | 9-11 | - | - | - | 18 | 4 | 0 |
| Upper Flats | 9 May | 55 | High | 5-10 | - | - | - | 10 | 5 | 3 |
| Map 3 | | | | | | | | | | |
| Off Inbocht Bay | 27 Apr | 52 | Low | 4-12 | - | - | - | 3 | 11 | 3 |
| Below Roe Jan | 27 Apr | 52 | Low | 4-12 | - | - | - | 2 | 1 | 0 |
| Cheviot | 1 May | 54 | High | 5-7 | - | - | - | 8 | 12 | 0 |
| Cheviot | 6 May | 54 | High | 5-8 | 7.20 | 194,039 | 48.80 | 15 | 7 | 7 |
| Cheviot | 8 May | 54 | High | 5-8 | - | - | - | 20 | 35 | 3 |
| Cheviot | 20 May | 60 | High | 5-7 | 5.50 | 173,481 | 77.00 | 37 | 14 | 8 |
| Cheviot | 21 May | 61 | High | 5-7 | 5.40 | 183,717 | 65.60 | 19 | 17 | 4 |
| Cheviot | 22 May | 64 | High | 5-7 | 14.00 | 446,440 | 74.50 | 40 | 26 | 18 |
| Cheviot | 23 May | 64 | High | 5-7 | 13.70 | 466,097 | 67.60 | 21 | 12 | 14 |

Table 4. (Continued). Summary of American shad egg collections on the Hudson River.

| | WATER | | | | | EGGS SHIPPED | | | SHAD COLLECTED | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Date | | Temp (F) | Tide | Depth (feet) | Liters | Number | Viability (%) | Roe | Males | Ripe |
| Map 4 | | | | | | | | | | | |
| Athens | 29 | Apr | 52 | High | 6-12 | - | - | - | 7 | 3 | 0 |
| Athens | 14 | May | 57 | Low | 9-11 | - | - | - | 4 | 0 | 1 |
| Rogers Island | 10 | May | 57 | High | 0-20 | 9.20 | 290,186 | 65.70 | 600 | 250 | 7 |
| Rogers Island | 13 | May | 55 | High | 0-20 | 25.20 | 1,024,177 | 76.70 | 336 | 166 | 98 |
| Rogers Island | 14 | May | 57 | Low | 0-20 | 17.00 | 544,072 * | ?? | 350 | 158 | 19 |
| Rogers Island | 15 | May | 56 | Low | 0-20 | 24.60 | 801,699 | 73.00 | 80 | 26 | 26 |
| Rogers Island | 16 | May | 57 | Low | 0-20 | 17.40 | 598,319 | 76.50 | 65 | 27 | 22 |
| Rogers Island | 18 | May | 60 | High | 12 | - | - | - | 17 | 6 | 1 |
| Rogers Island | 24 | May | 64 | Low | 0-20 | - | - | - | 230 | 102 | 15 |
| MAP 5 | | | | | | | | | | | |
| Castleton | 3 | May | 54 | High | 7-9 | 30.00 | 865,771 | 34.60 | 92 | 6 | 32 |
| Castleton | 4 | May | 55 | High | 8-10 | 32.10 | 936,862 | 73.00 | 106 | 35 | 50 |
| Castleton | 6 | May | 54 | High | 8-10 | 32.20 | 898,172 | 10.60 | 92 | 23 | 58 |
| Castleton | 8 | May | 55 | High | 5-8 | 31.50 | 1,048,962 | 45.20 | 87 | 17 | 36 |
| Castleton | 10 | May | 56 | High | 7-9 | 26.60 | 850,537 | 64.30 | 82 | 42 | 51 |
| Castleton | 11 | May | 56 | High | 9-10 | 8.00 | 269,284 | 57.90 | 32 | 8 | 14 |
| Castleton | 11 | May | 56 | High | 9-10 | 7.60 | 255,808 | 57.90 | 38 | 15 | 6 |
| Castleton | 13 | May | 56 | Low | 5-9 | 4.10 | 135,069 | 62.00 | 35 | 5 | 14 |
| Castleton | 16 | May | 57 | High | 9-10 | 35.40 | 1,104,404 | 78.30 | 87 | 32 | 52 |
| Castleton | 17 | May | 58 | High | 7-10 | 25.20 | 786,186 | 74.70 | 65 | 11 | 48 |
| Castleton | 18 | May | 60 | High | 7-10 | 17.00 | 544,073 * | ?? | 53 | 20 | 33 |
| Coxsackie | 17 | May | 59 | High | 7-10 | 1.60 | 50,467 | 83.20 | 4 | 4 | 3 |
| Totals | | | 57 | | | 404.30 | 12,940,602 | 62.00 | 2,794 | 1,218 | 669 |

* Eggs provided to Manning Hatchery
?? Not Available




Source Map: N.O.A.A. Chart 12348, Edition #29.

Map 1 - Areas sampled for American shad by gill net or haul seine between Kingston and Barrytown, NY, 25 April through 25 May 1995.

Key:

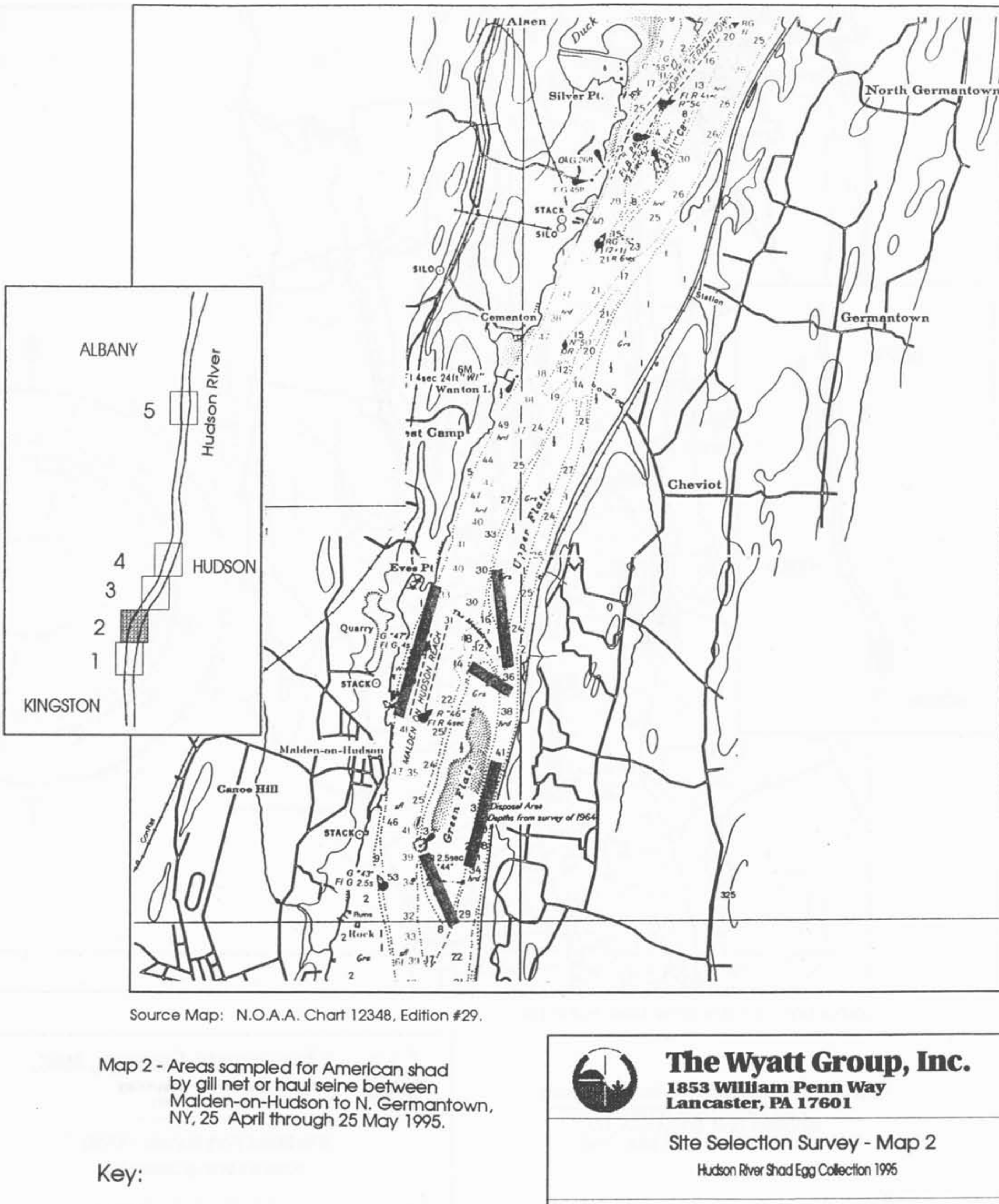
- Gill Net
- Haul Seine

**The Wyatt Group, Inc.**
**1853 William Penn Way**
**Lancaster, PA 17601**

Site Selection Survey - Map 1

Hudson River Shad Egg Collection 1995

| | |
|---|---|
| Barrytown, to Saugerties, NY | |
| Drawn by KEB | 11/16/95 |
| Approved by KWR | 11/16/95 |
| Filename: c:/client/srafrc/hud-map1.cdr | |




Source Map: N.O.A.A. Chart 12348, Edition #29.

Map 2 - Areas sampled for American shad by gill net or haul seine between Malden-on-Hudson to N. Germantown, NY, 25 April through 25 May 1995.

Key:

- Gill Net
- Haul Seine

**The Wyatt Group, Inc.**
**1853 William Penn Way**
**Lancaster, PA 17601**

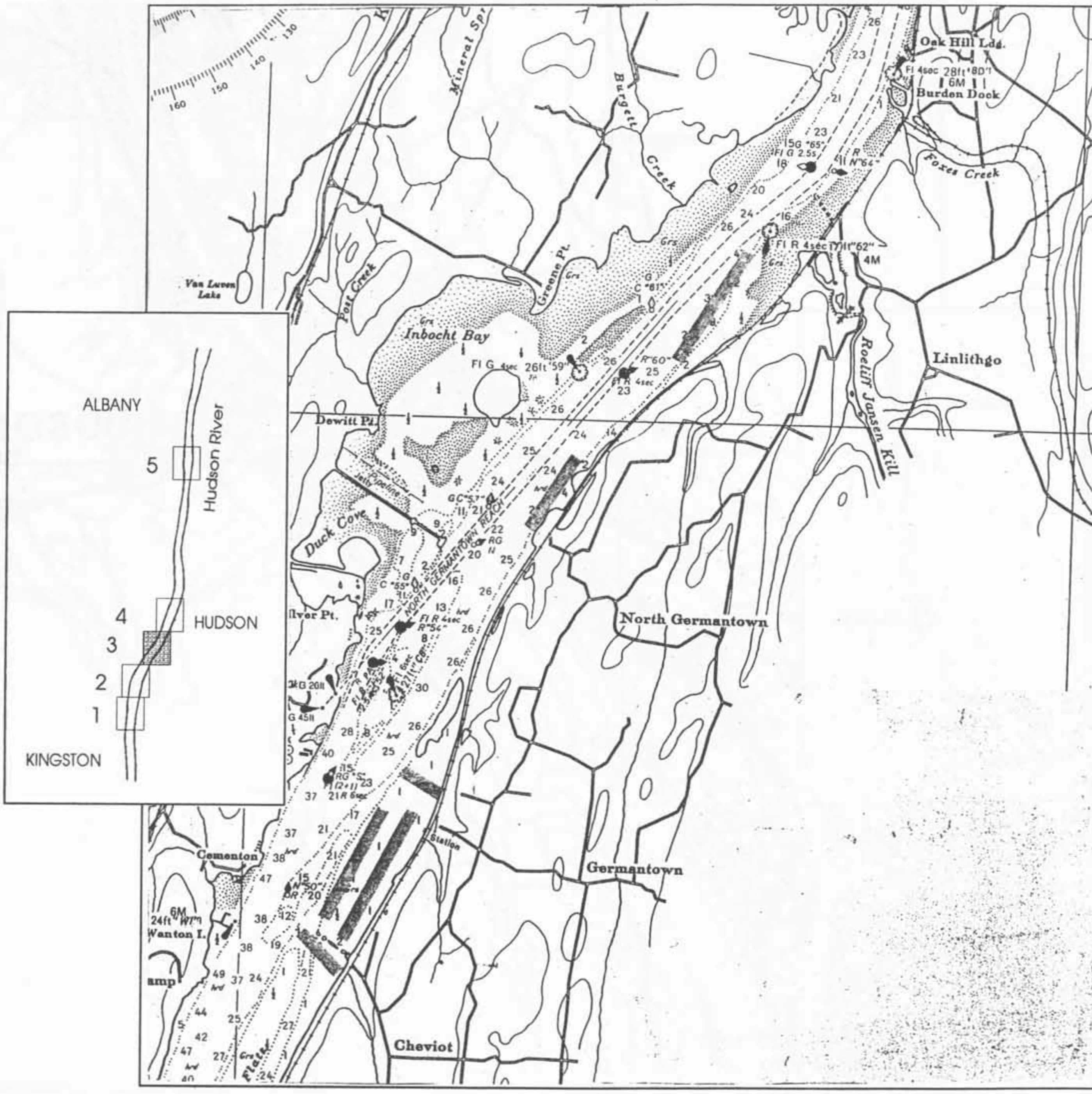
Site Selection Survey - Map 2

Hudson River Shad Egg Collection 1995

Malden-on-Hudson, to North Germantown, NY

| | |
|---|---|
| Drawn by KEB | 11/16/95 |
| Approved by KWR | 11/16/95 |

Filename: c:/client/srafrc/hud-map2.cdr




Source Map: N.O.A.A. Chart 12348, Edition #29.

Map 3 - Areas sampled for American shad by gill net or haul seine between Cheviot to Oak Hill Landing, NY, 25 April through 25 May 1995.

Key:

Gill Net

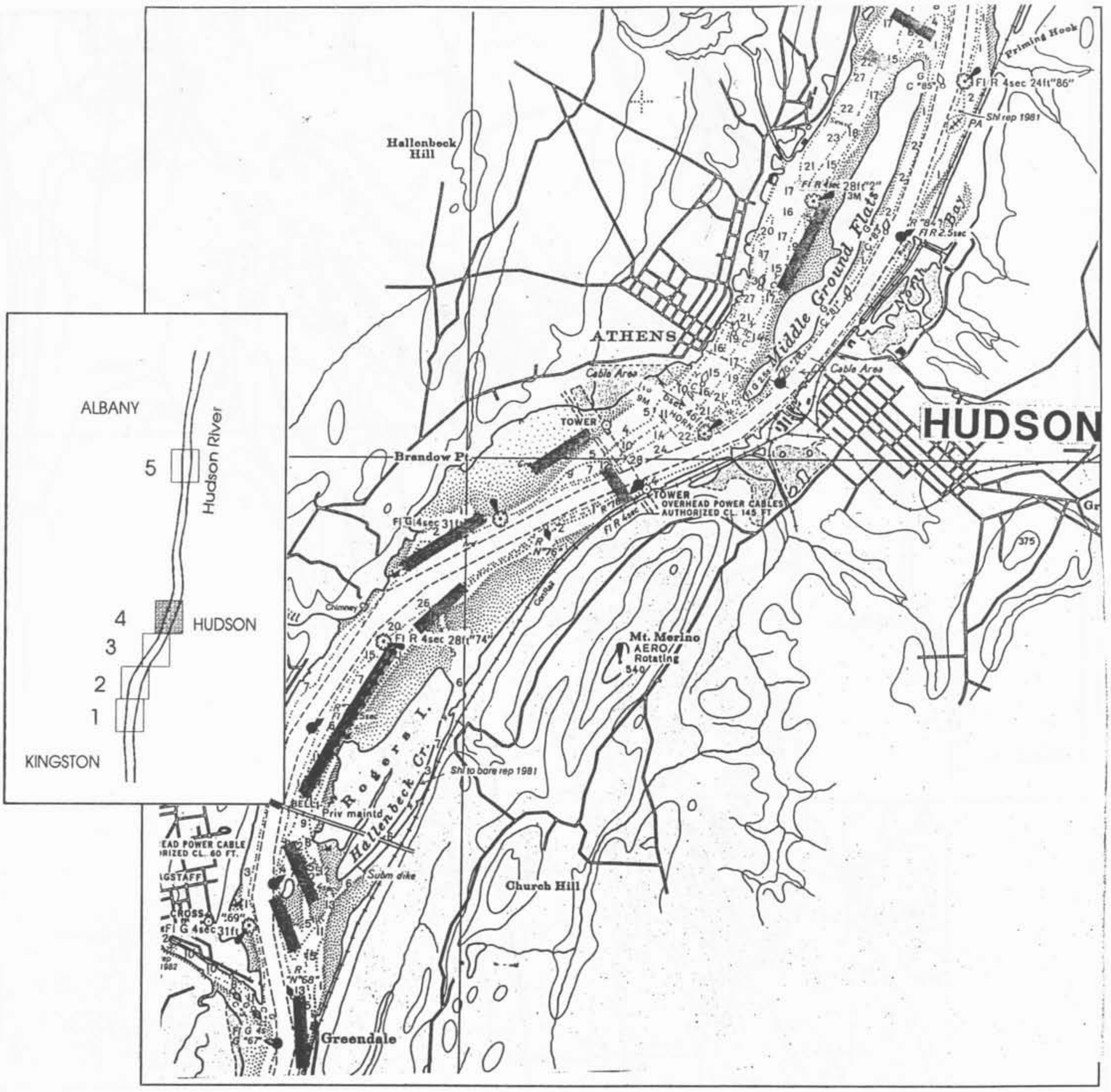
Haul Seine

**The Wyatt Group, Inc.**
**1853 William Penn Way**
**Lancaster, PA 17601**

Site Selection Survey - Map 3

Hudson River Shad Egg Collection 1995

| | |
|---|---|
| Cheviot, to Oak Hill Ldg., NY | |
| Drawn by KEB | 11/16/95 |
| Approved by KWR | 11/16/95 |
| Filename: c:/client/srafrc/hud-map3.cdr | |




Source Map: N.O.A.A. Chart 12348, Edition #29.

Map 4 - Areas sampled for American shad by gill net or haul seine between Greendale to Hudson, NY, 25 April through 25 May 1995.

Key:

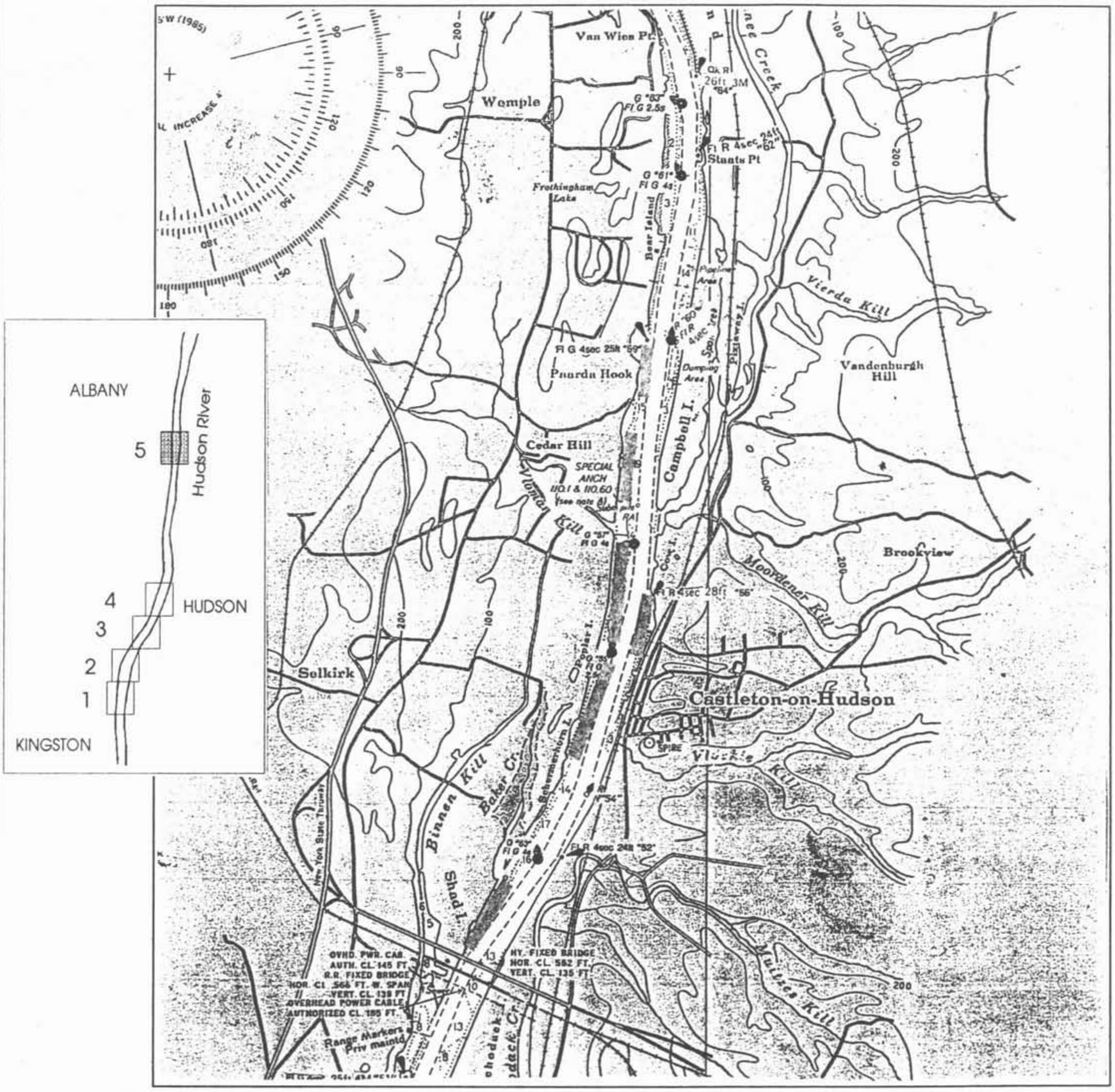
- Gill Net
- Haul Seine

**The Wyatt Group, Inc.**
**1853 William Penn Way**
**Lancaster, PA 17601**

Site Selection Survey - Map 4

Hudson River Shad Egg Collection 1995

| | |
|---|---|
| Greendale, to Hudson, NY | |
| Drawn by KEB | 11/16/95 |
| Approved by KWR | 11/16/95 |
| Filename: c:/client/srafrc/hud-map4.cdr | |




Source Map: N.O.A.A. Chart 12348, Edition #29.

Map 5 - Areas sampled for American shad by gill net or haul seine at Castelton-on-Hudson , NY, 25 April through 25 May 1995.

Key:

Gill Net
Haul Seine

**The Wyatt Group, Inc.**
**1853 William Penn Way**
**Lancaster, PA 17601**

Site Selection Survey - Map 5

Hudson River Shad Egg Collection 1995

| | |
|---|---|
| Castleton-on-Hudson | |
| Drawn by KEB | 11/16/95 |
| Approved by KWR | 11/16/95 |
| Filename: c:/client/srafrc/hud-map6.cdr | |

# JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1995

**Part 1**

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Benner Spring Fish Research Station
State College, PA

## INTRODUCTION

The Pennsylvania Fish and Boat Commission has operated the Van Dyke Research Station for Anadromous fishes since 1976 as part of an effort to restore diadromous fishes to the Susquehanna River 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 1995 were to stock 10-20 million American shad fry. All Van Dyke hatchery-reared American shad fry were marked by immersion in tetracycline bath treatments in order to distinguish hatchery-reared shad from those produced by natural spawning of transplanted adults.

Procedures were continued in 1995 to disinfect all eggs received at Van Dyke to prevent the spread of infectious diseases from out-of-basin sources. Research conducted in 1995 focused on development of techniques to mark American shad otoliths by five hour immersion of eggs in 1000 or 2000 mg/L oxytetracycline (Appendix 1), and comparison of survival of fry released in Conodoguinet Creek and Conestoga River with controls released at the mouths of those tributaries (Appendix 2).

## EGG SHIPMENTS

A total of 22.6 million eggs (747 L) were received in 36 shipments in 1995 (Table 1). This represented the largest number of eggs received since 1991 but was still well below the average of 34.6 million from 1982 to 1991 (Table 2). Overall egg viability (which we define as the percentage which ultimately hatches) was 53.9%.

Thirteen shipments of eggs were received at Van Dyke from the Delaware River (10.7 million eggs) with a viability of 44.9%. Five different sites were fished on the Hudson River, producing a total of 23 shipments (11.9 million eggs) with an overall viability of 62.0%. Low viability at the Castleton site is related to low viability of one shipment (shipment 3), not to some site-specific factor. Four shipments of eggs were delivered to MDNR's Manning Hatchery for culture there.

## SURVIVAL

Overall survival of fry was 91.2%, compared to 78% in 1994, 66% in 1993, 41% in 1992 and a range of 70% to 90% for the period 1984 through 1991. The increased survival was due primarily to the fact that most larvae were stocked at 7 days of age, before the onset of the critical period of high mortality from 9 to 14 days of age. Survival of individual tanks followed four patterns (Figure 1). Thirty-nine tanks exhibited 7d survival averaging 97.5%. Five tanks, reared to 19 to 23 days of age, exhibited survival of 83.7%, typical of high survival tanks in the past. Four tanks (G11, H21, D12, A12) suffered high mortality between 1 and 5 days of age which resulted in mean 7d survival of approximately 74%. One tank (A22) exhibited high mortality between 2 and 5 days of age, resulting in 7d survival of 24%.

The cause of these early mortality problems remains unknown. New open-cell foam bottom screens were used on all egg jars. This suggests that "old" foam was not the cause of the mortalities as was speculated by Hendricks and Bender (1994).

All the mortality problems noted in 1995 were associated with fry laying on the bottom of the tank, beginning the morning after hatch. This has been a common occurrence in the past and was thought to be related to decreases in water temperature or force-hatching the larvae too early, when the yolk-sac is too large. Most larvae tend to resume swimming after a day or two and if they don't lay on top of one another, mortality is minimal. Over the last two years we have been delaying hatch as much as possible to avoid the problem. In addition, we have been plumbing tanks with temporary "double down" influent pipes which direct a flow of water into the center "well" to prevent larvae from laying there and smothering each other. Both practices seem to reduce mortalities but do not prevent the problem.

The frequency of occurrence of mortality problems declined from 28 tanks in 1992 to 26 tanks in 1993, 4 tanks in 1994, and 5 tanks in 1995. We are hopeful that continued vigilance in fish culture hygiene will result in continued low frequency of the syndrome.

## FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 11.0 million. A total of 8.3 million was released in the Juniata River and 731 thousand in the Susquehanna River at Montgomery Ferry. American shad fry were stocked in tributaries for the first time, with 93 thousand in Muddy Creek, 220 thousand in Conodoguinet Creek, and 190 thousand in the Conestoga River. Uniquely marked controls were released in the Susquehanna River at the mouths of Conodoguinet Creek (230 thousand) and Conestoga River (198 thousand). In addition, 1 million fry were stocked in the Lehigh River to support restoration efforts there.

Some 24 thousand were transferred to raceways at Benner Spring for mark retention analysis. Thirty thousand were given to the Chesapeake Bay Foundation for experimental classroom culture as part of a public education initiative. One thousand each were transferred to the Conte Lab and the University of Massachusetts for research.

## 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 194 ppm oxytetracycline hydrochloride for 4h duration. Fry marking according to egg source was discontinued. All fry were marked according to stocking site. Fry stocked in the Juniata River or the Susquehanna River at Montgomery Ferry were marked at 5 days of age and stocked at 7-9 days of age. American shad fry were stocked in Conodoguinet Creek and the Conestoga River to support restoration efforts in those tributaries. Uniquely marked fry (controls) were also stocked at the mouths of those tributaries to evaluate relative survival for tributary stocking. Fry stocked in the Conodoguinet Creek were given a triple mark at 12, 15, and 18 days of age and stocked at 19 days of age. Fry stocked at the mouth of the Conodoguinet Creek were given a triple mark at 3, 13, and 17 days of age and stocked at 19 days of age. Fry stocked in the Conestoga River were given a quadruple mark at 3, 7, 15, and 19 days of age and stocked at 22 days of age. Fry stocked at the mouth of the Conestoga River were given a quadruple mark at 5, 9, 13, and 17 days of age and stocked at 22 days of age. Fry stocked in Muddy Creek were given a quadruple mark at 3, 13, 17, and 21 days of age and stocked at 22 days of age. Since the mouth of Muddy Creek is downstream from Holtwood Dam, there was no opportunity to capture marked fish in bio-monitoring collections, therefore no controls were stocked for Muddy Creek. Small lots of eggs were experimentally marked by 5 hour immersion in 1000 or 2000 mg/L oxytetracycline immediately after arrival at Van Dyke. They received additional marks by 4h immersion in 194 mg/L at 3 and 6 days of age.

Verification of mark retention was accomplished by stocking groups of marked fry in raceways and examining otolith samples collected later. Retention of tetracycline marks for American shad was 100% for all groups analyzed except the egg marking at 1000 mg/L (Table 6, Appendix 1).

## FINGERLING PRODUCTION

Fingerling production was discontinued in 1995 due to poor survival of fingerlings as evidenced by the lack of fingerling marks in otoliths from both juvenile and adult collections.

## SUMMARY

A total of 36 shipments (22.6 million eggs) was received at Van Dyke in 1995. Total egg viability was 53.9% and survival to stocking was 91.2%, resulting in production of 11.0 million fry. The majority of the fry were stocked in the Juniata River (8.3 million). Fry were also released in the Susquehanna River at Montgomery Ferry (731 thousand), Muddy Creek (93 thousand), Conodoguinet Cr. (220 thousand), Susquehanna River at the mouth of Conodoguinet Cr. (230 thousand), Conestoga River (198 thousand), Susquehanna River at the mouth of the Conestoga River, and the Lehigh River (1.0 million).

Overall survival of fry was 91.2%, up from 78% in 1994, 66% in 1993 and 41% in 1992. The increase in survival was largely due to stocking at an earlier age (7 days), before the onset of the critical period from 9 to 14 days of age. Survival was negatively impacted by minor re-occurrence of the mortality problems which occurred in 1992, 1993 and 1994. The cause of the problem remains unknown.

All American shad fry cultured at Van Dyke were marked by 4 hour immersion in 194 ppm oxytetracycline. Marks were assigned based on release site, regardless of egg source. Fry released in the Juniata River or the Susquehanna River at Montgomery Ferry were marked at 5 days of age and stocked at 7-9 days of age. Fry released in, or at the mouth of, tributaries received unique triple or quadruple marks and were stocked at 19-22 days of age. Retention of tetracycline marks was 100% for all production marks.

Immersion of American shad eggs for five hours in 1000ppm oxytetracycline produced marks in 2 of 20 specimens examined. Immersion in 2000ppm produced marks in 17 of 17 specimens examined, but subsequent analysis of wild-caught specimens revealed that autofluorescence in the nucleus, which could be mistaken for an egg mark, occurred in 44% of the specimens examined.

## RECOMMENDATIONS FOR 1995

1. Continue to disinfect all egg shipments at 80 ppm free iodine.
2. Continue to utilize Maryland's Manning Hatchery for production of marked fry and fingerlings for release below Conowingo Dam.
3. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
4. Continue to siphon egg shells from the rearing tank within hours of egg hatch.

5. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
6. Construct new foam bottom screens for Van Dyke jars each year.
7. Do not disinfect foam bottom screens prior to use.
8. Continue to hold Delaware River eggs until 8:00AM before processing.
9. Continue to maximize survival by stocking the majority of fry at 7 days of age.
10. Repeat the egg marking research using higher concentrations of oxytetracycline, and rear the specimens in ponds or raceways at least 100 days prior to mark analysis.

## LITERATURE CITED

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Figure 1. Survival of American shad fry, Van Dyke, 1995.

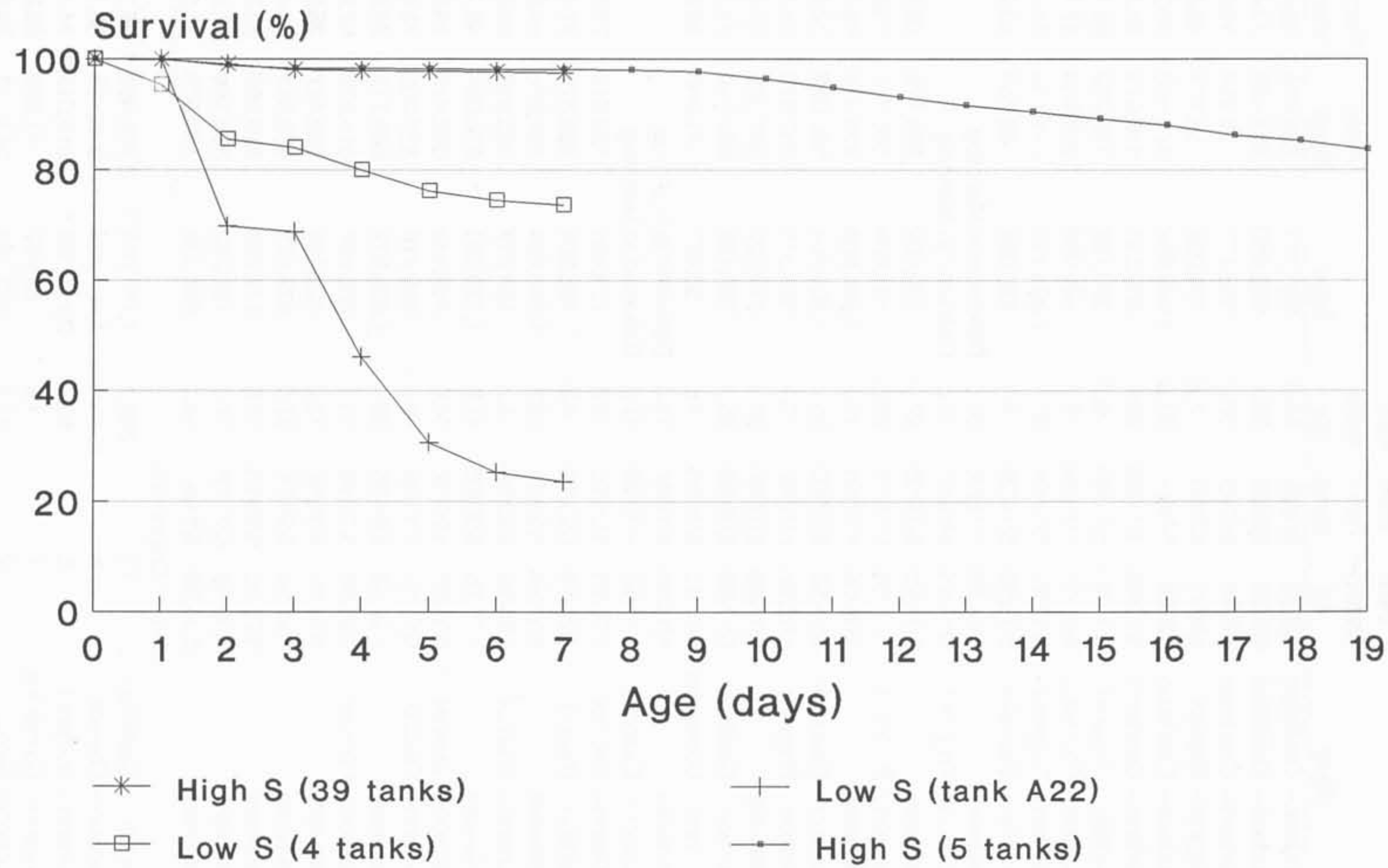

Table 1. American shad egg shipments, 1995.

| Shipment No. | River | Date Spawned | Date Received | Vol. Received (L) | Eggs | Viable Eggs | Percent Viable |
|---|---|---|---|---|---|---|---|
| 1 | Hudson– Castleton | 5/3/95 | 5/4/95 | 30.0 | 865,771 | 299,409 | 34.6% |
| 2 | Hudson– Castleton | 5/4/95 | 5/5/95 | 32.1 | 936,862 | 683,488 | 73.0% |
| 3 | Hudson– Castleton | 5/6/95 | 5/7/95 | 32.2 | 898,172 | 95,254 | 10.6% |
| 4 | Hudson– Cheviot | 5/6/95 | 5/7/95 | 7.2 | 194,039 | 94,754 | 48.8% |
| 5 | Hudson– Castleton | 5/8/95 | 5/9/95 | 31.5 | 1,048,962 | 474,003 | 45.2% |
| 6 | Hudson– Castleton | 5/10/95 | 5/11/95 | 26.6 | 850,537 | 546,814 | 64.3% |
| 7 | Hudson– Rogers I. | 5/10/95 | 5/11/95 | 9.2 | 290,186 | 190,779 | 65.7% |
| 8 | Hudson– Castleton | 5/11/95 | 5/12/95 | 15.6 | 525,092 | 303,830 | 57.9% |
| 9 | Hudson– Rogers I. | 5/13/95 | 5/14/95 | 25.2 | 1,024,177 | 785,134 | 76.7% |
| 10 | Hudson– Castleton | 5/13/95 | 5/14/95 | 4.1 | 135,069 | 83,763 | 62.0% |
| 11 | Delaware | 5/14/95 | 5/15/95 | 30.0 | Delivered to Manning | | |
| 12 | Hudson– Rogers I. | 5/14/95 | 5/15/95 | 17.0 | Delivered to Manning | | |
| 13 | Delaware | 5/15/95 | 5/16/95 | 27.9 | 860,890 | 574,176 | 66.7% |
| 14 | Hudson– Rogers I. | 5/15/95 | 5/16/95 | 24.6 | 801,699 | 585,231 | 73.0% |
| 15 | Delaware | 5/16/95 | 5/17/95 | 37.2 | 1,265,606 | 826,372 | 65.3% |
| 16 | Hudson– Castleton | 5/16/95 | 5/17/95 | 35.4 | 1,104,404 | 865,022 | 78.3% |
| 17 | Hudson– Rogers I. | 5/16/95 | 5/17/95 | 17.4 | 598,319 | 457,876 | 76.5% |
| 18 | Delaware | 5/17/95 | 5/18/95 | 23.4 | 813,227 | 548,399 | 67.4% |
| 19 | Hudson– Castleton | 5/17/95 | 5/18/95 | 25.2 | 786,186 | 586,910 | 74.7% |
| 20 | Hudson– Coxsackie | 5/17/95 | 5/18/95 | 1.6 | 50,467 | 41,995 | 83.2% |
| 21 | Delaware | 5/18/95 | 5/19/95 | 18.0 | Delivered to Manning | | |
| 22 | Hudson– Castleton | 5/18/95 | 5/19/95 | 17.0 | Delivered to Manning | | |
| 23 | Hudson– Cheviot | 5/20/95 | 5/21/95 | 5.5 | 173,481 | 133,512 | 77.0% |
| 24 | Hudson– Glasco | 5/20/95 | 5/21/95 | 4.8 | 163,304 | 126,379 | 77.4% |
| 25 | Delaware | 5/21/95 | 5/22/95 | 42.9 | 1,398,084 | 767,926 | 54.9% |
| 26 | Hudson– Cheviot | 5/21/95 | 5/22/95 | 5.4 | 183,717 | 120,533 | 65.6% |
| 27 | Delaware | 5/22/95 | 5/23/95 | 41.8 | 1,179,301 | 574,084 | 48.7% |
| 28 | Hudson– Cheviot | 5/22/95 | 5/23/95 | 14.0 | 446,440 | 332,415 | 74.5% |
| 29 | Hudson– Glasco | 5/22/95 | 5/23/95 | 9.0 | 309,476 | 227,392 | 73.5% |
| 30 | Delaware | 5/23/95 | 5/24/95 | 38.0 | 1,636,971 | 343,718 | 21.0% |
| 31 | Hudson– Cheviot | 5/23/95 | 5/24/95 | 13.7 | 466,097 | 314,975 | 67.6% |
| 32 | Delaware | 5/24/95 | 5/25/95 | 12.0 | 522,056 | 150,427 | 28.8% |
| 33 | Delaware | 5/25/95 | 5/26/95 | 25.0 | 878,075 | 302,051 | 34.4% |
| 34 | Delaware | 5/29/95 | 5/30/95 | 14.6 | 512,796 | 273,352 | 53.3% |
| 35 | Delaware | 5/30/95 | 5/31/95 | 17.5 | 799,392 | 364,164 | 45.6% |
| 36 | Delaware | 6/31/95 | 6/1/95 | 14.2 | 886,340 | 100,000 | 11.3% |
| Totals | | No. of Shipments | | | | | |
| | Hudson– Castleton | 10 | | 249.7 | 7,151,053 * | 3,938,493 * | 55.1% * |
| | Hudson– Cheviot | 5 | | 45.8 | 1,463,773 | 996,189 | 68.1% |
| | Hudson– Rogers I. | 5 | | 93.4 | 2,714,380 * | 2,019,019 * | 74.4% * |
| | Hudson– Coxsackie | 1 | | 1.6 | 50,467 | 41,995 | 83.2% |
| | Hudson– Glasco | 2 | | 13.8 | 472,780 | 353,771 | 74.8% |
| | Delaware | 13 | | 342.5 | 10,752,738 * | 4,824,668 * | 44.9% * |
| | Grand Total | 36 | | 746.8 | 22,605,192 * | 12,174,135 * | 53.9% * |

*Does not include eggs delivered to Manning.

Table 2. Annual summary of American shad production in the Susquehanna River Basin, 1976–1995.

| Year | Egg Vol. (L) | No. of Eggs (exp.6) | Egg Via-bility (%) | No. of Viable Eggs (exp.6) | No. of shad stocked (all rivers) Fry (exp.3) | Fing-erling (exp.3) | Total (exp.3) | Fish Stocked/ Eggs Rec'd | Fish Stocked/ Viable Eggs |
|---|---|---|---|---|---|---|---|---|---|
| 1976 | 120 | 4.0 | 52.0 | 2.1 | 518 | 266 | 784 | 0.194 | 0.373 |
| 1977 | 146 | 6.4 | 46.7 | 2.9 | 969 | 35 | 1,003 | 0.159 | 0.342 |
| 1978 | 381 | 14.5 | 44.0 | 6.4 | 2,124 | 6 | 2,130 | 0.104 | 0.330 |
| 1979 | 165 | 6.4 | 41.4 | 2.6 | 629 | 34 | 664 | 0.104 | 0.251 |
| 1980 | 348 | 12.6 | 65.6 | 8.2 | 3,526 | 5 | 3,531 | 0.283 | 0.431 |
| 1981 | 286 | 11.6 | 44.9 | 5.2 | 2,030 | 24 | 2,053 | 0.177 | 0.393 |
| 1982 | 624 | 25.9 | 35.7 | 9.2 | 5,019 | 41 | 5,060 | 0.196 | 0.548 |
| 1983 | 939 | 34.5 | 55.6 | 19.2 | 4,048 | 98 | 4,146 | 0.120 | 0.216 |
| 1984 | 1,157 | 41.1 | 45.2 | 18.6 | 11,996 | 30 | 12,026 | – | 0.728 |
| 1985 | 814 | 25.6 | 40.9 | 10.1 | 6,960 | 115 | 7,075 | 0.279 | 0.682 |
| 1986 | 1,536 | 52.7 | 40.7 | 21.4 | 15,876 | 61 | 15,928 | 0.302 | 0.744 |
| 1987 | 974 | 33.0 | 47.9 | 15.8 | 10,274 | 81 | 10,355 | 0.314 | 0.655 |
| 1988 | 885 | 31.8 | 38.7 | 12.3 | 10,441 | 74 | 10,515 | 0.331 | 0.855 |
| 1989 | 1,221 | 42.7 | 60.1 | 25.7 | 22,267 | 60 | 22,327 | 0.523 | 0.869 |
| 1990 | 897 | 28.6 | 56.7 | 16.2 | 12,034 | 253 | 12,287 | 0.430 | 0.758 |
| 1991 | 903 | 29.8 | 60.7 | 18.1 | 12,963 | 233 | 13,196 | 0.443 | 0.729 |
| 1992 | 532 | 18.5 | 68.3 | 12.6 | 4,645 | 34 | 4,679 | 0.253 | 0.371 |
| 1993 | 558 | 21.5 | 58.3 | 12.8 | 7,870 | 79.4 | 7,949 | 0.370 | 0.621 |
| 1994 | 551 | 21.2 | 45.9 | 9.7 | 7,720 * | 139.5 | 7,860 | 0.309 | 0.676 |
| 1995 | 768 | 22.6 | 53.9 | 12.2 | 10,930 ** | – | 10,930 | 0.426 | 0.789 |
| | | | | | | Total | 154,498 | | |
| | | | | | | Total since 1985 (OTC marked) | 123,101 | | |

*Includes 1,300,000 reared at Manning.

Table 3. American shad stocking and fish transfer activities, 1995.

| Date | Tank | Number | Mark (days) | Location | Origin | Age | Size |
|---|---|---|---|---|---|---|---|
| 5/19/95 | E21 | 149,000 | 5 | Thompsontown | Hudson– Castleton | 8 | Fry |
| 5/19/95 | E31 | 142,000 | 5 | Thompsontown | Hudson– Castleton | 8 | Fry |
| 5/19/95 | E41 | 257,000 | 5 | Thompsontown | Hudson– Castleton | 7 | Fry |
| 5/19/95 | F11 | 236,000 | 5 | Thompsontown | Hudson– Castleton | 7 | Fry |
| 5/19/95 | F21 | 237,000 | 5 | Thompsontown | Hudson– Castleton | 7 | Fry |
| 5/22/95 | F31 | 132,000 | 5 | Thompsontown | Hudson– Castleton | 8 | Fry |
| 5/23/95 | F41 | 161,000 | 5 | Millerstown | Hudson– Castleton | 7 | Fry |
| 5/23/95 | G11 | 91,000 | 5 | Millerstown | Hudson– Castleton | 7 | Fry |
| 5/23/95 | G21 | 162,000 | 5 | Millerstown | Hudson– Castleton | 7 | Fry |
| 5/25/95 | H11 | 174,000 | 5 | Millerstown | Hudson– Rogers I. | 7 | Fry |
| 5/26/95 | H21 | 238,000 | 5 | Millerstown | Hudson– Castleton | 7 | Fry |
| 5/28/95 | H31 | 389,000 | 5 | Millerstown | Hudson– Rogers I. | 7 | Fry |
| 5/29/95 | H41 | 391,000 | 5 | Millerstown | Hudson– Rogers I. | 8 | Fry |
| 5/29/95 | I11 | 83,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 5/30/95 | I21 | 196,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 5/30/95 | I31 | 184,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 5/30/95 | I41 | 187,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 5/30/95 | A12 | 212,000 | 5 | Millerstown | Hudson– Rogers I. | 7 | Fry |
| 5/30/95 | A22 | 70,000 | 5 | Millerstown | Hudson– Rogers I. | 7 | Fry |
| 5/31/95 | A32 | 264,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 5/31/95 | A42 | 298,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 5/31/95 | B12 | 246,000 | 5 | Millerstown | Delaware | 7 | Fry |
| 6/1/95 | B22 | 290,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 6/1/95 | B32 | 285,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 6/1/95 | B42 | 265,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 6/2/95 | C32 | 257,000 | 5 | Millerstown | Delaware | 8 | Fry |
| 6/2/95 | C42 | 267,000 | 5 | Millerstown | Delaware | 8 | Fry |
| 6/2/95 | D12 | 226,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 6/2/95 | D22 | 261,000 | 5 | Millerstown | Hudson– Castleton | 8 | Fry |
| 6/6/95 | G31 | 220,000 | 12,15,18 | Conodoguinet Cr. | Hudson– Castleton | 19 | Fry |
| 6/6/95 | G41 | 230,000 | 3,13,17 | Conodoguinet Cr. (mouth) | Hudson– Castleton | 19 | Fry |
| 6/6/95 | G31 | 5,000 | 12,15,18 | Benner Spring Raceway F1 | Hudson– Castleton | 19 | Fry |
| 6/6/95 | G41 | 5,000 | 3,13,17 | Benner Spring Raceway F2 | Hudson– Castleton | 19 | Fry |
| 6/6/95 | E22 | 5,000 | 5 | Benner Spring Raceway F3 | Delaware | 6 | Fry |
| 6/7/95 | D42 | 246,000 | 5 | Millerstown | Delaware | 9 | Fry |
| 6/7/95 | E12 | 250,000 | 5 | Millerstown | Delaware | 9 | Fry |
| 6/7/95 | E22 | 246,000 | 5 | Millerstown | Delaware | 9 | Fry |
| 6/7/95 | E32 | 119,000 | 5 | Millerstown | Hudson– Cheviot | 9 | Fry |
| 6/8/95 | E42 | 265,000 | 5 | Lehigh River | Delaware | 8 | Fry |
| 6/8/95 | F12 | 287,000 | 5 | Lehigh River | Delaware | 8 | Fry |
| 6/8/95 | F42 | 342,000 | 5 | Lehigh River | Delaware | 8 | Fry |
| 6/8/95 | G22 | 150,000 | 5 | Lehigh River | Delaware | 7 | Fry |
| 6/9/95 | F22 | 327,000 | 5 | Millerstown | Hudson– Cheviot | 9 | Fry |
| 6/9/95 | F32 | 224,000 | 5 | Millerstown | Hudson– Glasco | 9 | Fry |
| 6/9/95 | G12 | 310,000 | 5 | Millerstown | Hudson– Cheviot | 8 | Fry |
| 6/9/95 | H12 | 267,000 | 5 | Millerstown | Delaware | 7 | Fry |

Table 3. (continued).

| Date | Tank | Number | Mark (days) | Location | Origin | Age | Size |
|---|---|---|---|---|---|---|---|
| 6/13/95 | I22 | 30,000 | 5 | Ches. Bay Foundation | Delaware | 6 | Fry |
| 6/14/95 | C12 | 3,000 | 3,7,15,19 | Benner Spring Raceway E1 | Hudson– Rogers I. | 21 | Fry |
| 6/14/95 | C22 | 3,000 | 5,9,13,17 | Benner Spring Raceway E3 | Hudson– Rogers I. | 21 | Fry |
| 6/15/95 | C12 | 198,000 | 3,7,15,19 | Conestoga River | Hudson– Rogers I. | 22 | Fry |
| 6/15/95 | C22 | 190,000 | 5,9,13,17 | Conestoga R. (mouth) | Hudson– Rogers I. | 22 | Fry |
| 6/16/95 | I12 | 270,000 | 5 | Montgomery Ferry | Delaware | 10 | Fry |
| 6/16/95 | I22 | 362,000 | 5 | Montgomery Ferry | Delaware | 9 | Fry |
| 6/16/95 | I32 | 99,000 | 5 | Montgomery Ferry | Delaware | 8 | Fry |
| 6/19/95 | D32 | 93,000 | 3,13,17,21 | Muddy Cr. | Hudson– Cheviot | 22 | Fry |
| 6/19/95 | D32 | 3,000 | 3,13,17,21 | Benner Spring Raceway E4 | Hudson– Cheviot | 22 | Fry |
| 6/22/95 | H22 | 1,000 | control | Conte Lab., Turners Falls | Delaware | 21 | Fry |
| 6/22/95 | H32 | 1,000 | egg, 3, 6 | Univ. of Massachusetts | Delaware | 21 | Fry |

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1995.

| | Site | Fry |
|---|---|---|
| Releases | Juniata R.– Thompsontown | 1,153,000 |
| | Juniata R.– Millerstown | 7,186,000 |
| | Susquehanna R.– Montgomery Ferry | 731,000 |
| | Muddy Creek | 93,000 |
| | Conodoguinet Cr. | 220,000 |
| | Conodoguinet Cr. (mouth) | 230,000 |
| | Conestoga River | 198,000 |
| | Conestoga River (mouth) | 190,000 |
| | Sub–Total | 10,001,000 |
| | Lehigh River | 1,044,000 |
| Transfers | Benner Spring Raceways | 24,000 |
| | Ches. Bay Foundation | 30,000 |
| | Conte Lab | 1,000 |
| | Univ. Of Massachusetts | 1,000 |
| | Sub–Total | 56,000 |
| | Total Production | 11,101,000 |
| | Viable eggs | 12,174,000 |
| | Survival of fry (%) | 91.2% |

Table 5. Tetracycline marking regime for American shad stocked in the Chesapeake Bay watershed, 1995.

| Hatchery | Size | Egg Source | Stocking Location | Immersion Mark (days) | Feed mark | No. Stocked |
|---|---|---|---|---|---|---|
| King & Queen | Fry | York R. | James R. | Single (5) | – | 5,389,000 |
| King & Queen | Fry | York R. | York R. | Double (3,6) | – | 2,426,000 |
| Harrsion Lake | Fry | York R. | James R. | Single (5) | – | 732,000 |
| Harrsion Lake | Fry | York R. | York R. | Double (3,5) | – | 478,000 |
| Harrsion Lake | Fry | Potomac R. | Potomac R. | Single (5) | – | 1,200,000 |
| Van Dyke | Fry | Hudson | Conodoguinet Cr. | Triple (12,15,18) | – | 220,000 |
| Van Dyke | Fry | Hudson | Conodoguinet Cr. (Mouth) | Triple (3,13,17) | – | 230,000 |
| Van Dyke | Fry | Hudson | Conestoga R. | Quadruple (3,7,15,19) | – | 198,000 |
| Van Dyke | Fry | Hudson | Conestoga R. (Mouth) | Quadruple (5,9,13,17) | – | 190,000 |
| Van Dyke | Fry | Hudson | Muddy Cr. | Quadruple (3,13,17,21) | – | 93,000 |
| Van Dyke | Fry | Hudson/ Delaware | Juniata R. (Thompsontown) | Single (5) | – | 1,153,000 |
| Van Dyke | Fry | Hudson/ Delaware | Juniata R. (Millerstown) | Single (5) | – | 7,186,000 |
| Van Dyke | Fry | Hudson/ Delaware | Susquehanna R. (Montgomery Ferry) | Single (5) | – | 731,000 |
| Manning | Fry | Hudson/ Delaware | Below Conowingo Mid-channel release | Double (3,7) | – | 519,000 |
| Manning | Fry | Hudson/ Delaware | Below Conowingo Nearshore release | Double (3,11) | – | 410,000 |
| Manning | Fry | Susq. | Patuxent R. | Double (7,11) | – | 308,000 |
| Manning | Fing. | Susq. | Patuxent R. | Double (7,11) | Single | 117,000 |
| Manning | Fry | Nanticoke | Nanticoke R. | Triple (3,6,12) | – | 34,000 |
| Manning | Fing. | Nanticoke | Nanticoke R. | Triple (3,6,12) | Single | 8,400 |

Table 6. Tetracycline mark retention for American shad reared in 1995.

| Tank/ Raceway | Egg Source | Mark (days) | Mark (days) | Exhibiting Mark | Number Stocked | Disposition |
|---|---|---|---|---|---|---|
| Tank G31 | Hudson | 12,15,18 | 12,15,18 | 20/20(100%) | 220,000 | Stocked Conodoguinet Cr. |
| Tank G41 | Hudson | 3,13,17 | 3,13,17 | 20/20(100%) | 230,000 | Stocked Conodoguinet Cr. (mouth) |
| Tank C12 | Hudson | 3,7,15,19 | 3,7,15,19 | 17/17(100%) | 198,000 | Stocked Conestoga R. |
| Tank C22 | Hudson | 5,9,13,17 | 5,9,13,17 | 17/17(100%) | 190,000 | Stocked Conestoga R. (mouth) |
| Tank D32 | Hudson | 3,13,17,21 | 3,13,17,21 | 17/17(100%) | 93,000 | Stocked Muddy Cr. |
| BS Race-way F3 | All | 5 | 5 | 17/17(100%) | 9,070,000 | Stocked Above Dams |
| Tank H22 | Delaware | control | none | 0/20(0%) | – | not Stocked |
| Tank H32 | Delaware | egg,3,6 (1000ppm) | egg,3,6<br>0,3,6 | 2/20(10%)<br>18/20(90%) | – | not Stocked |
| Tank H42 | Delaware | egg,3,6 (2000ppm) | egg,3,6 | 17/17(100%) | – | not Stocked |

## Appendix 1.

# Efficacy of marking otoliths of American shad embryos by five hour immersion in 1000 or 2000mg/L oxytetracycline hydrochloride.

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## Introduction

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

Evidence gathered in 1993 and 1994 suggests that increased survival of released larvae can be achieved by releasing larvae at 7d of age, rather than holding them until 18-20d of age. Unfortunately, this severely limits the number of unique marks which can be applied to groups of larvae. Earlier research suggested that marks produced 3d apart were identifiable as double marks (Hendricks et al., 1988). Marking of American shad embryos, followed by marking of larvae at 3 and 6d of age, would permit triple marking, coupled with release at 7 days of age.

There are several reports in the literature involving marking of fish otoliths by immersion in tetracycline during the embryonic stage. Tsukamoto (1985) successfully marked eyed Ayu eggs by 24-48h immersion in 200-300 mg/l. Marks were retained at least five months. Dabrowski and Tsukamoto (1986) marked eyed peled eggs by 12h immersion in 600 mg/l. Marks were detected on all specimens after 19d, but after 87d only 38% of the specimens examined were marked. Muth and Nesler (1989) marked Colorado squawfish eggs (3d post-fertilization, 1-2d prior to hatch) by 12, 24, or 36h immersion in 200 or 350 mg/l. All specimens examined exhibited marks 15d after hatch. Ruhle and Winecki-Kuhn (1992) marked whitefish eggs by water-hardening them for one hour in various concentrations of TCH. Specimens treated in 2,000 mg/l retained marks for a minimum of 13 months, with some mark loss at 20 months. They speculated that the tetracycline was stored in the yolk and deposited during otolith formation since all fluorescence was confined to the otolith nucleus. Brooking et al. (1994) marked walleye eggs in 1000 mg/l OTC. One group of eggs was water hardened for 60-70 min in OTC and a second group was treated by 5h immersion at 12d after fertilization and 4d before hatching. Both groups exhibited marks when examined at 15d of age. A third group was marked again by 6h immersion in 500 mg/l at 3d of age. These generally exhibited two distinct marks, but on occasion, the marks blended together.

The purpose of this research was to determine if American shad embryos can be successfully marked by five hour immersions in 1000 or 2000mg/L tetracycline, and to produce unique triple marks by additional immersions of larvae at 3 and 6d of age.

## Materials and Methods

Plastic bags were placed in 5 gal. buckets and filled with 2.0L of 1000 or 2000mg/L OTC, with a third bag as an unmarked control. Buffers were added to the bags to return pH to pre-treatment levels. For the 1000 mg/L solution, 2.3g potassium phosphate plus 8.8g sodium phosphate was added to return pH to pre-treatment levels of 6.9. For the 2000 mg/L solution, 2.3g potassium phosphate plus 13.2g sodium phosphate was added to return pH to pre-treatment levels of 6.9.

Three small groups of eggs from shipment 33, Delaware River egg source, were used for the experiment. Eggs were disinfected and enumerated as per standard practice. Each bag received 0.5L of eggs (17,562). Oxygen was added to each bag and the bags sealed. Marking began at 11:40AM, approximately 12 to 15 hours after fertilization. Water temperature was 60F (15.6C). After a 5h immersion, the contents of each bag was poured into an egg incubation jar and the eggs incubated as per standard practice. Egg viability was determined by taking three samples of eggs (96 - 117 eggs/sample) from each jar and counting the number of live eggs in each sample.

At hatch, the three incubation jars were moved to separate rearing tanks and reared as per standard practice. Larvae in the two test tanks received additional marks by 4h immersion in 200mg/L OTC at 3 and 6d of age.

At 29 days of age, larvae were sampled from each tank. Otoliths were extracted under a dissecting microscope and viewed whole in immersion oil for the presence of an OTC mark. Fluorescent marks were rated based on brightness as follows: 0- no mark, + - faint mark, ++ - better mark, +++ - bright mark. Only marks rated ++ or +++ were considered acceptable.

## Results and Discussion

Egg viability (Table A1-1) was 18.1% in the untreated control, 19.9% in the 1000ppm treatment and 25.8% in the 2000ppm treatment. By comparison, egg viability in two production Van Dyke jars incubated from the same shipment was 35 and 36%. The lower viability in the control jar compared to the test jars, suggests that the treatment was not the cause for the low viability. Viability for the production jars was determined by Von Bayer estimates from dead eggs taken off and may not be comparable due to the different method. Alternatively, the additional handling required for the test may have contributed to higher egg mortality. Additional tests are needed to determine the affect of egg marking and additional handling on egg survival.

Eighteen-day survival of larvae was 74% for the untreated control, 78% for the 1000ppm treatment group and 87% for the 2000ppm treatment group. These are typical for fish reared to 18 days of age, suggesting that egg marking does not impact larval survival.

Tetracycline marks (Table A1-1) were visible in only 2 (10%) of 20 specimens from the 1000ppm group. All of the specimens in the 2000ppm group exhibited marks, but 2 (11.8%) of 17 exhibited faint marks (single +). These marks were viewed in unground otolith specimens from larvae sampled at 29 days of age. The marks were characterized by a pale yellow glow at the very center of the otolith nucleus. Unfortunately, larvae from these groups were not retained in raceways or ponds for sampling at a later date. Subsequent to that, we observed autofluorescence in the nucleus in a number of wild-caught specimens. As a result, we sampled otoliths from 52 wild-caught specimens and examined them for autofluorescence. Twenty-three (44%) of the otoliths exhibited autofluorescence at the nucleus which the reader felt would have masked a mark, if it were present. Additional testing, with specimens reared at least 100 days in raceways or ponds, is needed to determine if egg marks can be distinguished from autofluorescence in the nucleus.

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Table A1–1. Efficacy of marking otoliths of Delaware River source American shad embryos by 5h immersion in oxytetracycline, 1995.

| Egg Shipment | Jar | Eggs | Egg Survival (%) | 18d larval Survival (%) | OTC Concen–tration (mg/L) | unmarked | | Mark intensity + | | ++ | | +++ | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | N | % | N | % | N | % | N | % | |
| 33 | 11 | 17,562 | 18.1 | 74.0 | Control | 20 | 100.0% | 0 | 0.0% | 0 | 0.0% | 0 | 0.0% | 20 |
| 33 | 12 | 17,562 | 19.9 | 78.0 | 1000 | 18 | 90.0% | 1 | 5.0% | 1 | 5.0% | 0 | 0.0% | 20 |
| 33 | 14 | 17,562 | 25.8 | 86.9 | 2000 | 0 | 0.0% | 2 | 11.8% | 5 | 29.4% | 10 | 58.8% | 17 |

\+ Faint mark
++ Moderate mark intensity
+++ Bright mark
Note: Marks administered beginning at 11:40AM, 12 to 15 hours post fertilization.
Marks evaluated at 29 days of age without grinding.

## Appendix 2.

# Relative survival of American shad larvae released in tributaries vs. those released in the main stem Susquehanna River, 1995.

by
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## Introduction

American shad larvae reared at the Van Dyke Research Station for Anadromous Fish have traditionally been stocked into the Juniata River at 18-21d of age. When high muddy water prevented release in the Juniata River, larvae were released in the main-stem Susquehanna River at Montgomery Ferry. The rationale behind releasing larvae at 18-21d of age was based upon the observation that hatchery-reared shad larvae exhibit a period of high mortality from 9 to 14d of age associated with the transition from endogenous to exogenous feeding (Wiggins et al., 1985). It was assumed that improved survival in the wild could be attained by culturing the larvae through this "critical period" to ensure they received an adequate food supply and protection from predators.

Research conducted in 1994 demonstrated that larvae released at 7d of age experienced 7.8 times better survival compared to controls released at 20d of age, and 2.2 times better survival compared to production groups released at 14 to 18d of age (Hendricks, 1995). As a result, 1995 production larvae released in the mainstem Juniata River and the Susquehanna River at Montgomery Ferry were released at 7 days of age.

The 1993 agreement with the three upstream hydro operators called for fish passage at Holtwood and Safe Harbor Dams by 1997 and at York Haven Dam by 2000. With this agreement in place, the Pennsylvania Fish and Boat Commission began focussing attention on anadromous fish restoration in Susquehanna River tributaries. Projects were initiated to identify blockages to fish migration on tributaries and to provide fish passage by breaching/removal of blockages or installation of fish passage facilities. To support this effort, adult pre-spawn river herring and hatchery-reared American shad larvae were stocked in selected tributaries in 1995.

This paper reports on, and evaluates the success of, the American shad larval releases in tributary waters in 1995.

## Materials and Methods

All tributary stockings were done with larvae from the Hudson River egg source. Larvae released in tributaries were given unique tetracycline marks according to the schedule in Table 5 of the main report. Larvae released in tributaries had to be released at 19 to 22d of age to accomodate the tetracycline marks. For the Conodoguinet Cr. and Conestoga R. releases, uniquely marked controls were released at the mouths of those streams to allow comparison of recovery rates. For both of those streams, controls and test lots came from the same egg shipment, reared in adjacent tanks, and stocked on the same day. There was no control for the Muddy Cr. stocking since the mouth of Muddy Cr. is downstream from the main juvenile shad recapture site at Holtwood Dam.

Specific release sites were as follows:

1. Conodoguinet Cr., at North Middleton Township Park, .25 miles downstream from the Rt. 74 bridge.
2. Main-stem Susquehanna River, mouth of Conodoguinet Cr. at PFBC West Fairview Access.
3. Conestoga R., along Cabin Rd., 1 mile downstream from Rt 322 bridge at Hinkletown.
4. Conestoga R., 0.25 miles upstream from mouth, in Safe Harbor Recreation Park.
5. Muddy Cr., at Muddy Cr. Forks.

Juvenile American shad were recaptured during the Fall out-migration by lift net at Holtwood Dam, in intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam. Haul seine samples from sites in the Columbia/Marietta area were not used in the analysis since the mouth of the Conestoga River is downstream from the seine site.

Juvenile shad were frozen whole and delivered to Benner Spring Fish Research Station for otolith analysis. Otoliths were extracted, mounted, ground and analyzed according to standard procedures (Hendricks et al., 1991). Recovery rates were calculated for each release site by dividing the number of fish recovered by the number stocked and multiplying by 10,000. Relative survival was calculated by dividing the recovery rate for each release site by the highest recovery rate for all release sites.

## Results and Discussion

Results of the study are depicted in Table A2-1. Over 9 million larvae (91%) were stocked at the main release sites in the Juniata River (Millerstown and Thompsontown) and Susquehanna River (Montgomery Ferry). Only 731 thousand of these were stocked at

Montgomery Ferry, 1.2 million were stocked in the Juniata River at Thompsontown and 7.2 million were stocked in the Juniata River at Millerstown. These larvae were stocked at 7-9 days of age and, based on the results of Hendricks (1995), would be expected to experience better survival than the larvae released at 19 to 22 days of age in the tributaries.

Lesser numbers of larvae were released at the tributary sites: Conodoguinet Cr.- 220,000, mouth of Conodoguinet Cr.- 230,000, Conestoga R.- 198,000, mouth of Conestoga R.- 190,000, Muddy Cr.- 93,000.

Fish were recovered from each stocking site except Muddy Creek. Fish from the Muddy Creek release were less likely to be recovered since fewer were stocked. More importantly, the Holtwood Dam lift net site, where 65% of the recoveries were made, is above Holtwood dam and not accessible to fish stocked in Muddy Creek.

A total of 308 fish were recovered from the production stockings in the Juniata and Susquehanna Rivers, resulting in a recovery rate of 0.34 and relative survival of 0.27. Five fish were recovered from Conodoguinet Cr. for a recovery rate of 0.23 and relative survival of 0.18. Nine fish were recovered from the mouth of Conodoguinent Cr. for a recovery rate of 0.39 and relative survival of 0.31. Twenty-five fish were recovered from Conestoga R. for a recovery rate of 1.26 and relative survival of 1.00. Eight fish were recovered from the mouth of the Conestoga R. for a recovery rate of 0.42 and relative survival of 0.33.

The fact that relative survival was higher for sites at the mouths of Condoguinet Cr. and Conestoga R. than for the production releases upriver is surprising in light of the higher survival expected from larvae released at an earlier age. This may be due to near-field site specific considerations, or downriver sites may be more suitable for survival in general. In addition, the research which demonstrated higher survival for larvae stocked earlier, involved stocking at Thompsontown, but most of the production larvae released in this study were released at a new site at Millerstown. It is possible that the Millerstown site may not be as good a site as Thompsontown. I consider that unlikely, since observations indicated that the Millerstown site is devoid of predators. Another possibility is that stocking large numbers of larvae at one site may result in intra-specific competition or attraction of predators to the site. Johnson (1993) documented a positive linear aggregative response to stocking of American shad larvae at the Thompsontown site during 1990-1992. Thus, repeated stocking of large numbers of larvae at any one site may attract predators to that site and reduce survival.

The highest recovery rate (1.26) was exhibited by the group stocked upstream in the Conestoga River. The recovery rate for this group was three times that achieved by any other group including the group of production larvae stocked in mainstem areas upstream. The lowest recovery rate (0.18) was exhibited by the group stocked in the Conodoguinet Creek. The difference in survival between the two tributary stockings is probably related to environmental or ecological considerations. Data on abundance of forage and predators at these sites might provide insights, but that data is lacking. What is clear, is that American shad larvae stocked in tributaries do survive and contribute to the population of juvenile outmigrants.

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Table A2–1. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at Holtwood, Peach Bottom and Conowingo, 1995.

| Year | Stocking Site | Age at Release (days) | Release Dates | Fry Released Number | Fry Released % | Juveniles Recovered Number | Juveniles Recovered % | Recovery Rate | Relative Survival |
|---|---|---|---|---|---|---|---|---|---|
| 1995 | Juniata R./ Susq. R. @ Mont. Ferry | 7–9 | 5/19–6/16 | 9,070,000 | 91% | 308 | 87 | 0.34 | 0.27 |
| | Conodoguinet Cr. | 19 | 6/6 | 220,000 | 2% | 5 | 1 | 0.23 | 0.18 |
| | mouth of Conodoguinet Cr. | 19 | 6/6 | 230,000 | 2% | 9 | 3 | 0.39 | 0.31 |
| | Conestoga R. | 22 | 6/15 | 198,000 | 2% | 25 | 7 | 1.26 | 1.00 |
| | mouth of Conestoga R. | 22 | 6/15 | 190,000 | 2% | 8 | 2 | 0.42 | 0.33 |
| | Muddy Cr. | 22 | 6/19 | 93,000 | 1% | 0 | 0 | 0.00 | 0.00 * |
| | | | Total | 10,001,000 | | 355 | | | |

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

# Job III, Part 2

## 1995 Experimental American Shad (*Alosa sapidissima*) Culture

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### Background

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

We developed successful natural spawn techniques that allow for the production of large numbers of *Alosids* for larval and juvenile stocking and assessment efforts. We propose to: 1) produce and stock cultured *Alosids*; 2) monitor the abundance and mortality of larval and juvenile shad using marked hatchery-produced fish; 3) assess the contribution of hatchery-produced fish on the resident/pre-migratory stock in Chesapeake Bay tributaries; 4) determine the relationship of hatchery fish behavior, migrations, abundance and mortality rates to wild stocks; 5) estimate the contribution of hatchery fish to the adult spawning population and monitor recovery of wild stocks.

Maryland Department of Natural Resources (MD DNR) Fisheries Division initiated a cooperative project with Potomac Electric Power Company (PEPCO) and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) to restore viable American shad (*Alosa sapidissima*) runs in Maryland through stocking of hatchery-produced fish. In 1993 and 1994, work consisted of experimental transportation, handling, natural spawning and incubation of American shad at Manning State Fish Hatchery. Our knowledge of the reproductive biology of this species has been increased by these studies (Mylonas et al. 1995). The Patuxent River was chosen for stocking. A spawning, culture, stocking and assessment experiment was successfully initiated in 1995. We propose a larger project for 1996 since an upcoming addition to the hatchery will increase capacity for an annual production of 10 to 15 million larvae utilizing 300-500 females.

### Adult fish capture and handling

There are many methods available for capturing migrating adult shad. Possible methods include gill netting, pound netting, electrofishing and hook and lining. All of these methods impart significant stress on the fish which is antithetical to successful hatchery spawning. Adult fish obtained from the fish lift at the Conowingo Dam on the Susquehanna River are less stressed, permitting selection of desirable specimens. Fish are collected throughout the day at the lift. Suitable candidates are placed in circular holding tanks at 10 ppt. salinity and held overnight to allow for some recovery from handling. The following day, 30-90 fish (67% male, 33% female) are placed in a circular truck tank (1000 gallons) at 10 ppt. salinity, 10 mg/ℓ minimum D.O. and ambient water temperature. The water is treated with approximately 0.02 mℓ/gal MS-222 to reduce the effects of stress. This is an extremely light dose and it is unknown if there is any real effect. We plan to experiment with dosages in the future. A circular flow of approximately 25 cm/second is introduced to aid in swimming orientation.

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

## Adult fish hormone implantation

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

Processing of adult fish begins with an ovarian biopsy using a 4mm glass catheter. Biopsies have shown that ovaries of migrating shad contain eggs at several different stages of development. These include primary-growth oocytes, ripening eggs, mature eggs or overripe eggs. We can select viable candidates for hormone implantation based on these samples. Fish are then measured (fork length), weighed and implanted with pelletized gonadotropin-releasing hormone analog (GnRHa, 25$\mu$g, males and 50$\mu$g, females) ) obtained from the Center of Marine Biotechnology of the University of Maryland. This implant is prepared with Ethylene-Vinyl acetate copolymer (EVAc) according to Zohar et al. (1990). This polymer allows for a constant release of hormone over a period of up to 21 days (Mylonas et al. 1993). This method further reduces the need for handling that would be required if multiple injections become necessary. Males and females are distributed among four natural spawn systems. Adult mortality seems to increase with water temperature. Ideal holding temperature appears to be approximately 65°F.

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

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

## Egg incubation

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

Incubation experiments were performed to determine the effects of salinity on water hardening. Eggs spawned in 5 ppt. salinity were smaller in size (44,000 eggs/ℓ) than eggs released in fresh water (20,000 eggs/ℓ). The advantage of salt water spawning is two-fold. In addition to reducing stress on adults, smaller chorions allow for twice the number of incubating ova per jar.

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

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

## Larval rearing and marking

Survival was good in circular tanks but poor in raceways, probably due to food availability. Circular tanks enable food to circulate in the water column and more completely distribute food throughout the tank. At age three days, a feed regimen is begun. Larvae will convert to feed at age 3-5 days and feed aggressively on both artemia and Larval AP100. Excess food is siphoned off the bottom of the tanks daily.

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

Larval fish are stocked directly into rivers or shipped to PEPCO ponds for grow-out. Optimal survival is reached when larvae are shipped soon after conversion to feed (<10 days). Therefore, shorter-term marking schedules result in better production levels. Fish stocked in ponds are grown for at least 45 days, transferred to hatchery tanks for growout and receive a number of feed marks.

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

## 1995 Strip Spawned American Shad Culture Results

Manning hatchery received 107 liters (20,000 eggs/ℓ) of fertilized eggs from the Hudson and Delaware Rivers. The eggs were incubated, hatched and reared to post-larval/pre-juvenile stage (18 days old). Two OTC marks were applied to fish to be stocked in the upper Bay for use in a recapture experiment. We wished to determine the best habitat for optimal larval shad survival. Larvae for inshore stocking were given a mark on days 3 and 11. Larvae for mid-channel stocking were marked at days 3 and 7. Approximately 410,000 larvae were stocked inshore at Lapidum and 519,000 larvae were stocked offshore in mid-channel.

## 1995 Experimental American Shad Culture Results

Ninety-nine female shad produced 93 liters of eggs. Only three females completely expelled the entire contents of their ovaries. Single females in small spawning systems delivered 1.6 and 1.3 liters of eggs each and upon examination, their ovaries still contained maturing ova. This is an indication that there is a declining stimulus for egg maturation and ovulation. We hope to increase fecundity per female through better egg "staging", reduction in handling stress and modification of the GnRHa implant and implantation procedures. Improving spawning procedures should yield two to three liters of eggs per fish (44,000/ℓ).

Fertilization rates varied from 15 to 97 percent with the highest fertilization rates occurring when the largest number of eggs are released.

Overall fertilization averaged 67%. Egg counts averaged 44,000 per liter (wet). This resulted in 4.1 million total eggs produced with 2.7 million fertilized eggs produced. There were 2.4 million eggs at hatch and 914,000 surviving to larval stocking. Of these, 308,000 were stocked as larvae in the Patuxent River. The remainder were raised to juvenile size. Currently spawning occurs 48 to 120 hours (day 2-5) after implantation. Egg deposition and fertilization declines rapidly after this. Data from the past two spawning seasons indicate that the preferred operation schedule is during April and May when water temperatures are from 60-70°F. Fertilized eggs develop well at these temperatures. In this range adult mortality remains extremely low and maturation proceeds well. Most females collected during this period were in pre-ovulatory condition. At higher temperatures, stress-related mortality, abortion and incidence of overripe females increase rapidly. All Patuxent River larvae received an OTC mark at days 7 and 11. Fish grown to juvenile size were given a feed mark and 10% were implanted with CWT.

In 1995 we initiated shad propagation for the Nanticoke River using natal brood stock. We collected adults from commercial pound nets operating in the River. Only 21 adults were captured and transported to the hatchery, despite considerable effort. We were not able to select brood stock candidates in ideal reproductive condition. Only 100,000 fertilized eggs were produced from these fish. We feel that in order to mount a credible restoration effort we need to overcome this severe lack of acceptable brood stock needed for production. This trial produced 100,000 fertilized eggs from five females. 34,000 larvae and 8400 juveniles were stocked in the Nanticoke River. Larvae were marked at days 3,6 and 12. Juveniles were given a feed mark before stocking.

## 1995 Stocking results for cultured fish

Approximately one million cultured larval shad were stocked each year in the Susquehanna River in 1992, 1994 and 1995. Hatchery-produced fish comprised 33%, 39% and 20% of juveniles collected in upper Bay surveys respectively. This represents a large impact of hatchery fish considering the level of stocking. The experiment performed to determine optimal stocking habitat for shad larvae provided some interesting results. Twice as many shad (14 %) stocked mid-channel were recaptured than those stocked inshore (6%), indicating differing survival rates.

A seine survey conducted in the Patuxent River collected 330 juvenile shad. Most fish have not been checked for hatchery marks but several samples examined were of larval and juvenile stocking origin. CWT fish were also represented in field sampling. Prior to our collections, wild juvenile shad had not been captured in several surveys conducted in the Patuxent River since 1960.

During the striped bass restoration effort conducted by MD DNR, we have observed a high level of natal tributary straying by adult, hatchery-produced fish returning to spawn. With this in mind, we excised otoliths from the adult shad collected in the Nanticoke River to determine if cultured fish from Susquehanna River stocking are straying into other tributaries. Otolith examination revealed that 25% of the upstream migrating adult shad we collected were cultured fish from the Susquehanna River. We feel that any river-specific genetic identity that may have existed has been compromised by Susquehanna River stockings. Given the lack of brood stock, we believe that adults can be taken from where they are most useful for production. The fish lift at Conowingo dam provides an ample supply of quality brood stock which may be used to produce cultured fish for stocking in any Bay tributary.

Review of the 1995 Nanticoke River trial indicated some sampling problems. The river is difficult to seine effectively and the majority of available juvenile *Alosid* habitat is in Delaware. We propose to study the Choptank River in 1996. This river may also provide a useful contrast to the more impacted Patuxent River watershed.

## Cultured Alosids used as a stock assessment tool

An earlier MD DNR hatchery project for striped bass (*Morone saxatillis*) restoration stocked 4.6 million juveniles from 1985 to 1995. These hatchery-produced fish comprised a large proportion of the juvenile populations sampled in targeted rivers (30-85%). Mark/recapture procedures were useful in the estimation of abundance and mortality of wild stocks. Absolute measures of abundance have been used to validate relative measures of abundance, such as juvenile indices (Minkkinen et al., 1995). These abundance estimates correlate ($r^2$=0.99, p=0,05) to juvenile abundance indices used in striped bass management. Work conducted by the University of Maryland Chesapeake Biological Laboratory with striped bass larvae showed excellent larval survival and that this could have a tremendous impact on stock size (Houde et al. 1990). Hatchery adults returning to the Conowingo dam have comprised between 69 and 90 percent of shad collected from 1989 to 1995 in the Susquehanna River (Markham, 1995). Larval and juvenile shad stocking efforts in the Patuxent River in 1995 indicate excellent survival. This indicates that habitat conditions in this river are suitable for restoration.

We propose to mark and stock fish as larvae, early phase juveniles and late phase juveniles. All cultured shad will be given a larval OTC immersion mark. Shad grown to juvenile size will also receive an OTC feed mark. Ten percent of all juvenile fish are implanted with Coded Wire Tags (Northwest Technologies). This will enable identification of discrete stocking events. Field sampling for juveniles will be conducted July through October. A ¼" mesh, 200' beach seine will be set at nine fixed sites on the Patuxent River. At least as many sites will be sampled on the Choptank River. The ratio of wild versus hatchery and different hatchery stockings will be used to calculate stock parameters. The goal of field sampling is to develop abundance and instantaneous mortality estimates for larvae and juveniles. The use of mark/recapture models to determine the abundance and instantaneous mortality of fish stocks has been commonly employed as a stock assessment tool (Ricker 1975). Although marking individuals captured from wild stocks are more commonly used, hatchery-produced fish can also be used with these models.

Spring sampling to assess returning adults will be accomplished with experimental and commercial nets. Initially we propose to only collect adults in the Patuxent River for otolith analysis to determine the contribution of hatchery fish to the spawning stock. When adults are abundant enough to make it feasible we propose to floy tag adults from pound nets in the lower river and recapture them in upriver fyke nets to make abundance estimates. These estimates of spawning stock size will be used to monitor recovery and will be extremely useful in analyzing stock recruitment factors. Water quality parameters collected would also be used to examine recruitment factors. Estimates of both adult spawners and juvenile recruitment from our surveys could be used when lifting the moratorium and managing fisheries in Maryland Fishery Management Plans.

## Conclusion

Results indicate we have the ability to produce suitable numbers of fish to conduct a credible restoration effort in selected Maryland tributaries. We are encouraged by the abundance of hatchery-produced juvenile shad present in the Patuxent River. This population was comprised of fish stocked as larvae, early juveniles and late juveniles. Analysis of recapture data will permit the calculation of abundance and mortality estimates. In 1996, restoration efforts will continue in the Susquehanna, Choptank and Patuxent River.

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## 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 1995 in an effort to document general and relative abundance, distribution, growth, and timing of outmigration. Otoliths from sub-sampled shad were analyzed for tetracycline marks to indicate what proportion of the collection was of hatchery origin. Also, some cultured fish were distinctively marked and stocked into select tributaries above Conowingo Dam (see Job III) and recovery of shad with those marks provides information on their relative survival and contribution to the nursery and outmigrant population.

The Wyatt Group (Lancaster, PA) was contracted by the PA Fish and Boat Commission (PFBC) to perform net collections and supply juvenile shad for otolith analysis. Many individuals supplied information for this report. For their contributions, appreciation is extended to Mark Plummer (Wyatt Group), Chris Frese (RMC Environmental Services), Dale Weinrich (Maryland DNR), and Mike Hendricks (PA Fish and Boat Commission). Scott Rhoades and Todd Sudie (PFBC) processed most of the otoliths and Ted Jacobsen (Ecology III) administered the otolith contract.

## ADULT SHAD TRAP AND TRANSFER AND HATCHERY 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 marked larvae from PFBC facilities in Pennsylvania. Juveniles occurring in the river below Conowingo and the upper Chesapeake Bay may result from natural spawning below or above dams and hatchery fry stockings either in Maryland waters or from upstream releases in Pennsylvania.

Of the record 61,650 adult shad collected at Conowingo Dam in 1995, 55,766 fish were hauled to stocking sites at Middletown and Columbia during the period 8 April through 11 June. Observed transport and delayed mortalities amounted to 761 fish (1.4%). Overall sex ratio (SR) in these transfers was about 1.1 to one favoring males. This stocking level compares with about 28,100 live shad in 1994 (1.8 to 1 sex ratio); 11,200 in 1993 (SR 1.3:1), 14,500 in 1992 (SR 1:1), and 22,000 in 1991 (SR 1.6:1). Additionally, 21,300 river herring, mostly bluebacks, were stocked at Middletown, Columbia, and in Conowingo Pond at Glen Cove Marina.

During the 1995 shad production season, PA Fish and Boat Commission biologists reared and released 10 million shad fry in the Susquehanna watershed above dams. This stocking level compares with 3.0 to 7.2 million fry stocked each year in 1990-1994. All fry were released between 19 May and 19 June in the following numbers and locations (tetracycline marks in parentheses):

| | | |
|---|---|---|
| Juniata River at Thompsontown - | 1.153 million aged 7-8 days | (day 5) |
| Juniata River at Millerstown - | 7.186 million aged 7-9 days | (day 5) |
| Susquehanna at Montgomery Ferry - | 0.731 million aged 8-10 days | (day 5) |
| Conodoguinet Creek - | 0.450 million aged 19 days | (days 3,13,17 & 12,15,18) |
| Conestoga River - | 0.388 million aged 22 days | (days 3,7,15,19 & 5,9,13,17) |
| Muddy Creek - | 0.093 million aged 22 days | (days 3,13,17,21) |

Maryland DNR reared and double-marked shad at their Manning Hatchery and stocked 929,000 fry in the Susquehanna River at Lapidum below Conowingo Dam. The nearshore release included 410,000 fry marked on days 3 and 11; and an offshore (mid-channel) stocking was comprised of 519,000 fry marked on days 3 and 7.

## METHODS AND TIMING

Juvenile American shad occurrence and outmigration in the river above Conowingo Dam was assessed at several locations during the summer and fall of 1995 as shown below.

| Gear | Location | Frequency | Dates |
|---|---|---|---|
| Haul seine | Columbia | weekly | 7/20 - 10/18 |
| Lift net | Holtwood | weekly | 8/14 - 09/26 |
| | | 2x/week | 10/03 - 11/29 |
| Screens | Peach Bottom | 3x/week | 10/08 - 11/19 |
| Strainers | Conowingo | weekly | 10/08 - 11/19 |

Seining at Columbia was conducted by biologists from Wyatt Group (Lancaster, PA) once each week on 14 dates during the period 20 July through 18 October. Sampling consisted of 3 to 11 hauls per date in late afternoon and evening with a net measuring 400-ft. x 6-ft. with 3/8" stretch mesh. Other seine sampling areas in 1995 included Marietta (one date), and several sites in the Juniata River above Thompsontown and in the mainstem above Clarks Ferry. Upstream locations were sampled once each month in August through early October (12 sample days).

An 8-ft. square lift net with 3/4" mesh body and 1/4" mesh liner was used by Wyatt Group at Holtwood Dam's inner forebay (10 lifts/date) in early evening hours once each week during mid-August through September and twice weekly in October and November. Lift netting occurred on 23 dates and effort totalled 230 lifts.

At Conowingo Dam, RMC Environmental Services (Drumore, PA) checked cooling water strainers for impinged shad weekly during 8 October through 19 November. RMC biologists also inspected intake screen washes at Peach Bottom Atomic Power Station three times each week during this same 7-week period. As part of their annual juvenile *Alosa* recruitment survey, Maryland DNR sampled for shad and herring with electrofishing gear in the Susquehanna Flats every other week (7 dates) during August through October. Lower river and upper Bay collecting sites used in 1995 are shown in Figures 4-1 and 6-2.

Samples of shad from most collections were returned to PFBC's Benner Spring Research Station for tetracycline mark and microstructure analysis of otoliths. 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 fluorescent rings indicative of tetracycline immersion treatments. The marking regime used by PFBC in 1995 is described in Job III.

## RESULTS

### Seine Surveys

The principal purpose for seine sampling in the lower river during summer and fall months was to document the occurrence and relative abundance of both naturally produced juvenile shad from transplanted adults, and hatchery stocked fish. Sampling was concentrated at three sites near the Columbia Boro boat launch since this location proved very effective in past years. During the 14-week sampling season, a total of 489 juvenile shad were taken in 102 seine hauls, including a single collection effort of four hauls at Marietta on 26 July. Of these, 413 fish were used for otolith analysis.

Upriver collections were aimed at documenting natural production of shad from transplanted adults and included seining at two sites in the Juniata River (Thompsontown and Lewistown) and at several sites in the mainstem Susquehanna between Clarks Ferry and Sunbury (Montgomery Ferry, Hoover Island, Sweigart Island, and Shady Nook). Sampling occurred once monthly during August through early October and effort amounted to six hauls per site per month (72 total hauls). Only two juvenile shad were collected, both at Lewistown Narrows on 12 September.

Shad catch-per-unit-effort (CPUE) with seines in the Columbia-Marietta samples in 1995 averaged 4.79 fish/haul and daily rates ranged from 2.4 to 17.7. Over approximately the same time period in 1994, seine CPUE at Columbia-Wrightsville and Marietta was 3.75 (394 fish in 105 hauls). Table 1 shows juvenile shad catch and effort by date for all lower river seine collections in 1995.

**Lift Netting at Holtwood Dam**

Wyatt personnel initiated lift netting at Holtwood's inner forebay on 14 August and continued weekly through the end of September. Sampling changed to twice each week in October and November with three missed dates in November due to high water. The first two shad were taken on 26 September and 6 October. Shad first appeared in abundance on 17 October (82 fish), peaked on 26 and 30

October (1,463 fish), and tapered off to the last successful collection on 8 November (18 fish). Total catch for the season was 2,100 shad in 230 lifts. Fourteen blueback herring and four alewives were also collected at Holtwood in early November. Shad CPUE during the 3-week peak of outmigration amounted to 30.0 fish/lift (2,098 shad in 70 lifts). In 1994, CPUE during a comparable 3-week migration peak was only 2.6. Low catch rate at Holtwood in 1994 was blamed on unusual water clarity associated with low flows (i.e. net avoidance). A total of 245 specimens from Holtwood collections were processed by PFBC for otolith analysis. Daily catch of shad with lift net at Holtwood during autumn 1995 is shown in Table 2.

**Peach Bottom APS and Conowingo Dam**

With the cooperation of PECO Energy Company, RMC biologists examined intake water travelling screen washes for impinged American shad at the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pond. As noted above, screen sampling occurred three times each week (M-W-F) during the weeks of 8 October through 19 November. Collections for the season amounted to 265 juvenile shad, about ten times the numbered recovered here in 1993-1994. Most of these fish (92%) were collected during the week of 22 October. A total of 128 otoliths were processed from these samples. Thirty-eight juvenile blueback herring were collected at Peach Bottom on four dates and six alewives were taken on 22 October.

During the same period as Peach Bottom collections, cooling water strainers at the Conowingo hydroelectric project were examined for impinged shad once each week. A total of 14 juvenile American shad and 15 blueback herring were taken in small numbers (1-6 fish) between 29 October and 19 November. Otoliths were processed from six of these shad.

## Susquehanna River Mouth and Flats

Maryland DNR researchers collected 24 juvenile American shad by electrofisher from the upper Chesapeake Bay during August through October. This compares to 36 shad taken here in 1994 and 31 in 1993. An additional 36 shad were collected in DNR's juvenile finfish seine survey in the upper Bay. Otoliths from all 60 shad taken in DNR collections were analyzed by PFBC staff. Electrofisher collection results by location and date are provided in Table 6 of Job VI.

## Otolith Mark Analysis

Otoliths from 856 juvenile American shad taken in summer and fall collections by Wyatt Group, RMC, and Maryland DNR were analyzed for hatchery mark assessment. A total of 413 shad from seine collections at Columbia and Marietta was successfully processed. Overall, 361 of the fish (87.4%) were marked and the remaining 53 fish (12.6%) were wild. Hatchery fish dominated collections on all 14 dates from mid-July through mid-October comprising 70-100% of samples with sample sizes ranging from 16 to 31 fish per date. Of the 361 marked fish from these collections, 317 (87.8%) were single-marked on day 5 indicating that they were stocked as 7-10 day old larvae in the Juniata River or at Montgomery Ferry. These were a mixture of Delaware and Hudson source fish. Remaining marked shad in seine collections included four fish (1.1%) with the triple mark on days 12, 15, and 18 stocked upstream in Conodoguinet Creek at Carlisle, and 40 fish (11.1%) marked on days 3, 13, and 17 which were stocked at the mouth of Conodoguinet Creek. This tributary enters the Susquehanna at Fairview across the river from Harrisburg. The two shad recovered in the Juniata River at Lewistown on 12 September were wild and one fish taken by electrofisher at Dock Street Dam on 27 September was single-marked.

Of the 245 shad otoliths processed from Holtwood lift net collections, 237 (96.7%) were hatchery origin. Wild fish occurred in five collections, but only in small numbers (1-2). As was the case upstream, single-marked fish were most abundant here comprising 201 (84.8%) of the hatchery total. Multiple-marked fish in Holtwood collections included 5 fish (2.1%) each from the two Conodoguinet stockings; 20 fish (8.4%) marked on days 3, 7, 15, and 19 stocked upstream in the Conestoga River; and six fish (2.5%) with the quad-mark combination 5, 9, 13, and 17 stocked at the mouth of the Conestoga. All multiple marked shad were Hudson River egg source.

Of the total 128 shad examined from Peach Bottom collections, 114 (89.1%) carried hatchery marks and 104 of these were single-marked. Four fish were from the Conodoguinet stockings and six from the Conestoga. Four of six fish analyzed from Conowingo strainer collections were hatchery origin.

All 60 juvenile shad from Maryland DNR's electrofisher and seine collections in the upper Chesapeake Bay were successfully processed for otolith marks. Twelve fish (20%) were hatchery origin of which 11 were double-marked (eight on days 3 and 7 - mid-channel; three on days 3 and 11 - nearshore) stocked below Conowingo Dam by DNR, and one was single-marked (stocked above dams by PFBC). The remaining 48 fish (80%) were wild.

Otolith analysis of shad samples from all collecting dates and sites above and below Conowingo Dam is presented in Table 3. Above Conowingo, the 796 shad examined included samples from every week between 20 July and 9 November. Monthly sample sizes for otolith analysis ranged from 78 in July to 339 in October for all sites combined. Overall, a total of 717 fish (90.1%) were tetracycline marked and 79 (9.9%) were wild.

Single-marked shad stocked as 7-10 day old fry in the Juniata River and at Montgomery Ferry made up 626 of 717 hatchery fish (87.3%) in all collections above Conowingo Dam. Remaining fish included 49 (6.8%) stocked at the mouth of the Conodoguinet; 9 (1.3%) stocked upstream in that tributary; 25 (3.5%) stocked upstream in the Conestoga River; and 8 (1.1%) stocked at the mouth of the Conestoga.

## DISCUSSION

### In-Stream Movements and Outmigration Timing

Juvenile shad collections at Holtwood and Peach Bottom in 1995 indicated that outmigration from the river occurred during the 3-week period from mid-October through the first week of November as water temperature declined from 18°C to 8°C and flows increased from 6,600 cfs to 54,700 cfs.

All juvenile shad collected with seines at Columbia and Marietta during the 1995 season were taken prior to the outmigration period. Single and triple-marked fish appeared in seine collections at Columbia as early as 20 July. These fish were first stocked on 19 May (Juniata) and 6 June (Conodoguinet Creek) suggesting that pre-migratory movements of 25-50 miles were accomplished in 40-60 days or less. Shad fry stocked in the Juniata first appeared in Holtwood collections on 17 October coinciding with the onset of outmigration.

### 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. As pointed out earlier, lower river seine collections included 102 hauls on 14 dates over 14 weeks from mid-July through mid-October. With a catch of 489 juvenile shad, the overall catch per unit effort (CPUE) was about 4.8 fish per haul. CPUE was highest during July and September at 7.1 and 6.2, respectively, and lowest in August and October samples (4.0 and 3.1). Individual hauls produced between zero and 32 fish.

Gear avoidance associated with water clarity and/or daytime sampling was demonstrated. Wyatt biologists collected 80 shad at Columbia/Marietta in 54 hauls before nightfall (CPUE = 1.5) and 409 fish in 48 hauls after dark (CPUE = 8.5). Also, on dates when turbidity was lowest, most fish were collected after dark. The table below compares stocking numbers and juvenile recovery data from 1995 with overall seine catch and effort at similar sites in the river during the prior 3-year period.

| Year | Adult Females | Fry Stocked | Seine Dates | Shad Catch | No. Hauls | Juvenile CPUE |
|---|---|---|---|---|---|---|
| 1995 | 27,000 | 10.00M | 7/20-10/18 | 489 | 102 | 4.79 |
| 1994 | 10,000 | 6.42M | 7/26-11/03 | 502 | 155 | 3.24 |
| 1993 | 4,350 | 6.54M | 7/15-10/20 | 275 | 156 | 1.76 |
| 1992 | 7,275 | 3.04M | 7/17-10/22 | 304 | 153 | 1.99 |

The lift net at Holtwood produced 2,100 juvenile shad in 100 lifts during 6 October through 8 November, 1995. This gear has effectively sampled shad at Holtwood for 11 years and the table below compares catch and effort for those periods which encompassed successful collection periods.

| Year | Dates | Effort (lifts) | Shad Catch | CPUE |
|---|---|---|---|---|
| 1995 | 10/06-11/08 | 100 | 2,100 | 21.00 |
| 1994 | 09/08-11/17 | 210 | 206 | 0.98 |
| 1993 | 09/28-11/22 | 170 | 1,093 | 6.43 |
| 1992 | 09/17-10/29 | 130 | 39 | 0.30 |
| 1991 | 10/14-12/16 | 210 | 208 | 0.99 |
| 1990 | 09/26-11/16 | 200 | 3,980 | 19.90 |
| 1989 | 09/22-10/26 | 116 | 556 | 4.79 |
| 1988 | 10/26-12/07 | 154 | 929 | 6.03 |
| 1987 | 09/10-11/20 | 358 | 832 | 2.32 |
| 1986 | 10/06-12/02 | 393 | 2,928 | 7.45 |
| 1985 | 10/16-12/19 | 378 | 3,625 | 9.59 |
| | **Average** | **242** | **1,500** | **6.20** |

Cooling water strainers at Conowingo and intake screens at Peach Bottom are passive samplers. Although catch numbers are typically small, these collections may provide useful information on relative abundance since they are not influenced by vagaries of net sampling and weather conditions. Juvenile shad CPUE at Peach Bottom in 1995 of 12.6 fish per sampling date was substantially greater than that observed in past years (0.03 to 1.13 in 1992-1994). CPUE at Conowingo in 1995 could not be readily compared with prior years due to a change in sampling frequency.

A cursory review of this data suggests that overall shad stock abundance in 1995 was well above that of 1994 and the long-term averages. Since the preponderance of shad collected (90%) were hatchery origin, and the 1995 hatchery release of 10 million fry was comparable to the average stocking for the period 1984-1994, it appears that survival of hatchery fish in 1995 was improved over prior years. Conversely, the relative scarcity of wild fish in summer-fall collections is perplexing. Over the past several years, the wild component of seine and lift net collections in the lower Susquehanna had improved to 40-60% of the total stock, based on production from 11,000 to 28,000 adult transplants from Conowingo. The stocking of over 55,000 live shad in 1995 was expected to produce the majority of juveniles in the river. A modest high flow event in mid-June may have displaced some wild juveniles into lower river impoundments (or to the Bay), as was the case in 1989, but more likely, lack of production related to spawning failure due to unknown causes.

Seine collections in the mainstem Susquehanna above Clarks Ferry and in the Juniata River were largely unsuccessful with only two shad taken in 72 hauls at seven sites over a 3-month period. Unusually low water conditions persisted throughout the sampling period and Wyatt Group biologists included use of a 50-ft. seine to work shallow areas. Lack of juvenile shad in upstream collections may relate to gear avoidance (water clarity and shallow depth), or paucity of fish. The latter situation seems likely considering the relative scarcity of wild juvenile shad in all downstream collections.

## Growth

Wild juvenile shad collected with seines at Columbia and Marietta averaged 59 mm total length (TL) in late-July (range 40-84 mm) and grew to an average 113 mm (range 95-120 mm) by late September. Hatchery fish in these collections were about the same size as wild fish during this nursery period, improving from an average 58 mm TL in late July (range 26-83 mm) to 115 mm in late September (range 76-128 mm). Triple-marked fish stocked in Conodoguinet Creek exhibited similar mean sizes to those stocked in Juniata and mainstem waters. Growth rates for both stocks (hatchery and wild) during this period averaged 0.9 mm/day, a value similar to that recorded in prior years. By mid-October, hatchery fish in Columbia seine collections (n = 49) still averaged only 115 mm.

Only eight wild juvenile shad were taken in lift net collections at Holtwood Dam between mid-October and early November. These fish averaged 145 mm and ranged from 117 to 168 mm. Hatchery fish collected here in October (n = 153) showed a similar size averaging 142 mm (range 98-187 mm). Cultured fish in November collections (n = 88) were generally smaller with a mean size of 127 mm. As was the case upstream, no size discrepancy was noted between single and multiple-marked juveniles. Wild shad (n = 14) collected at Peach Bottom during the week of October 23-27 averaged 155 mm TL (range 106-185) while hatchery fish (n = 101) were similar in size to those at Holtwood averaging 140 mm (range 101-176 mm). Juvenile river herring in Peach Bottom collections averaged about 130 mm TL.

The size disparity between hatchery origin juvenile shad taken at Columbia in mid-October (avg. 115 mm) and those at Holtwood and Peach Bottom in late October (140-142 mm) suggests either that larger fish selectively preceded small fish during outmigration or, more likely, that they were already closer to the recovery sites, using Lake Clarke and Lake Aldred as nurseries. It is plausible that these lake habitats induced better growth (i.e. more food). This spatial separation is further evidenced by the appearance of smaller (i.e. upstream) fish in November collections at Holtwood.

**Stock Composition and Mark Analysis**

Relative survival of the various hatchery released batches of larval shad is discussed in Job III, Appendix 2. As expected, most tetracycline-marked recoveries at Columbia, Holtwood, and Peach Bottom resulted from the 9.07 million fish marked on day 5 and released at Thompsontown, Millerstown, and Montgomery Ferry at 7-10 days of age. Stockings included 3.64 million (40%) Delaware River source fish and 5.43 million (60%) Hudson River source fish. The 450,000 fry stocked in Conodoguinet Creek and 388,000 in Conestoga River were all Hudson fish.

Although we cannot separate single-marked Hudson and Delaware shad recoveries in downstream collections in 1995, a considerable survival advantage of between 3.4 and 6.5 to one was noted for Hudson fish in prior years. However, even accounting for this potential advantage for Hudson River source shad, it is evident that multiple-marked fish stocked in tributaries in 1995 showed excellent survival.

Based on otolith analysis of 796 shad from all collections above Conowingo Dam in 1995, only 10% (79 fish) were naturally produced. The wild fish component of combined upriver otolith analyses in 1991-1994 ranged from 22% to 58%. Recovery of juvenile shad at Holtwood, Peach Bottom, and Conowingo may be less biased and more representative of the outmigrant population. Of the 379 otoliths examined from those collections in 1995, only 24 (6%) were wild. This compares to 19% wild fish at Holtwood in 1994, and 49% in 1993. The 80% wild fish component in upper Chesapeake Bay shad collections in 1995 compares to 61% wild in 1994.

## SUMMARY

Aside from a brief flow event in mid-June, river conditions during the summer of 1995 were low and stable. The haul seine was effective in taking juvenile shad at Columbia during late July through mid-October. Overall catch per unit effort with this gear of 4.79 shad/haul was higher than in past years. Outmigration from the river occurred at Holtwood Dam between mid-October and the first week in November coinciding with a high flow event and rapidly dropping water temperatures. Catch per effort here with the lift net (21 shad per lift) was the highest reported in the past 11 years.

Hatchery released fry grew well, reaching an average size of about 142 mm within 5-months of release. Wild shad grew at about the same rate as hatchery fish and maintained similar average sizes in combined monthly collections. The larger average size of fish in Holtwood samples compared to those at Columbia in October suggested that juveniles nursing in lower river impoundments grew faster than those in free-flowing reaches. Downstream recovery rates of hatchery-marked shad indicated that, relative to their abundance at stocking, shad placed in tributaries as 19-22 day old fry survived better than those released in Juniata River and mainstem waters as 7-10 day old larvae. Reproduction of transplanted adult shad was poor with relatively few unmarked wild fish being taken at all recovery sites throughout the survey period.

Figure 1. Lower Susquehanna River showing juvenile shad collecting locations in 1995

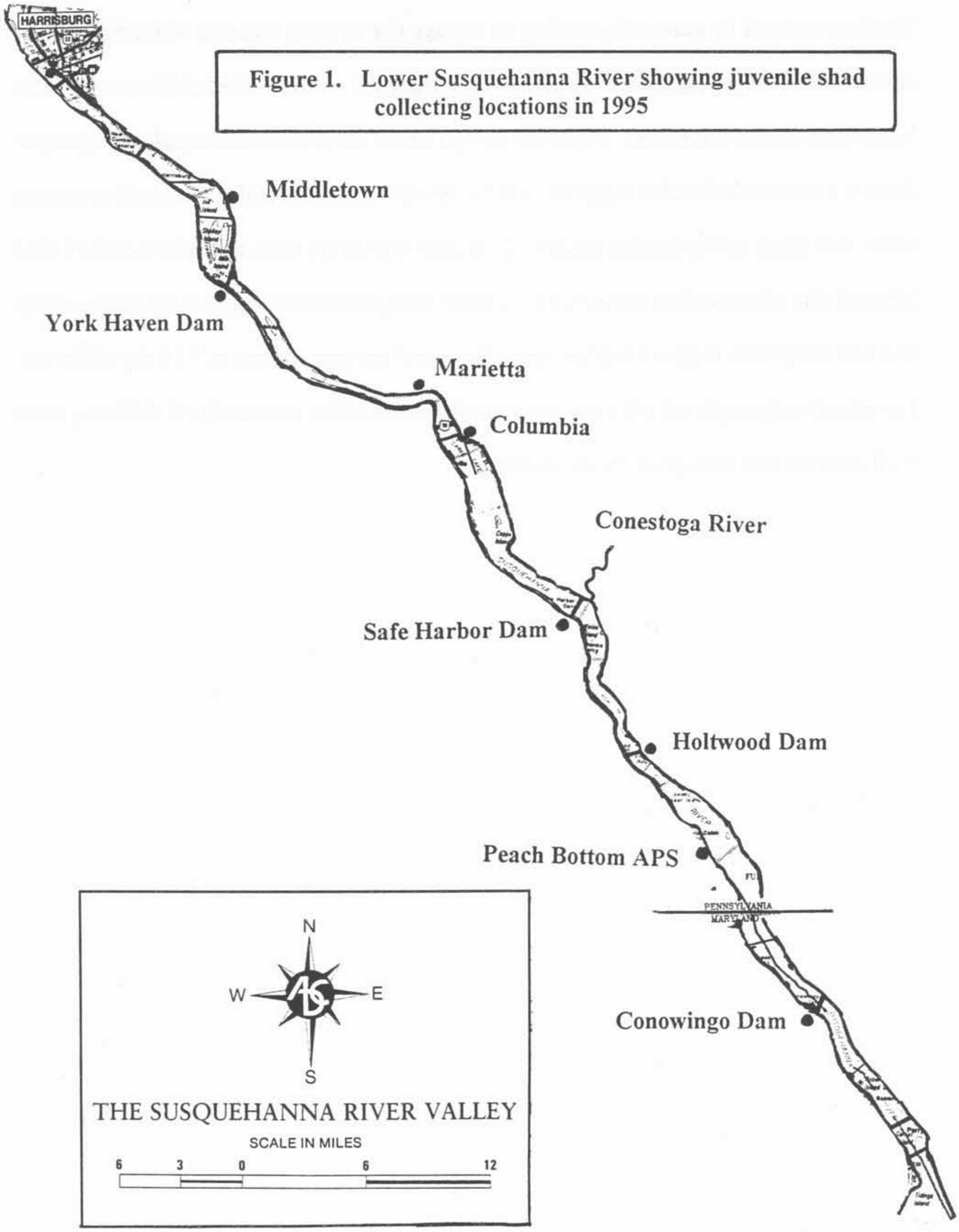

Table 1. **Summary of Juvenile American Shad Collected with Seines in the lower Susquehanna River near Columbia, PA , July-October, 1995.**

| Date | Afternoon | | Evening | | Total | |
|---|---|---|---|---|---|---|
| | Hauls | Shad | Hauls | Shad | Hauls | Shad |
| 07/20 | 4 | 9 | 3 | 18 | 7 | 27 |
| 07/26* | 4 | 20 | 0 | - | 4 | 20 |
| 07/26 | 0 | - | 3 | 53 | 3 | 53 |
| 08/02 | 4 | 0 | 4 | 24 | 8 | 24 |
| 08/09 | 6 | 4 | 5 | 25 | 11 | 29 |
| 08/17 | 4 | 2 | 3 | 33 | 7 | 35 |
| 08/24 | 4 | 10 | 3 | 30 | 7 | 40 |
| 08/30 | 4 | 1 | 5 | 41 | 9 | 42 |
| 09/06 | 3 | 0 | 3 | 43 | 6 | 43 |
| 09/14 | 3 | 0 | 3 | 31 | 6 | 31 |
| 09/20 | 3 | 0 | 3 | 34 | 6 | 34 |
| 09/27 | 4 | 4 | 3 | 42 | 7 | 46 |
| 10/05 | 3 | 0 | 3 | 15 | 6 | 15 |
| 10/11 | 4 | 11 | 4 | 8 | 8 | 19 |
| 10/18 | 4 | 19 | 3 | 12 | 7 | 31 |
| **Totals** | **54** | **80** | **48** | **409** | **102** | **489** |

* Marietta

Table 2. Summary of Juvenile American Shad Collected by Lift Net in the Holtwood Inner Forebay during August-November, 1995. Effort was 10 lifts per date.

| Date | Water Temp. (C) | Flow (cfs) | Number Shad | CPUE (fish/lift) |
|---|---|---|---|---|
| 08/14 | 28.3 | 5,700 | 0 | 0 |
| 08/18 | 30.0 | 4,700 | 0 | 0 |
| 08/22 | 29.4 | 3,800 | 0 | 0 |
| 08/29 | 27.2 | 3,100 | 0 | 0 |
| 09/05 | 27.2 | 2,800 | 0 | 0 |
| 09/15 | 24.4 | 2,500 | 0 | 0 |
| 09/19 | 22.2 | 3,600 | 0 | 0 |
| 09/26 | 20.0 | 4,300 | 1 | 0.1 |
| 10/03 | 18.9 | 3,200 | 0 | 0 |
| 10/06 | 22.2 | 5,000 | 1 | 0.1 |
| 10/10 | 20.6 | 8,200 | 0 | 0 |
| 10/12 | 21.1 | 9,400 | 0 | 0 |
| 10/17 | 17.7 | 6,600 | 82 | 8.2 |
| 10/19 | 16.1 | 8,500 | 19 | 1.9 |
| 10/26 | 11.7 | 54,700 | 689 | 68.9 |
| 10/30 | 11.1 | 25,700 | 774 | 77.4 |
| 11/01 | 11.1 | 20,800 | 347 | 34.7 |
| 11/06 | 11.1 | 18,200 | 169 | 16.9 |
| 11/08 | 7.8 | 19,200 | 18 | 1.8 |
| 11/10 | 7.2 | 18,700 | 0 | 0 |
| 11/15 | 3.9 | 88,100 | No sample - High water | |
| 11/21 | 5.0 | 52,900 | 0 | 0 |
| 11/24 | 3.9 | 54,300 | No sample - High water | |
| 11/27 | 3.9 | 41,100 | 0 | 0 |
| 11/29 | 3.9 | 36,100 | 0 | 0 |
| | Totals | | **2,100** | **9.1 (overall)**<br>**21.0 (10/6-11/8)** |

Table 3. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1995.

| Collection Site | Coll. Date | Immersion marks: Day 5 | Days 12,15,18 | Days 3,13,17 | Days 3,7, 15,19 | Days 5,9, 13,17 | Days 3,13, 17,21 | Days 3,7 | Days 3,11 | Total Hatchery | Wild Micro-structure Not Marked | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lewistown | 9/12/95 | | | | | | | | | 0 | 2 | 2 |
| Dock St. | 9/27/95 | 1 | | | | | | | | 1 | | 1 |
| Marrietta | 7/26/95 | 14 | | | | | | | | 14 | 6 | 20 |
| Columbia | 7/20/95 | 21 | | 2 | | | | | | 23 | 3 | 26 |
| | 7/26/95 | 24 | | 4 | | | | | | 28 | 4 | 32 |
| | 8/2/95 | 19 | | 3 | | | | | | 22 | 1 | 23 |
| | 8/9/95 | 16 | | 6 | | | | | | 22 | 5 | 27 |
| | 8/17/95 | 18 | | 5 | | | | | | 23 | 7 | 30 |
| | 8/24/95 | 25 | 1 | 5 | | | | | | 31 | 3 | 34 |
| | 8/30/95 | 26 | | 3 | | | | | | 29 | 3 | 32 |
| | 9/6/95 | 21 | 2 | | | | | | | 23 | 7 | 30 |
| | 9/14/95 | 26 | | | | | | | | 26 | 5 | 31 |
| | 9/20/95 | 24 | | 6 | | | | | | 30 | 3 | 33 |
| | 9/27/95 | 22 | | 4 | | | | | | 26 | 5 | 31 |
| | 10/5/95 | 14 | 1 | 1 | | | | | | 16 | 0 | 16 |
| | 10/11/95 | 16 | | 1 | | | | | | 17 | 1 | 18 |
| | 10/18/95 | 31 | | | | | | | | 31 | 0 | 31 |
| Seine Hauls only | | 318 | 4 | 40 | 0 | 0 | 0 | 0 | 0 | 362 | 55 | 417 |
| Percent | | 76% | 1% | 10% | 0% | 0% | 0% | 0% | 0% | 87% | 13% | |
| Holtwood | 9/26/95 | | | | 1 | | | | | 1 | 0 | 1 |
| | 10/6/95 | | | | 1 | | | | | 1 | 0 | 1 |
| | 10/17/95 | 28 | | 1 | 12 | 4 | | | | 45 | 2 | 47 |
| | 10/19/95 | 12 | 1 | | 4 | 1 | | | | 18 | 1 | 19 |
| | 10/26/95 | 53 | | | | 1 | | | | 54 | 1 | 55 |
| | 10/30/95 | 25 | 2 | 2 | 1 | | | | | 30 | 2 | 32 |
| | 11/1/95 | 35 | | 1 | 1 | | | | | 37 | 2 | 39 |
| | 11/6/95 | 32 | 1 | 1 | | | | | | 34 | 0 | 34 |
| | 11/8/95 | 16 | 1 | | | | | | | 17 | 0 | 17 |
| | | | | | | | | | | 237 | 9 | 246 |

Table 3. (continued).

| Collection Site | Coll. Date | Immersion marks: Day 5 | Days 12,15,18 | Days 3,13,17 | Days 3,7, 15,19 | Days 5,9, 13,17 | Days 3,13, 17,21 | Days 3,7 | Days 3,11 | Total Hatchery | Wild Micro- structure Not Marked | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Peach | 10/23/95 | 74 | | 2 | 3 | | | | | 79 | 10 | 89 |
| Bottom | 10/25/95 | 14 | | | 2 | 1 | | | | 17 | 3 | 20 |
| | 10/27/95 | 4 | | | | | | | | 4 | 1 | 5 |
| | 10/30/95 | 1 | | | | | | | | 1 | 0 | 1 |
| | 11/1/95 | 6 | | 1 | | | | | | 7 | 0 | 7 |
| | 11/3/95 | 2 | | | | | | | | 2 | 0 | 2 |
| | 11/6/95 | 2 | | 1 | | | | | | 3 | 0 | 3 |
| | 11/9/95 | 1 | | | | | | | | 1 | 0 | 1 |
| Conowingo | 10/23/95 | | | | | 1 | | | | 1 | 0 | 1 |
| Strainers | 10/27/95 | 2 | | | | | | | | 2 | 2 | 4 |
| | 11/3/95 | 1 | | | | | | | | 1 | 0 | 1 |
| Holt./P. Bot./Con. | | 308 | 5 | 9 | 25 | 8 | 0 | 0 | 0 | 355 | 24 | 379 |
| Percent | | 81% | 1% | 2% | 7% | 2% | 0% | 0% | 0% | 94% | 6% | |
| Total (above Con.) | | 626 | 9 | 49 | 25 | 8 | 0 | 0 | 0 | 717 | 79 | 796 |
| Percent | | 79% | 1% | 6% | 3% | 1% | 0% | 0% | 0% | 90% | 10% | |
| Below | 7/17/95 | | | | | | | | | 0 | 1 | 1 |
| Cono– | 7/18/95 | | | | | | | | | 0 | 1 | 1 |
| wingo | 7/19/95 | | | | | | | 1 | | 1 | 9 | 10 |
| | 8/2/95 | | | | | | | 1 | | 1 | 2 | 3 |
| | 8/14/95 | | | | | | | | | 0 | 1 | 1 |
| | 8/15/95 | | | | | | | | | 0 | 9 | 9 |
| | 8/16/95 | | | | | | | 1 | 1 | 2 | 2 | 4 |
| | 8/29/95 | | | | | | | 2 | | 2 | 2 | 4 |
| | 9/11/95 | | | | | | | | | 0 | 1 | 1 |
| | 9/12/95 | | | | | | | 3 | 2 | 5 | 14 | 19 |
| | 10/11/95 | | | | | | | | | 0 | 1 | 1 |
| | 10/24/95 | 1 | | | | | | | | 1 | 5 | 6 |
| Total (below Con.) | | 1 | 0 | 0 | 0 | 0 | 0 | 8 | 3 | 12 | 48 | 60 |
| Percent | | 2% | 0% | 0% | 0% | 0% | 0% | 13% | 5% | 20% | 80% | |

Key to immersion marks:

Day 5– stocked at 7d of age, Juniata River or Susquehanna River above Clarks Ferry.
Day 12,15,18– stocked in Conodoguinet Cr.
Days 3,13,17– stocked at the mouth of Conodoguinet Cr.
Days 3,7,15,19– stocked in the Conestoga River.
Days 5,9,13,17– stocked at the mouth of the Conestoga River.
Days 3,13,17,21– stocked in Muddy Cr.
Days 3,7– reared at Manning, stocked below Conowingo Dam, mid–channel release.
Days 3,11– reared at Manning, stocked below Conowingo Dam, nearshore release.

Job V., Task 1. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1995

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Abstract

A total of 336 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam fish lifts in 1995. Based on tetracycline marking and otolith microstructure, 16% of the 331 readable otoliths were identified as wild and 84% hatchery. Only one of 279 otoliths with hatchery microstructure did not exhibit a tetracycline mark.

Wild fish represented a significantly higher proportion of the catch in samples collected in Upper Chesapeake Bay pound nets (42%) than that found in Conowingo Fish Lift collections (16%). Double marked fish (releases below Conowingo Dam) represented 7% of the marked fish in the Conowingo Lift samples and 44% of the marked fish in the pound net samples.

Using age composition and otolith marking data, the lift catch was partitioned into its component year classes for both hatchery and wild fish. Results indicated that for the 1987-1989 year classes, stocking of approximately 400 hatchery larvae was required to return one adult to the lifts. For wild fish, transport of 1.4 adults to upstream areas was required to return one wild fish to the lifts.

## Introduction

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

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

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

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

In Spring 1987, it was observed that otoliths of "wild" Susquehanna River juvenile American shad (as determined by the absence of a tetracycline mark) appeared to have different microstructural characteristics than hatchery-reared shad. Specifically, the increments formed during the first 20 days appeared to be wider and more distinct in wild juveniles than in hatchery-reared fish. In addition, hatchery-reared fish exhibited an increase in increment width and definition somewhere around increment 20-25, possibly as a result of increased growth rate after stocking. Hendricks, et al. (1994) developed a method to distinguish between wild and hatchery-reared American shad based solely on otolith microstructure. This report represents a continuation of that work, focusing on evaluation of otoliths from adult American shad collected in 1995.

## Methods

A representative sample of adult shad returning to Conowingo Dam was obtained by sacrificing every 100th shad to enter each lift. Adult American shad collected in pound nets at Rocky Point, Beaverdam and Cherry Tree (Upper Chesapeake Bay) were also sacrificed for otolith analysis. Net mortalities and weak looking fish were used for the Upper Bay pound net sample.

Each sampled fish was sexed, measured and decapitated. Whole heads were frozen and delivered to the Van Dyke Hatchery. Otoliths (sagittae) were extracted and one otolith was mounted on a microscope slide, while the other was retained in a vial as a backup. Otoliths were delivered to Benner Spring Fish Research Station. The first 45 otoliths mounted were processed before we decided to subsample to reduce processing time. These samples were collected on a variety of dates between May 20 and June 10. After processing this group, we subsampled by processing every other otolith collected at each lift on each date, always beginning with the first otolith collected. This resulted in a subsample size of slightly more than 1/2 of the remaining samples.

Otoliths were ground on both sides to produce a thin sagittal section. Under white light, each otolith specimen was classified hatchery or wild based upon visual microstructural characteristics. The classifications were done by two experienced researchers.

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

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

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

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

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

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

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

Historical fish lift catch data was compiled from SRAFRC Annual Progress Reports for the years 1972 through 1994. Age composition data was gathered from the same sources. For 1991-1995, age composition data was taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 1984 through 1990 age composition data was determined from the overall fish lift database as reported in SRAFRC Annual Progress Reports by RMC Environmental Services. This database includes holding and transport mortalities which skew the data slightly toward females and older fish (Hendricks, Backman, and Torsello, 1991). For 1979 through 1983, age composition data was taken from angling, gill net and pound net collections made by the Maryland DNR in the Conowingo Tailrace and the upper Chesapeake Bay. For 1972 through 1979, age composition data was derived by averaging the data from 1980 through 1982.

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

## Results and Discussion

A total of 624 shad was sacrificed from the lift catch at Conowingo Dam in 1995. Of those, 336 were subsampled for otolith analysis. For 5 of those, otoliths were broken, not extracted, or had unreadable grinds, leaving 331 readable otoliths (Table 1). A total of 52 (16%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 84% of the specimens were identified as hatchery in origin. Only one otolith (<1%) had hatchery microstructure and no tetracycline mark. Two-hundred and seventy-eight otoliths (84%) exhibited tetracycline marks including single, double, triple and quadruple immersion marks. Four specimens (1%) exhibited feed marks, applied as pond-reared fingerlings. Three of the specimens exhibited a triple immersion mark (days 3, 13, and 17) and a single feed mark indicative of Upper Spring Creek or Canal Pond culture, depending upon age. The other feed marked specimen exhibited a double immersion mark (days 5 and 9) and a double feed mark indicative of culture in Marylands Elkton ponds in 1991.

Random samples of adults have been collected since 1989 and the results of the classifications are summarized in Table 2. Estimates of hatchery contribution to the adult population entering the Conowingo Dam fish lifts during 1989-1994 ranged from 67% to 89% (Table 2, Figure 1). The percentage of fish with hatchery microstructure which also exhibited tetracycline marks was 28% in 1989, 54% in 1990, 66% in 1991, 90% in 1992, 97% in 1993, 93% in 1994, and 99% in 1995.

The contribution of wild fish to the lift catch is surprisingly low, considering the closure of the Maryland shad fishery since 1980. Analysis of otoliths of adult American shad collected in Upper Chesapeake Bay pound nets suggests that the pound nets and fish lifts are sampling intermixed stocks. Wild fish constituted 52% of the pound net catch in 1993, 44% of the pound net catch in 1994, and 42% of the pound net catch in 1995 (Table 1). The lift catch included only 17% wild fish in 1993, 10 % wild fish in 1994, and 16% wild fish in 1995 (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 = 33.91, df =1, 1995 data) and therefore the stocks at those two sites have different constituencies. Similar results were obtained in 1993 and 1994. One possible explanation for this is that Upper Bay stocks, whether wild or hatchery, do not have a strong urge to move upstream and do not enter the lifts with the same frequency as do fish which originated upstream.

Another surprising feature of the results prior to 1993, was the low return of hatchery fish released below Conowingo Dam (double tetracycline mark). In 1993 to 1995, recovery of double marked shad improved dramatically. In 1993, twenty double marked fish were recovered in the Lift sample, representing 16% of the total and 21% of the marked fish. Three double marked fish were recovered in the pound net samples representing 6% of the total and 25% of the marked fish. In 1994, twenty-two double marked fish were recovered in the Lift sample, representing 8% of the total and 11% of the marked fish (Table 1). Fourteen double marked fish were recovered in the pound net samples representing 24% of the total and 54% of the marked fish. In 1995, nineteen double marked fish were recovered in the Lift sample, representing 6% of the total and 7% of the marked fish (Table 1). Twenty-nine double marked fish were recovered in the pound net samples representing 25% of the total and 44% of the marked fish.

Age frequencies were analyzed using scale age data (Table 3). For wild fish, mean ages were 4.7 for males and 4.8 for females (Table 3). For hatchery fish mean age was higher, 4.9 for males and 5.1 for females. Sex ratios were 3.0 to 1, males to females, for wild fish and 1.2 to 1 for hatchery fish. Both these facts are consistent with an expanding population of wild fish, suggesting that returns of wild fish may increase 1996.

Adult shad collected at the lifts were partitioned into their respective year classes using scale age data and corrected for hatchery contribution (Table 4). Total recruitment of hatchery-reared fish to the lifts by year class ranged from 76 for the 1974 year class to 37,286 for the 1990 year class.

Analysis of otoliths to assess hatchery contribution was not conducted prior to 1989. As a result, data for year classes prior to 1986 could not be partitioned into hatchery and wild and is of limited use (see un-shaded area, Table 4). In addition, year classes after 1989 are not fully recruited. Thus, the only truly reliable data is for year classes from 1987 to 1989. For this period, the number of hatchery larvae required to produce one returning adult ranged from 389 to 461 with an average of 412. For the 1990 year class, only 151 larvae were required to produce one returning adult. Since all adults from the 1990 year class have not yet returned, the final larvae to recruit ratio for 1990 will be less than 151. For the 1986 year class, 546 larvae were required to produce one returning adult. This is an minor under-estimate since the 241 adults recruited in 1988 (Table 4) undoubtedly included some wild fish. Including the 1986 and 1990 year classes, an average of 386 hatchery larvae were required to produce one returning adult.

The actual ratio may be smaller still. At a recruitment rate of 400 to 1, stocking 10 million larvae each year would result in 25,000 returning adults each year. In 1995, the catch of hatchery-reared adults at the lifts was 52,000 (84% of 61,650). This suggests that the current ratio may be more like 200 to 1! In addition, straying of Susquehanna River origin fish, as evidenced by the capture of five (25%) Van Dyke marked fish on the spawning grounds in the Nanticoke River (unpublished data), was not accounted for.

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

A similar analysis was tabulated for wild fish (Table 5). Once again, data for year classes prior to 1987 and after 1989 are of limited value because they were not partitioned into hatchery and wild or they have not been fully recruited. For the period 1987 to 1989, it took an average of 1.4 adults transported to produce one returning adult, well below replacement. Stress during trucking may account for reduced performance of transported spawners. The high fecundity of the species has the potential to overcome this, since just a few successful spawners can produce huge numbers of offspring. Another possible explanation is that there may be some threshold number of spawners required to ensure successful spawning. Whatever the cause, improved stock/recruitment ratios for wild fish are required for successful restoration.

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Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1995.

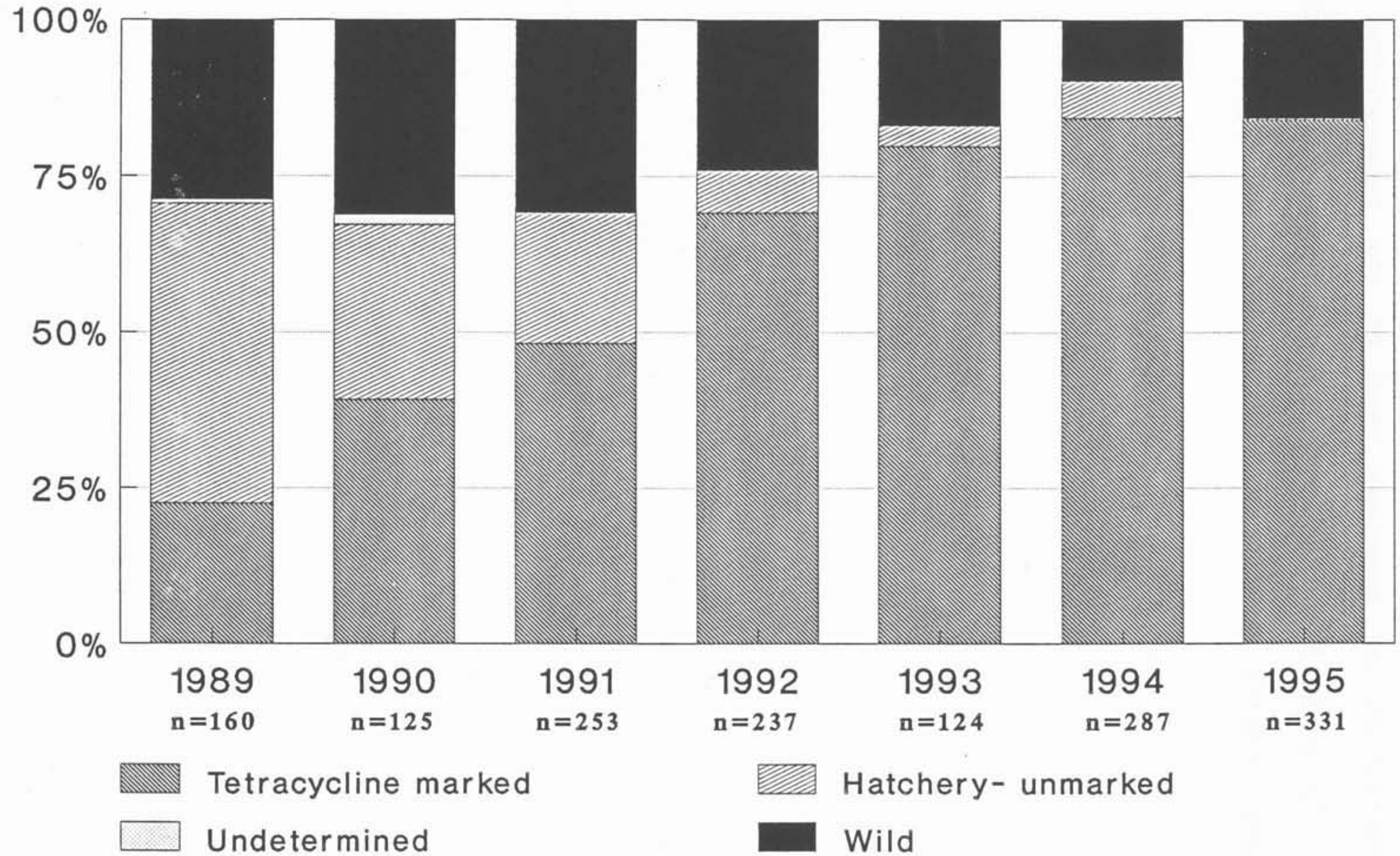

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts and Susquehanna Flats pound nets, 1995. One of every 100 fish collected in each lift was sacrificed. Subsample analyzed consisted of every other fish sacrificed, beginning with the first fish sacrificed each day.

| | | | Conowingo Dam | | Susq. Flats | |
|---|---|---|---|---|---|---|
| | | | N | % | N | % |
| Wild Microstructure, No TC Mark | | | 52 | 16% | 48 | 42% |
| Hatchery Microstructure | No TC Mark* | | 1 | 0% | – | 0% |
| | Single TC Mark | Day 5 | 27 | 8% | 6 | 5% |
| | | Day 18 | 13 | 4% | 3 | 3% |
| | Double TC Mark | Days 5,9 | 17 | 5% | 29 | 25% |
| | | Days 5,19 | 2 | 1% | – | 0% |
| | Triple TC Mark | Days 5,9,13 | 172 | 52% | 19 | 17% |
| | | Days 3,13,17 | 25 | 8% | 5 | 4% |
| | Quadruple TC Mark | Days 5,9,13,17 | 7 | 2% | – | 0% |
| | | Days 3,13,17,21 | 5 | 2% | 1 | 1% |
| | | Days 3,7,11,21 | 2 | 1% | – | 0% |
| | Quintuple TC Mark | Days 5,9,13,17,21 | 4 | 1% | – | 0% |
| | Feed Marks | Days 3,13,17 + single feed mark | 3 | 1% | – | 0% |
| | | Days 5,9 + double feed mark | 1 | 0% | – | 0% |
| | | Days 5,9 + double feed mark | – | 0% | 1 | 1% |
| | | Days 5,19 + single feed mark | – | 0% | 1 | 1% |
| | | Days 5,19 + triple feed mark | – | 0% | 1 | 1% |
| | | Total Hatchery | 279 | 84% | 66 | 58% |
| | | Total readable otoliths | 331 | | 114 | |
| | | Unreadable Otoliths** | 5 | | 4 | |
| | | Total | 336 | | 118 | |

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

Table 2. Composition of the catch of adult American shad at Conowingo Dam fish lifts, based on microstructure classification and tetracycline marking, 1989–1995. Estimates of population proportions were derived from sample classifications corrected based on error rates from a blind classification trial.

| Year | | Wild Microstructure | Microstructure Unknown | Hatchery Microstructure No TC Mark | Hatchery Microstructure TC Marked | Total Hatchery | Total |
|---|---|---|---|---|---|---|---|
| 1989 | N (sample) | 29 | 1 | 94 | 36 | 130 | 160 |
| | % (sample) | 18% | 1% | 59% | 23% | 81% | |
| | **% (population)** | **29%** | **1%** | **48%** | **23%** | **71%** | |
| 1990 | N (sample) | 32 | 2 | 42 | 49 | 91 | 125 |
| | % (sample) | 26% | 2% | 34% | 39% | 73% | |
| | **% (population)** | **31%** | **2%** | **28%** | **39%** | **67%** | |
| 1991 | N (sample) | 68 | 0 | 63 | 122 | 185 | 253 |
| | % (sample) | 27% | 0% | 25% | 48% | 73% | |
| | **% (population)** | **31%** | **0%** | **21%** | **48%** | **69%** | |
| 1992 | N (sample) | 54 | 0 | 19 | 164 | 183 | 237 |
| | % (sample) | 23% | 0% | 8% | 69% | 77% | |
| | **% (population)** | **24%** | **0%** | **7%** | **69%** | **76%** | |
| 1993 | N (sample) | 21 | 0 | 4 | 99 | 103 | 124 |
| | % (sample) | 17% | 0% | 3% | 80% | 83% | |
| | **% (population)** | **17%** | **0%** | **3%** | **80%** | **83%** | |
| 1994 | N (sample) | 28 | 0 | 17 | 242 | 259 | 287 |
| | % (sample) | 10% | 0% | 6% | 84% | 90% | |
| | **% (population)** | **11%** | **0%** | **5%** | **84%** | **89%** | |
| 1995 | N (sample) | 52 | 0 | 1 | 278 | 279 | 331 |
| | % (sample) | 16% | 0% | 0% | 84% | 84% | |
| | **% (population)** | **15%** | **0%** | **1%** | **84%** | **85%** | |

Table 3. Age frequency by sex and origin for American shad sacrificed for otolith analysis at the Conowingo Dam Fish Lifts, 1995.

| Scale | Wild | | Hatchery | | |
|---|---|---|---|---|---|
| Age | Male | Female | Male | Female | Totals |
| III | – | – | 2 | – | 2 |
| IV | 13 | 3 | 20 | 1 | 37 |
| V | 20 | 7 | 88 | 80 | 195 |
| VI | 5 | 3 | 33 | 29 | 70 |
| VII | – | – | 3 | 10 | 13 |
| ? | 1 | – | 6 | 7 | 14 |
| Total | 39 | 13 | 152 | 127 | 331 |

Table 4. Stock/recruitment ratio by year class for American shad fry stocked in the Susquehanna River above dams and collected in the Conowingo Dam Fish Lifts.

| | Trap | % Age Composition | | | | | | | Hatchery | Number of Adult shad collected in trap by Year Class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Catch | 8 | 7 | 6 | 5 | 4 | 3 | 2 | Contribution | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
| 1972 | 182 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | | |
| 1973 | 65 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | | |
| 1974 | 121 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 2 | | | | | | | | | |
| 1975 | 87 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 15 | 2 | | | | | | | | |
| 1976 | 82 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 47 | 14 | 2 | | | | | | | |
| 1977 | 165 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 38 | 94 | 28 | 3 | | | | | | |
| 1978 | 54 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 1 | 13 | 31 | 9 | 1 | | | | | |
| 1979 | 50 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 0 | 1 | 12 | 28 | 9 | 1 | | | | |
| 1980 | 139 | | | 2.72 | 33.15 | 57.06 | 6.52 | | | 0 | 0 | 4 | 46 | 79 | 9 | | | | |
| 1981 | 328 | | | 1.94 | 11.62 | 51.61 | 32.90 | 1.94 | | | | 0 | 6 | 38 | 169 | 108 | 6 | | |
| 1982 | 2,039 | | | 1.74 | 24.68 | 61.90 | 11.69 | | | | | | 0 | 35 | 503 | 1262 | 238 | 0 | |
| 1983 | 413 | | 2.72 | 28.29 | 55.82 | 9.31 | 3.88 | | | | | | | 11 | 117 | 231 | 38 | 16 | 0 |
| 1984 | 167 | 0.00 | 7.38 | 12.08 | 8.72 | 59.73 | 12.08 | 0.00 | | | | | | | 0 | 12 | 20 | 15 | 100 |
| 1985 | 1,546 | 0.00 | 1.66 | 6.89 | 30.17 | 50.83 | 10.45 | 0.00 | | | | | | | | 0 | 26 | 106 | 466 |
| 1986 | 5,195 | 0.00 | 1.58 | 10.45 | 35.11 | 35.90 | 16.57 | 0.39 | | | | | | | | | 0 | 82 | 543 |
| 1987 | 7,667 | 0.00 | 3.93 | 13.76 | 25.80 | 45.70 | 10.57 | 0.25 | | | | | | | | | | 0 | 301 |
| 1988 | 5,146 | 0.00 | 3.96 | 31.65 | 38.13 | 21.22 | 4.68 | 0.36 | | | | | | | | | | | 0 |
| 1989 | 8,218 | 0.00 | 4.35 | 18.12 | 41.55 | 30.19 | 5.56 | 0.24 | 0.71 | | | | | | | | | | |
| 1990 | 15,719 | 0.15 | 5.52 | 32.70 | 45.20 | 14.97 | 1.45 | | 0.67 | | | | | | | | | | |
| 1991 | 27,227 | | 10.73 | 36.72 | 38.42 | 12.43 | 1.69 | | 0.69 | | | | | | | | | | |
| 1992 | 25,721 | 0.58 | 12.28 | 35.67 | 36.84 | 11.70 | 2.92 | | 0.76 | | | | | | | | | | |
| 1993 | 13,546 | 0.00 | 3.20 | 21.60 | 52.80 | 21.60 | 0.80 | 0.00 | 0.83 | | | | | | | | | | |
| 1994 | 32,330 | 0.00 | 3.28 | 22.63 | 54.74 | 19.34 | 0.00 | 0.00 | 0.89 | | | | | | | | | | |
| 1995 | 61,650 | 0.00 | 4.10 | 22.08 | 61.51 | 11.67 | 0.63 | 0.00 | 0.84 | | | | | | | | | | |
| Tot. Recruits to Trap: | | | | | | | | | | 103 | 123 | 76 | 93 | 174 | 799 | 1,613 | 329 | 219 | 1,411 |
| Fry releases (above Cono.) | | | | | | | | | | 0 | 0 | 0 | 0 | 518,000 | 968,901 | 2,124,000 | 629,500 | 3,526,275 | 2,029,650 |
| **stock\recruit ratio (X 1000)** | | | | | | | | | | | | | | 0.34 | 0.83 | 0.76 | 0.52 | 0.06 | 0.69 |
| **#fry to produce 1 adult** | | | | | | | | | | | | | | 2,982 | 1,212 | 1,317 | 1,913 | 16,097 | 1,439 |

Note: The 1990 year class is not fully recruited.

Table 4. (continued).

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Hatchery Contribution | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1973 | 65 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1974 | 121 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1975 | 87 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1976 | 82 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1977 | 165 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1978 | 54 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1979 | 50 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1980 | 139 | | | 2.72 | 33.15 | 57.06 | 6.52 | | | | | | | | | | | |
| 1981 | 328 | | | 1.94 | 11.62 | 51.61 | 32.90 | 1.94 | | | | | | | | | | |
| 1982 | 2,039 | | | 1.74 | 24.68 | 61.90 | 11.69 | | | | | | | | | | | |
| 1983 | 413 | | 2.72 | 28.29 | 55.82 | 9.31 | 3.88 | | | | | | | | | | | |
| 1984 | 167 | 0.00 | 7.38 | 12.08 | 8.72 | 59.73 | 12.08 | 0.00 | | 20 | | | | | | | | |
| 1985 | 1,546 | 0.00 | 1.66 | 6.89 | 30.17 | 50.83 | 10.45 | 0.00 | | 786 | 162 | | | | | | | |
| 1986 | 5,195 | 0.00 | 1.58 | 10.45 | 35.11 | 35.90 | 16.57 | 0.39 | | 1824 | 1865 | 861 | | | | | | |
| 1987 | 7,667 | 0.00 | 3.93 | 13.76 | 25.80 | 45.70 | 10.57 | 0.25 | | 1055 | 1978 | 3504 | 810 | | | | | |
| 1988 | 5,146 | 0.00 | 3.96 | 31.65 | 38.13 | 21.22 | 4.68 | 0.36 | | 204 | 1629 | 1962 | 1092 | 241 | | | | |
| 1989 | 8,218 | 0.00 | 4.35 | 18.12 | 41.55 | 30.19 | 5.56 | 0.24 | 0.71 | 0 | 254 | 1057 | 2424 | 1762 | 324 | | | |
| 1990 | 15,719 | 0.15 | 5.52 | 32.70 | 45.20 | 14.97 | 1.45 | | 0.67 | 15 | 582 | 3444 | 4761 | 1577 | 153 | 0 | | |
| 1991 | 27,227 | | 10.73 | 36.72 | 38.42 | 12.43 | 1.69 | | 0.69 | | 0 | 2017 | 6899 | 7217 | 2335 | 318 | 0 | 0 |
| 1992 | 25,721 | 0.58 | 12.28 | 35.67 | 36.84 | 11.70 | 2.92 | | 0.76 | | | 114 | 2401 | 6973 | 7202 | 2286 | 572 | 0 |
| 1993 | 13,546 | 0.00 | 3.20 | 21.60 | 52.80 | 21.60 | 0.80 | 0.00 | 0.83 | | | 0 | 0 | 360 | 2429 | 5936 | 2429 | 90 |
| 1994 | 32,330 | 0.00 | 3.28 | 22.63 | 54.74 | 19.34 | 0.00 | 0.00 | 0.89 | | | | 0 | 0 | 881 | 6072 | 14690 | 5190 |
| 1995 | 61,650 | 0.00 | 4.10 | 22.08 | 61.51 | 11.67 | 0.63 | 0.00 | 0.84 | | | | | | | 2134 | 11489 | 32005 |
| | | | | | | | | | Tot. Recruits to Trap: | 3,904 | 6,469 | 12,959 | 18,387 | 18,130 | 13,324 | 16,747 | 29,179 | 37,286 |
| | | | | | | | | | Fry releases (above Cono.) | 5,018,800 | 4,047,600 | 11,995,690 | 6,227,590 | 9,899,430 | 5,179,790 | 6,450,685 | 13,464,650 | 5,619,000 |
| | | | | | | | | | **stock\recruit ratio (X 1000)** | 0.78 | 1.60 | 1.08 | 2.95 | 1.83 | 2.57 | 2.60 | 2.17 | 6.64 |
| | | | | | | | | | **#fry to produce 1 adult** | 1,286 | 626 | 926 | 339 | 546 | 389 | 385 | 461 | 151 |
| | | | | | | | | | | | | | | | | Average 1987–1989: | | 412 |
| | | | | | | | | | | | | | | | | Average 1986–1990: | | 386 |

(Shaded cells:) Corrected for hatchery contribution.

Note: The 1990 year class is not fully recruited.

Table 5. Stock/recruitment ratio by year class for adult American shad collected in the Conowingo Dam Fish Lifts and transported to the Susquehanna River above dams.

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Wild Contribution | Number of Adult shad collected in trap by Year Class 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | | |
| 1973 | 65 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | | |
| 1974 | 121 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 2 | | | | | | | | | |
| 1975 | 87 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 15 | 2 | | | | | | | | |
| 1976 | 82 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 47 | 14 | 2 | | | | | | | |
| 1977 | 165 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 38 | 94 | 28 | 3 | | | | | | |
| 1978 | 54 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 1 | 13 | 31 | 9 | 1 | | | | | |
| 1979 | 50 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | 0 | 1 | 12 | 28 | 9 | 1 | | | | |
| 1980 | 139 | | | 2.72 | 33.15 | 57.06 | 6.52 | | | 0 | 0 | 4 | 46 | 79 | 9 | | | | |
| 1981 | 328 | | | 1.94 | 11.62 | 51.61 | 32.90 | 1.94 | | | | 0 | 6 | 38 | 169 | 108 | 6 | | |
| 1982 | 2,039 | | | 1.74 | 24.68 | 61.90 | 11.69 | | | | | | 0 | 35 | 503 | 1262 | 238 | 0 | |
| 1983 | 413 | | 2.72 | 28.29 | 55.82 | 9.31 | 3.88 | | | | | | | 11 | 117 | 231 | 38 | 16 | 0 |
| 1984 | 167 | 0.00 | 7.38 | 12.08 | 8.72 | 59.73 | 12.08 | 0.00 | | | | | | | 0 | 12 | 20 | 15 | 100 |
| 1985 | 1,546 | 0.00 | 1.66 | 6.89 | 30.17 | 50.83 | 10.45 | 0.00 | | | | | | | | 0 | 26 | 106 | 466 |
| 1986 | 5,195 | 0.00 | 1.58 | 10.45 | 35.11 | 35.90 | 16.57 | 0.39 | | | | | | | | | 0 | 82 | 543 |
| 1987 | 7,667 | 0.00 | 3.93 | 13.76 | 25.80 | 45.70 | 10.57 | 0.25 | | | | | | | | | | 0 | 301 |
| 1988 | 5,146 | 0.00 | 3.96 | 31.65 | 38.13 | 21.22 | 4.68 | 0.36 | | | | | | | | | | | 0 |
| 1989 | 8,218 | 0.00 | 4.35 | 18.12 | 41.55 | 30.19 | 5.56 | 0.24 | 0.29 | | | | | | | | | | |
| 1990 | 15,719 | 0.15 | 5.52 | 32.70 | 45.20 | 14.97 | 1.45 | | 0.33 | | | | | | | | | | |
| 1991 | 27,227 | | 10.73 | 36.72 | 38.42 | 12.43 | 1.69 | | 0.31 | | | | | | | | | | |
| 1992 | 25,721 | 0.58 | 12.28 | 35.67 | 36.84 | 11.70 | 2.92 | | 0.24 | | | | | | | | | | |
| 1993 | 13,546 | 0.00 | 3.20 | 21.60 | 52.80 | 21.60 | 0.80 | 0.00 | 0.17 | | | | | | | | | | |
| 1994 | 32,330 | 0.00 | 3.28 | 22.63 | 54.74 | 19.34 | 0.00 | 0.00 | 0.11 | | | | | | | | | | |
| 1995 | 61,650 | 0.00 | 4.10 | 22.08 | 61.51 | 11.67 | 0.63 | 0.00 | 0.16 | | | | | | | | | | |
| | | | | | | | | | Tot. Recruits to Trap: | 103 | 123 | 76 | 93 | 174 | 799 | 1,613 | 329 | 219 | 1,411 |
| | | | | | | | | | Adult releases above Cono. (transported): | | | | | | | | | | |
| | | | | | | | | | **stock\recruit ratio (X 1000)** | | | | | | | | | | |
| | | | | | | | | | **# of transported adults needed to produce 1 returning adult:** | | | | | 0 | 0 | 0 | 0 | 0 | 0 |

Note: The 1990 year class is not fully recruited.

Table 5. (continued).

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Wild Contribution | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1973 | 65 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1974 | 121 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1975 | 87 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1976 | 82 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1977 | 165 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1978 | 54 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1979 | 50 | | | 2.13 | 23.15 | 56.86 | 17.04 | 1.94 | | | | | | | | | | |
| 1980 | 139 | | | 2.72 | 33.15 | 57.06 | 6.52 | | | | | | | | | | | |
| 1981 | 328 | | | 1.94 | 11.62 | 51.61 | 32.90 | 1.94 | | | | | | | | | | |
| 1982 | 2,039 | | | 1.74 | 24.68 | 61.90 | 11.69 | | | | | | | | | | | |
| 1983 | 413 | | 2.72 | 28.29 | 55.82 | 9.31 | 3.88 | | | | | | | | | | | |
| 1984 | 167 | 0.00 | 7.38 | 12.08 | 8.72 | 59.73 | 12.08 | 0.00 | | 20 | | | | | | | | |
| 1985 | 1,546 | 0.00 | 1.66 | 6.89 | 30.17 | 50.83 | 10.45 | 0.00 | | 786 | 162 | | | | | | | |
| 1986 | 5,195 | 0.00 | 1.58 | 10.45 | 35.11 | 35.90 | 16.57 | 0.39 | | 1824 | 1865 | 861 | | | | | | |
| 1987 | 7,667 | 0.00 | 3.93 | 13.76 | 25.80 | 45.70 | 10.57 | 0.25 | | 1055 | 1978 | 3504 | 810 | | | | | |
| 1988 | 5,146 | 0.00 | 3.96 | 31.65 | 38.13 | 21.22 | 4.68 | 0.36 | | 204 | 1629 | 1962 | 1092 | 241 | | | | |
| 1989 | 8,218 | 0.00 | 4.35 | 18.12 | 41.55 | 30.19 | 5.56 | 0.24 | 0.29 | 0 | 104 | 432 | 990 | 720 | 132 | | | |
| 1990 | 15,719 | 0.15 | 5.52 | 32.70 | 45.20 | 14.97 | 1.45 | | 0.33 | 8 | 287 | 1696 | 2345 | 777 | 75 | 0 | | |
| 1991 | 27,227 | | 10.73 | 36.72 | 38.42 | 12.43 | 1.69 | | 0.31 | | 0 | 906 | 3100 | 3243 | 1049 | 143 | 0 | 0 |
| 1992 | 25,721 | 0.58 | 12.28 | 35.67 | 36.84 | 11.70 | 2.92 | | 0.24 | | | 36 | 758 | 2202 | 2274 | 722 | 180 | 0 |
| 1993 | 13,546 | 0.00 | 3.20 | 21.60 | 52.80 | 21.60 | 0.80 | 0.00 | 0.17 | | | 0 | 0 | 74 | 497 | 1216 | 497 | 18 |
| 1994 | 32,330 | 0.00 | 3.28 | 22.63 | 54.74 | 19.34 | 0.00 | 0.00 | 0.11 | | | | 0 | 0 | 181 | 1244 | 3009 | 1063 |
| 1995 | 61,650 | 0.00 | 4.10 | 22.08 | 61.51 | 11.67 | 0.63 | 0.00 | 0.16 | | | | | | | 394 | 2124 | 5916 |
| Tot. Recruits to Trap: | | | | | | | | | | 3,896 | 6,023 | 9,397 | 9,095 | 7,255 | 4,209 | 3,719 | 5,810 | 6,997 |
| Adult releases above Cono. (transported): | | | | | | | | | | 842 | 36 | | 967 | 4,172 | 7,202 | 4,736 | 6,469 | 15,075 |
| **stock\recruit ratio (X 1000)** | | | | | | | | | | 4627.07 | 167319.33 | | 9405.15 | 1739.02 | 584.43 | 785.26 | 898.17 | 464.16 |
| **# of transported adults needed to produce 1 returning adult:** | | | | | | | | | | 0.2 | 0.0 | 0.0 | 0.1 | 0.6 | 1.7 | 1.3 | 1.1 | 2.2 |

Average 1987–1989: 1.4

Note: The 1990 year class is not fully recruited.

(shaded) Corrected for wild contribution.

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

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## Introduction

The American shad fishery in Maryland waters of the Chesapeake Bay has been closed to sport and commercial fishing since 1980. Since then, the Maryland Department of Natural Resources (MDNR) has monitored the number of adult American shad present in the upper Chesapeake Bay during the spring spawning season. Besides providing an estimate of the adult spawning population, this mark-recapture effort also provides length, age, sex, and spawning history information concerning this stock. The adult sampling is followed by a juvenile recruitment survey designed to assess reproductive success. The information obtained through these activities is provided to SRAFRC to aid in restoration of American shad to the Susquehanna River.

## Methods and Materials

Collection procedures for adult American shad in 1995 were nearly identical to those in 1994. Three commercial pound nets were sampled, one at Cherry Tree Point in Aberdeen Proving Ground and two in the Susquehanna Flats (Figure 1). Hook and line sampling in the Conowingo tailrace continued unchanged from the previous year. Tagging procedures and data collection followed the methodology established in past years and is described in previous SRAFRC reports.

Juvenile production in 1995 was again monitored by project personnel with the Smith-Root electrofisher. The Susquehanna Flats shoreline area was gridded off into 21 separate cells approximately 2,000 feet long (Figure 2). Based on juvenile American shad abundance over the previous five years, mean catch-per-unit-effort (CPUE) for each of these 21 cells was calculated and each cell was assigned to either a high or low density strata. Each strata was then weighted and, based on the method of optimal allocation, six high density and three low density cells were randomly selected and sampled bi-weekly. Sampling results from the Department's Juvenile Seine Survey were also utilized in analysis of the reproductive success of American shad in the upper Bay during 1995.

**Results**

Pound net tagging for 1995 began on 23 March and continued until 18 May, while hook and line effort commenced on 25 April and ended 1 June. Of the 1,784 adult American shad captured, 1,125 (63.1%) were tagged and 203 (18.0%) subsequently recaptured (Table 1). Of these 203 recaptures, four occurred outside the upper Bay system in the Delaware River. The 203 total also does not reflect the 78 multiple recaptures, six unverifiable tag numbers, and 19 fish tagged prior to 1995.

Recapture data for the 1994 season is summarized as follows:

**a.** 196 fish recaptured by the Conowingo Fish Lifts (does not include 78 multiple recaptures, 19 pre-1995 tagged fish, and 6 fish with unverifiable tag numbers)

3 fish recaptured by pound net

0 fish recaptured by hook and line from the tailrace

4 fish recaptured outside the system

**b.** 147 fish recaptured originally caught by hook and line

52 fish recaptured originally caught by pound net

**c.** 149 fish recaptured in the same area as initially tagged

53 fish recaptured upstream of their initial tagging site (includes 4 recaptures from the Delaware River)

1 fish recaptured downstream of its initial tagging site

**d.** shortest period at large: 1 day

longest period at large: 43 days (1995 fish only)

mean number days at large: 11.9

**e.** number of pre-1995 tagged fish recaptured: 19

number of pre-1995 multiple recaptures: 6

The 1995 adult American shad Petersen population estimate for the upper Chesapeake Bay was 333,891 (Table 2), and has been increasing exponentially since 1980 ($r^2$=0.79, $P \leq 0.0001$) (Figure 3). Since four recaptures occurred outside the upper Bay system, an emigration factor was calculated in order to adjust for the number of fish marked (M) in the Petersen statistic, but lost and unavailable for later recapture. The Conowingo tailrace population estimate was 210,546 (Table 3), and has also been increasing exponentially since 1984 ($r^2$=0.82, $P \leq 0.0001$) (Figure 4).

Effort, catch, and catch-per-unit-effort (CPUE) by gear type for adult American shad in the upper Bay during 1995 and comparison with previous years is presented in Table 4. Pound net CPUE has been marginally increasing since 1980 ($r^2$=0.24, $P \leq 0.09$), and hook and line CPUE has been increasing since 1986 ($r^2$=0.47, $P \leq 0.03$).

A total of 501 adult American shad ( 298 pound net, 203 hook and line) were examined for physical characteristics by DNR biologists in 1995 (Table 5). The 1990 year-class (age 5, sexes combined) was the most abundant year-class sampled in the upper Bay by pound net and hook and line, accounting for 34.9% and 38.9%, respectively, of the total catch (Table 5). Age frequency modes occurred at age 5 for males in both pound net and hook and line catches. Age frequency modes for females occurred at age 6 in pound net catches and equally at ages 5 and 6 in hook and line catches. Both sexes (gears combined) were present in age groups 4-6; there were no age 3 females and only one age 8 female. Males were more abundant at ages 3-5, and females were more abundant at ages 6-7. The overall incidence of repeat spawning in male American shad decreased from 12.1% in 1994 to 3.9% in 1995. Similarly, female American shad repeat spawning decreased from 12.8% in 1993 to 11.2% in 1995.

Juvenile *Alosa* sampling in the upper Bay during 1995 again produced good numbers of American shad. A total of 24 juvenile American shad were collected by electrofisher in 1994. Supplemental haul seine sampling by the Department's Juvenile Seine Survey in 1995 captured another 36 juvenile American shad. Table 6 provides a breakdown by cell and date of the juvenile American shad collected by electrofishing from the upper Chesapeake Bay during 1995.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1995.

| GEAR TYPE | LOCATION | CATCH | NUMBER TAGGED |
|---|---|---|---|
| Pound Net | Cherry Tree | 472 | 162 |
| | Rocky Point | 425 | 271 |
| | Beaver Dam | 262 | 119 |
| | Total | 1,159 | 552 |
| Hook and Line | Conowingo Tailrace Susquehanna River | 625 | 573 |
| Fish Lift | Conowingo Tailrace Susquehanna River | 61,572 | |
| | TOTALS | 63,356 | 1,125 |

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1995 using the Petersen estimate.

Chapman's Modification to the Petersen estimate -

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

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

For the 1994 survey -

C = 63,356
R = 199
M = 1,053*

Therefore -

$$N = \frac{(63,356 + 1)\ (1,053 + 1)}{(199 + 1)}$$

= **333,891**

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

Using Chapman (1951):

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

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

$$\text{Upper } N^* = \frac{(63,356 + 1)\ (1,053 + 1)}{173.20 + 1} = 383,345$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(63,356 + 1)\ (1,053 + 1)}{228.64 + 1} = 290,795$$ @ .95 confidence limits

* M adjusted for emigration and 3% tag loss

Table 3. Population estimate of adult American shad in the Conowingo tailrace during 1995 using the Petersen estimate.

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Chapman's Modification to the Petersen estimate -

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

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

For the 1994 survey -

C = 55,943
R = 147
M = 556*

Therefore -

$$N = \frac{(55,943 + 1)\ (556 + 1)}{(147 + 1)}$$

= **210,546**

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

Using Chapman (1951):

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

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

Upper $N^* = \frac{(55,943 + 1)\ (556 + 1)}{125.08 + 1}$ = 247,155 @ .95 confidence limits

Lower $N^* = \frac{(55,943 + 1)\ (556 + 1)}{172.76 + 1}$ = 179,336 @ .95 confidence limits

* M adjusted 3% tag loss

Table 4. Catch, effort, and catch-per-unit-effort (CPUE) for adult American shad by pound net and hook and line during the 1980-1995 tagging program in the upper Chesapeake Bay.

| YEAR | LOCATION | DAYS FISHED | TOTAL CATCH | CATCH PER POUND NET DAY | POPLN. EST. |
|---|---|---|---|---|---|
| **Pound Net** | | | | | |
| 1980 | Rocky Pt. | 26 | 50 | 1.92 | 5,531 |
| 1981 | Rocky Pt. | 38 | 50 | 0.86 | 9,357 |
| 1982 | Rocky Pt. | 27 | 62 | 2.29 | 37,551 |
| 1985 | Rocky Pt. | 10 | 30 | 3.00 | 14,283 |
| 1988 | Rocky Pt. | 33 | 87 | 2.64 | |
| | Cherry Tree | 41 | 75 | 1.83 | |
| | Romney Creek | 41 | 8 | 0.20 | |
| | 1988 Total | 115 | 170 | 1.48 | 38,386 |
| 1989 | Rocky Pt. | 32 | 91 | 2.84 | |
| | Cherry Tree | 62 | 295 | 4.76 | |
| | Beaver Dam | 11 | 14 | 1.27 | |
| | 1989 Total | 105 | 400 | 3.81 | 75,820 |
| 1990 | Rocky Pt. | 38 | 221 | 5.82 | |
| | Cherry Tree | 71 | 178 | 2.50 | |
| | 1990 Total | 109 | 399 | 3.66 | 123,830 |
| 1991 | Rocky Pt. | 38 | 251 | 6.61 | |
| | Cherry Tree | 56 | 594 | 10.61 | |
| | Bohemia River | 54 | 209 | 3.87 | |
| | 1991 Total | 148 | 1054 | 7.12 | 141,049 |
| 1992 | Cherry Tree | 56 | 147 | 2.63 | |
| | Bohemia River | 47 | 43 | 0.87 | |
| | 1992 Total | 103 | 190 | 1.80 | 105,255 |
| 1993 | Cherry Tree | 48 | 255 | 5.31 | |
| | Cara Cove | 45 | 26 | 0.58 | |
| | 1993 Total | 93 | 281 | 3.02 | 47,563 |
| 1994 | Cherry Tree | 48 | 320 | 6.67 | |
| | Cara Cove | 46 | 26 | 0.57 | |
| | 1994 Total | 94 | 346 | 3.68 | 129,482 |
| 1995 | Cherry Tree | 57 | 472 | 8.28 | |
| | Rocky Point | 48 | 425 | 8.85 | |
| | Beaver Dam | 23 | 262 | 11.39 | 333,891 |
| | | 128 | 1159 | 9.05 | |

Table 5. Catch (N), age composition (%), number and percent of repeat spawners, and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1995 upper Chesapeake Bay spring tagging operation.

| | MALE | | | | FEMALE | | | |
|---|---|---|---|---|---|---|---|---|
| AGE GROUP | N(%) | RPTS. | MEAN | RANGE | N(%) | RPTS. | MEAN | RANGE |
| **Pound Net** | | | | | | | | |
| III | 28(9) | 0 | 334 | 295-380 | 0 | - | - | - |
| IV | 56(19) | 2 | 370 | 340-420 | 38(13) | 0 | 405 | 380-435 |
| V | 60(20) | 5 | 413 | 375-455 | 44(15) | 3 | 433 | 385-465 |
| VI | 7(2) | 1 | 451 | 430-485 | 48(16) | 16 | 470 | 415-510 |
| VII | 2(1) | 0 | 483 | 480-485 | 14(5) | 4 | 501 | 470-535 |
| VIII | 0 | - | - | - | 1 | 1 | 485 | - |
| % Repeat Spawners | | 5.2 | | | | 16.6 | | |
| **Hook and Line** | | | | | | | | |
| III | 10(5) | 0 | 342 | 302-366 | 0 | - | - | - |
| IV | 36(18) | 0 | 383 | 352-428 | 25(12) | 0 | 414 | 380-485 |
| V | 45(22) | 1 | 411 | 360-445 | 34(17) | 0 | 441 | 411-468 |
| VI | 15(7) | 1 | 453 | 429-476 | 34(17) | 3 | 471 | 440-502 |
| VII | 0 | - | - | - | 4(2) | 0 | 503 | 488-525 |
| % Repeat Spawners | | 1.9 | | | | 3.1 | | |
| **All gears combined** | | | | | | | | |
| III | 38(8) | 0 | 336 | 295-380 | 0 | 0 | - | - |
| IV | 92(18) | 2 | 375 | 340-428 | 63(13) | 0 | 408 | 380-485 |
| V | 105(21) | 6 | 412 | 360-455 | 78(16) | 3 | 437 | 385-468 |
| VI | 22(4) | 2 | 452 | 429-485 | 82(10) | 19 | 471 | 415-510 |
| VII | 2 | 0 | 483 | 480-485 | 18(3) | 4 | 502 | 470-535 |
| VIII | 0 | - | - | - | 1 | 1 | 485 | - |
| % Repeat Spawners | | 3.9 | | | | 11.2 | | |

Table 6. Juvenile American shad captured by date and cell and associated catch-per-unit-effort (American shad caught per shock hour) during the 1995 upper Chesapeake Bay electrofishing survey. No sampling at a particular date and cell is representedby a blank space.

| CELL NO. | AUGUST 2 | AUGUST 15 | AUGUST 29 | SEPTEMBER 12 | SEPTEMBER 27 | OCTOBER 11 | OCTOBER 24 | CATCH | SHOCK TIME (SEC) | CPUE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 1 | | 2 | | X | | 3 | 1500 | 7.2 |
| 2 | | | X | 1 | | X | | 1 | 1500 | 2.4 |
| 3 | X | | 1 | | X | X | 1 | 2 | 2500 | 2.9 |
| 4 | X | | | | | X | | 0 | 1000 | 0.0 |
| 5 | X | | | | | | | 0 | 500 | 0.0 |
| 6 | | | | | X | | | 0 | 500 | 0.0 |
| 7 | | | 1 | 2 | X | | 2 | 5 | 2000 | 9.0 |
| 8 | | | | | | | | 0 | 0 | 0.0 |
| 9 | | X | | X | X | | X | 0 | 2000 | 0.0 |
| 10 | | | X | | | 1 | | 1 | 1000 | 3.6 |
| 11 | | | | X | X | | | 0 | 1000 | 0.0 |
| 12 | 1 | 1 | X | X | X | X | | 2 | 3000 | 2.4 |
| 13 | | 1 | | | | X | | 1 | 1000 | 3.6 |
| 14 | | | | | | | | 0 | 0 | 0.0 |
| 15 | X | X | | 1 | | | X | 1 | 2000 | 1.8 |
| 16 | X | | X | X | X | | 2 | 2 | 2500 | 2.9 |
| 17 | | X | X | | | | X | 0 | 1500 | 0.0 |
| 18 | | | | | | | | 0 | 0 | 0.0 |
| 19 | X | X | | | X | X | X | 0 | 2500 | 0.0 |
| 20 | 1 | 1 | 2 | | X | | 1 | 5 | 2500 | 7.2 |
| 21 | 1 | X | X | X | | X | X | 1 | 3000 | 1.2 |
| TOT | 3 | 4 | 4 | 6 | 0 | 1 | 6 | **24** | 31500 | 2.74 |

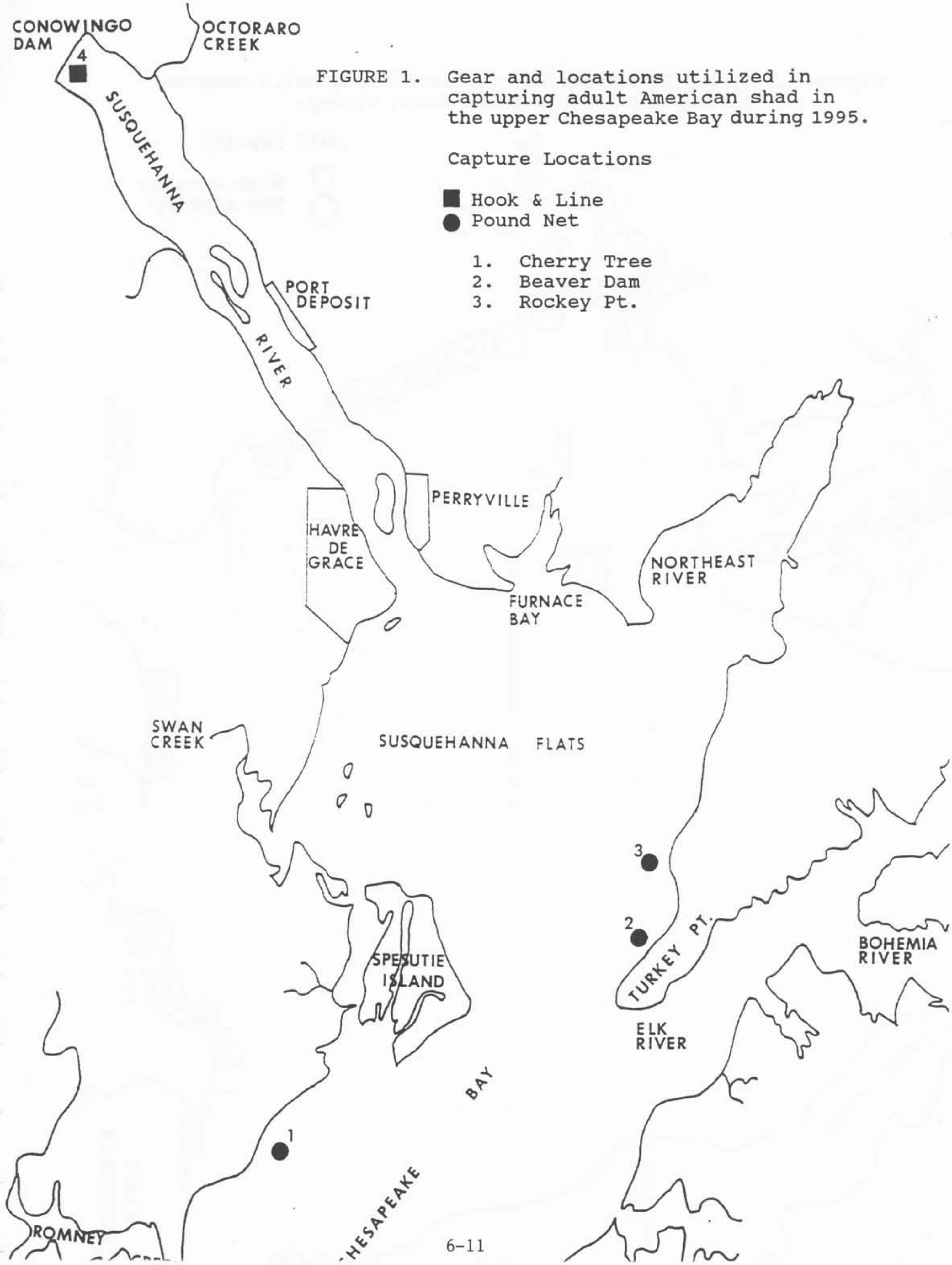



FIGURE 1. Gear and locations utilized in capturing adult American shad in the upper Chesapeake Bay during 1995.

Figure 2. Upper Chesapeake Bay electrofishing cells sampled during the 1995 juvenile *Alosa* survey.

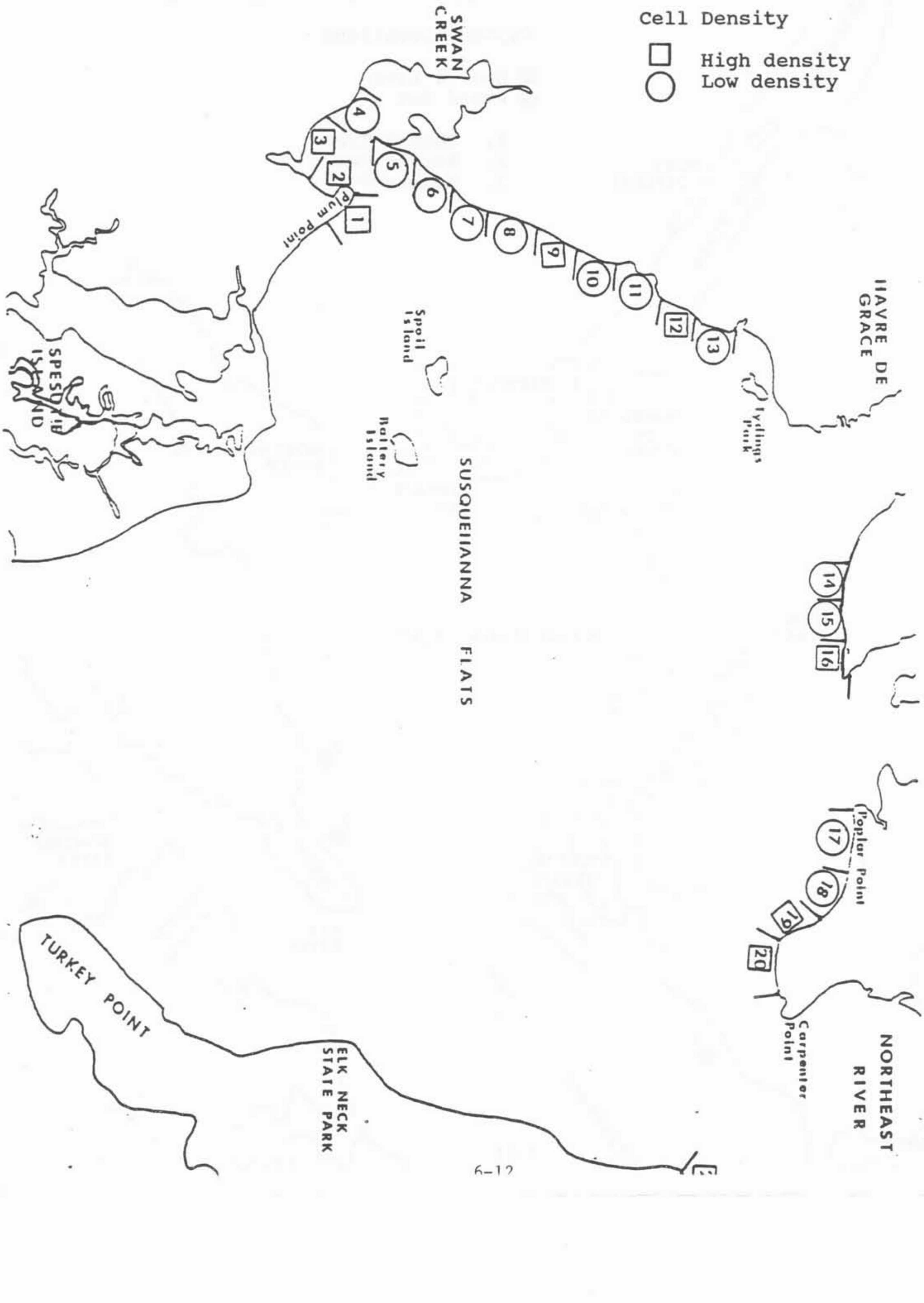


Figure 3. Population estimates of American shad captured in the upper Chesapeake Bay, 1980-1995. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.

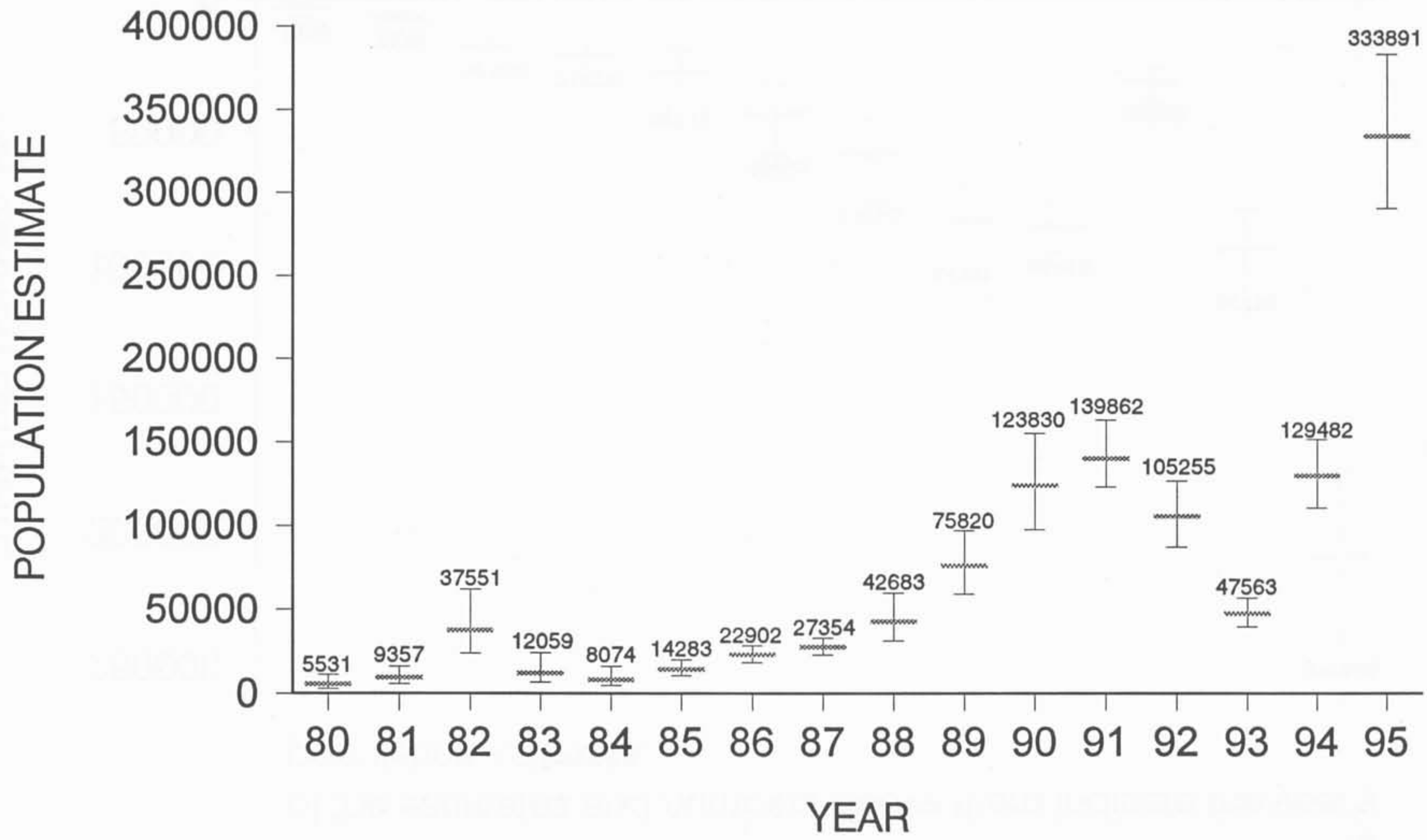
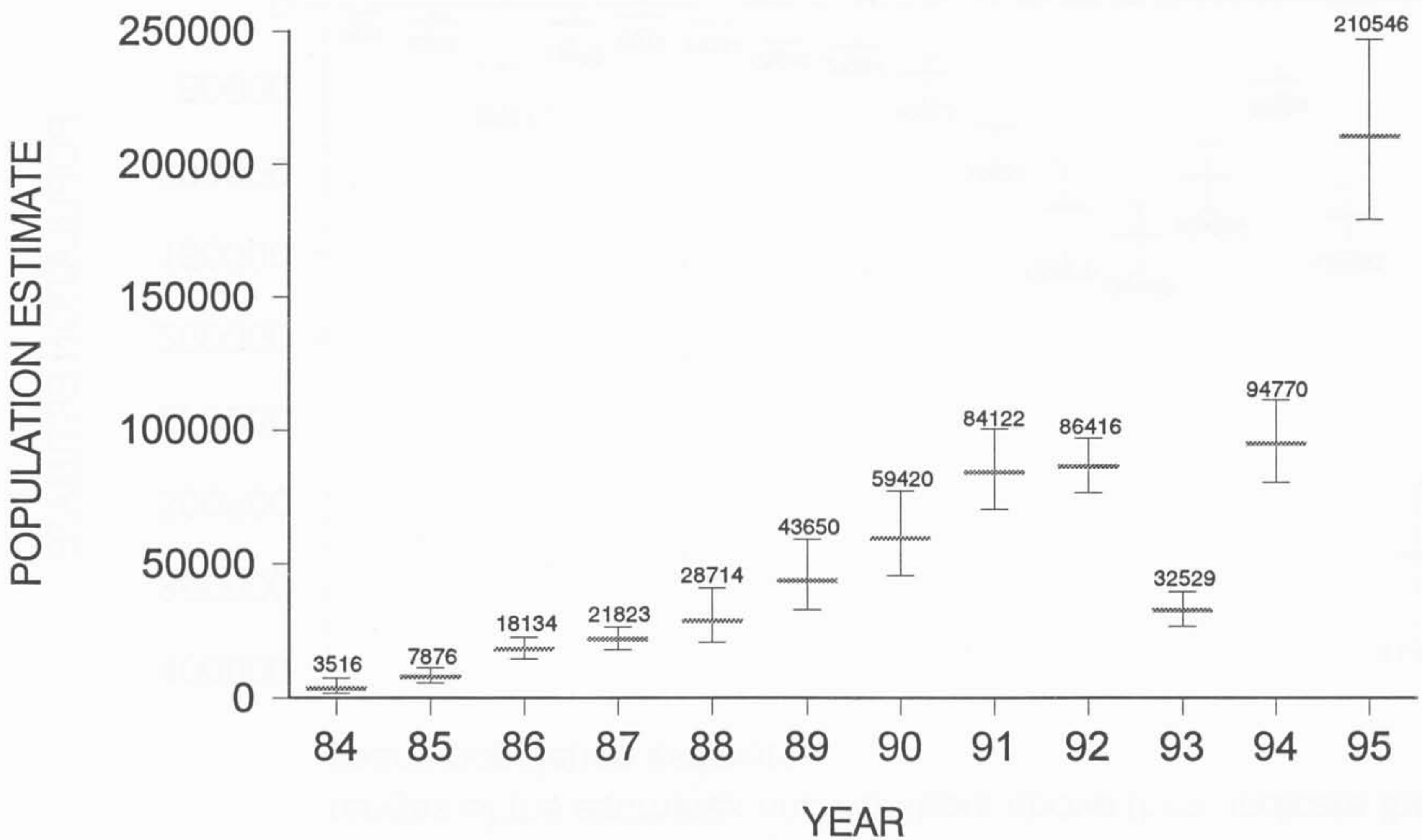


Figure 4. Population estimates of American shad captured in the Conowingo Dam tailrace, 1984-1995. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.



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