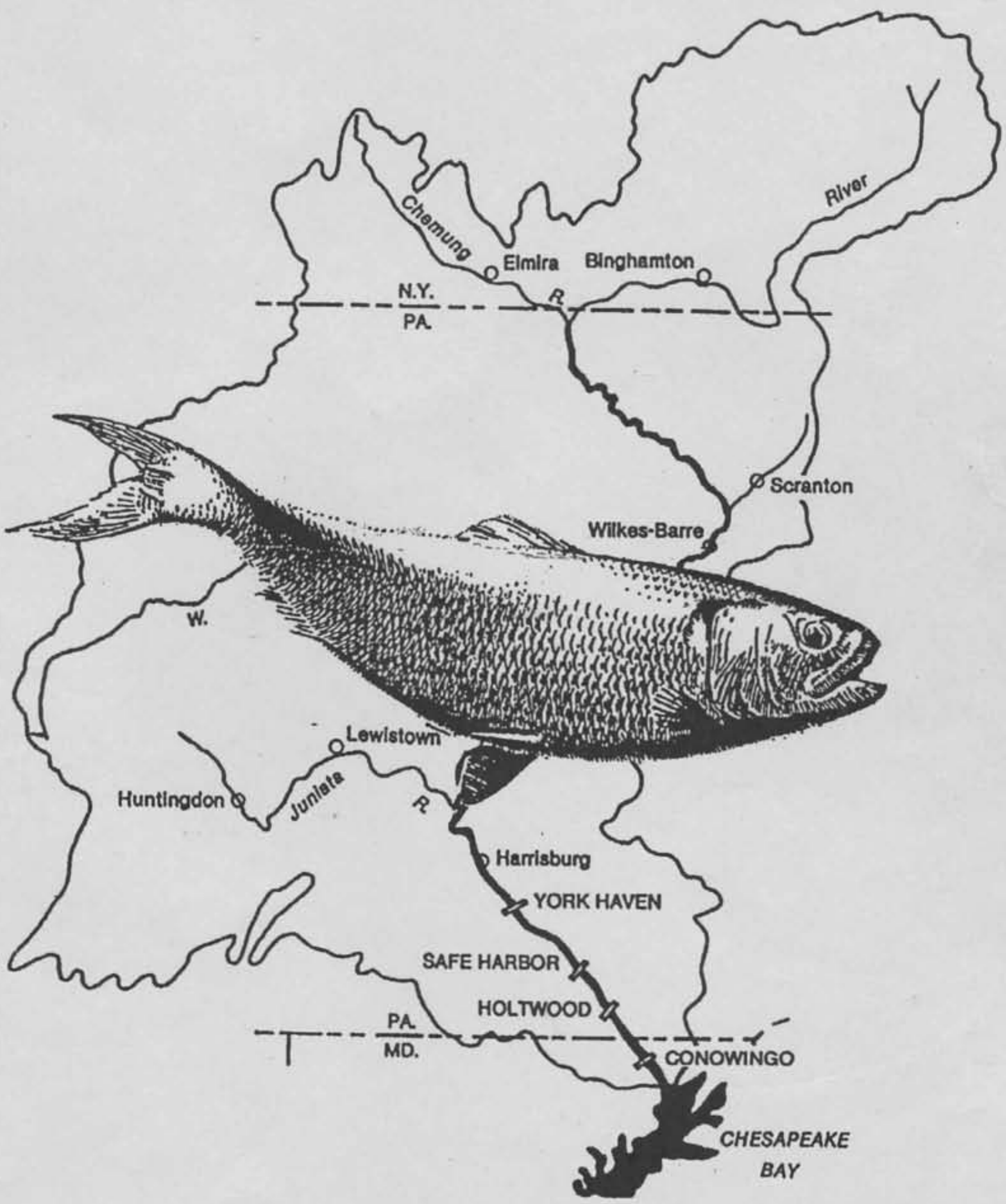
# Restoration of American Shad to the Susquehanna River

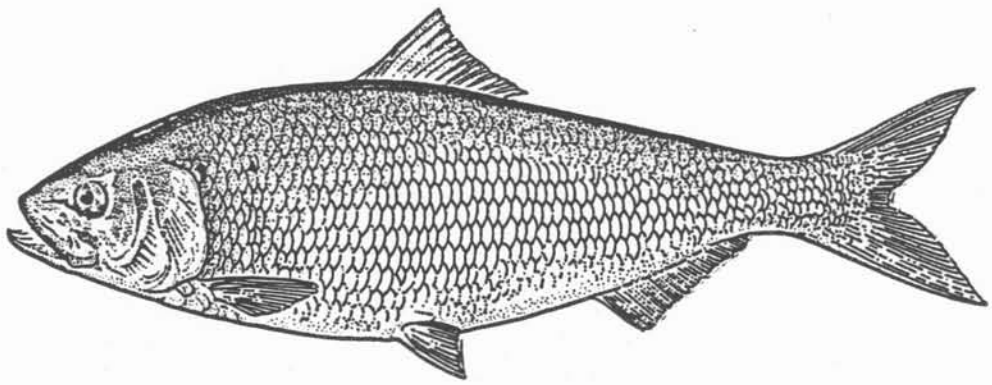
## Annual Progress Report
## 1996




Susquehanna River
Anadromous Fish Restoration Committee

February 1997

# RESTORATION OF AMERICAN SHAD TO THE SUSQUEHANNA RIVER



## ANNUAL PROGRESS REPORT

# 1996

## SUSQUEHANNA RIVER ANADROMOUS FISH RESTORATION COOPERATIVE

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

FEBRUARY 1997

## EXECUTIVE SUMMARY

This 1996 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, SRAFRC was reorganized, and fish lifts were constructed at Holtwood and Safe Harbor dams. The restoration program represents a continuing commitment among all parties to return shad and other migratory fishes to historic spawning and nursery waters above dams in the Susquehanna River.

The 1996 population estimate for adult American shad in the upper Chesapeake Bay and lower Susquehanna River was 203,216 fish (Petersen Index). This was based on recapture of 154 marked shad from a tagged population of 810 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 tag returns used in this analysis came from the Conowingo lifts. Estimated stock size in 1996 was substantially lower than in 1995 (333,891 shad) and this may be a reflection of the unusual high river flows during April through mid-May which limited catch and tag recapture opportunity. The Conowingo tailrace population estimate for shad in 1996 was 112,217 fish.

Fish trapping began at the East lift at Conowingo Dam on 1 April. Shad were first taken on 15 April but daily operations did not begin until the 23rd. Lift operations were suspended due to high water or mechanical problems for 17 days in 1996 between 16 April and 19 May. Due to high water and effects of winter flooding, the West lift could not begin fish trapping until 10 May with daily operation beginning on 20 May. Both facilities ended lift operations on June 14.

Trap operators handled 725,000 fish representing 41 taxa. This was considerably fewer than the 2-4 million fish trapped each spring in 1992-1995. Gizzard shad comprised 90% of the total catch. Alosa species included 37,513 American shad, 1,132 blueback herring, 4 alewives, and no hickory shad. Though American shad catch in 1996 was reduced from the record high set in 1995 it still comprised the second best year ever at Conowingo. Much of the apparent decline in shad abundance relates to reduced operations due to high water. Blueback herring and alewife numbers in collections were the smallest in many years. These species are typically attracted to the West lift which did not begin operating until the herring runs were over. For the season, the West lift collected 11,473 shad and 872 herring in 28 lift days and the East Lift took 26,040 shad and 264 herring in 49 days. Catch per fishing hour for shad at the East lift in 1996 averaged 61.7 fish compared with 68.8 in 1995 and 51.6 in 1994.

A total of 33,825 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, 410 blueback herring were stocked in mainstem waters above dams. Gravid shad and herring were provided to DNR for tank and strip spawning. Overall sex ratio of shad in lift collections was 1.1 to 1 favoring males. Males and females ranged in age from III to VII. Most males (81%) were aged IV-V, and most females (85%) were V-VI. Based on scale analysis of 354 shad, only 19 (5.4%) were repeat spawners.

Otoliths were successfully examined from 379 adult shad sacrificed at the fish lifts. Of these, 172 (45%) showed wild microstructure and no tetracycline (TC) marks. All remaining samples (55%) were of hatchery origin exhibiting the full range of one to five TC immersion marks. Of all hatchery shad in this collection, 133 (64%) carried triple marks, a mixture of Hudson and Delaware River egg sources. Four otoliths displayed pond-reared fingerling feed tags. The wild component of the Conowingo trap sample was the highest recorded to date. This is a reflection of improved reproduction of transferred adults in 1991-1992 and/or relatively low numbers of cultured fish stocked in 1992 returning as 4-year olds. A second otolith sample from 115 shad taken in pound nets in the Upper Chesapeake Bay was comprised of 70% wild and 30% hatchery fish. The largest component of the marked cohort (35%) 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 8 May to 10 June, 14.41 million shad eggs were delivered to Van Dyke from the Delaware River (8.31 M), the Hudson River (5.69 M), and the Susquehanna (0.41 M). Overall viability of these eggs was 63%, and production for the Susquehanna amounted to 7.466 million fry. Van Dyke also stocked 993,000 Delaware source fry into the Lehigh River.

Most shad produced at Van Dyke in 1996 received a single tetracycline mark on day 3 and were stocked as 6-8 day old larvae into the Juniata River at Millerstown (4.83 M) and at Montgomery Ferry on the mainstem (0.94 M). Fish for all other stocking locations received distinct multiple marks. First-time stockings were made, with appropriate media attention, in the West Branch at Montoursville (561,100) and the North Branch at Berwick (682,500). In the lower river, Conodoguinet Creek received 171,700 fry and Conestoga River received 277,100. The final stocking was 42,900 fry in Standing Stone Creek in the upper Juniata drainage.

Maryland DNR's Joseph Manning Hatchery received about 1.1 million viable shad eggs from the Delaware and Hudson rivers and produced 880,000 larvae which were double-marked and stocked at Lapidum below Conowingo Dam. An experimental one-tank natural spawning system was set-up at Conowingo Dam in 1996. Thirty-two females produced 22.5 l of eggs with an average viability of 35%. About 207,000 marked larvae from this source were stocked below Conowingo. Manning hatchery also received 346 female shad from Conowingo and induced spawning in several tank trials. This produced a total of 10.8 million eggs of which 31% were viable. Larvae from these efforts were stocked into the Patuxent and Choptank rivers and provided to Potomac Electric for grow-out in ponds. Maryland also successful reared hickory shad, stocking both larvae and fingerlings in the Choptank and Patuxent rivers.

Using funds from the PA Fish and Boat Commission, 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 1996, shad were routinely sampled with seines at Columbia, PA and by electrofishing at several sites above and below Clarks Ferry and in the upper Juniata River. Lift nets could not be used at Holtwood as in past years and cast netting here was relatively unsuccessful. Cooling water strainers and screens at Conowingo and Peach Bottom were examined. Maryland DNR collected shad with electrofisher and seines in the upper Chesapeake Bay.

Mean monthly river flows during summer and fall were above normal and highly variable. A total of 282 juvenile shad (1-56 per week) were collected with seines at Columbia during mid-July through mid-October. Catch per unit effort (CPUE) with seines at Columbia in 1996 (2.70) was less than that measured in 1995 but very close to the long-term average for this gear and site. Electrofishing produced 81 shad from several sites, and 109 shad were taken from intake screens at Peach Bottom Atomic Power Station. Outmigration from the river occurred during late October in association with a high flow event. Maryland DNR collected 131 juvenile shad in the upper Chesapeake Bay by electrofisher (11) and seines (120).

A total of 401 juvenile shad from all collections above Conowingo Dam were returned to Benner Spring for tetracycline mark analysis. Otoliths from 167 fish (42%) were unmarked and displayed wild microstructure. This compares to a wild fish component of only 10% in 1995. Most marked fish (76%) carried the single day-3 mark (Juniata and Montgomery Ferry) which represented 77% of total stockings above dams. Of the remaining hatchery fish in collections, 17% were from the North Branch stocking (9% of total release); 4% from the West Branch (8% of release); and 2% from Conodoguinet Creek (2% of release). Thus, fry released in the West Branch (Hudson source) displayed the highest relative survival rate. Eighty-three percent of fish examined from upper Bay collections were wild, similar to the average value for the past few years.

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 $266,500 of which about $260,600 was spent in 1996. The PA Fish and Boat Commission funded juvenile shad net and electrofishing 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 (FPTAC) for Holtwood, Safe Harbor, and York Haven hydroelectric projects met to discuss fish passage facility development and future evaluation needs at these dams. Despite delays and added costs associated with January ice and floods, construction of fish lifts at Holtwood and Safe Harbor proceeded throughout 1996 and both lifts are expected to be operational by spring 1997. York Haven's FPTAC reached agreement to amend the 1993 agreement to allow York Haven to build a conventional fish ladder with attraction flow control gates at the East Channel Dam instead of the earlier agreed powerhouse fish lift. Barring any unforeseen delays, this facility should be operational by April 2000.

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

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**JOB III, PART 1. AMERICAN SHAD HATCHERY OPERATIONS IN PENNSYLVANIA, 1996**

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## JOB I. SUMMARY OF THE OPERATIONS AT THE CONOWINGO DAM FISH PASSAGE FACILITIES IN SPRING 1996

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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 1996 operation and maintenance of the East and West lifts remained with SECO.

Objectives of 1996 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 1996 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. Five reconnaissance surveys (herring checks) were conducted between 18 and 27 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 27 March at the bridge over Deer Creek and at the mouth of Deer Creek. Water temperatures during these surveys varied slightly by area and ranged from 42.8°F to 49.1°F.

Modifications and repairs to both lifts began in the fall of 1995 to ensure efficient and reliable operation during the 1996 season. Preseason work on the East Lift was completed prior to April and included maintenance of numerous lift components and operating systems. The pneumatic system was inspected and cylinders cleaned and hoses and fittings were inspected and replaced as necessary.

Final upgrades and maintenance to the West lift were completed in late April. Repairs and upgrades to the West lift were hampered due to the January flood. Upgrades to the lift included the fabrication and installation of the following: sluice gates, gate platforms, control house pad, conduit and wiring, limit torque actuators, gate stems, control house, benchboard, and motor control center wiring.

Unlike 1994 and 1995, both service units which supply attraction flow water were operable in 1996. Attraction velocities and the volume of attraction water used at the lift were similar to those used in years prior to 1994.

To avoid competition with attraction flow at the West lift, Unit 1 was shut down whenever river flows were less than 60,000 cfs. In 1996, 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.

Negotiations between SECO and SRAFRC resulted in a modified West lift operation schedule for 1996. The intent of the new schedule was to maximize the American shad catch during peak periods of the season while reducing the total hours of lift operation resulting in catch statistics similar to historical data and less wear and tear on the lift equipment. In 1996, the West lift was scheduled to operate from 1100-1900 hrs on 15 to 30 April, 0700-1900 hrs during May, and again from 1100-1900 hrs on 1 through 7 June with operation terminating on 7 June. However, due to start-up delays resulting from high river flows, the lift was operated from 0700-

1900 hours during this weather-shortened season, 10 May to 14 June.

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 previous season, natural river flows were high and unstable, disrupting the lift operation schedule at various times. Half-day lift operation (1100-1900 hr) on alternate days (if river flows allowed) at the East lift occurred from 1 April to 8 May and again on 18 and 20 May due to small numbers of shad in the catch. Full day lift operation (0700-1900 hr) at the East lift commenced on 9 May while the West lift commenced operation on 10 May. Full day operation continued (except for 18 and 20 May) through 14 June. The first American shad was captured at the East lift on 15 April while the West lift captured its first American shad on 10 May. Lift operation were terminated on 14 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, two major outages occurred. On 28 and 29 April, the East lift was shut down to replace the crowder screen hoist cable that snapped shortly after operations commenced on 28 April. The total down time for this repair was 9 hours. Upon inspection of other cables at the East lift, one of the main cables responsible for lifting and lowering the hopper was found to have 9 broken strands. After consultation with a hoist expert, it was decided to replace both main hopper cables in the interest of safety and efficient operation. The repair/change out commenced on 30 April and was completed on 4 May resulting in 40 hours of down time. However, it is doubtful that the shad catch was impeded by this delay since during the time of the outage, the river rose from approximately 50,000 cfs on 29 April to approximately 150,000 cfs on 2 May. The numerous high water events during the season resulted in more lost fishing time than any of the mechanical breakdowns. Minor outages occurred at the West lift that involved electrical problems with the weir gates and the crowder. Repairs were quickly made and resulted in minimal down time (2.5 hours).

The mechanical aspects of West lift operation in 1996 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 1996. Matrix charts, developed during past years, were expanded upon and used during 1996. 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 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 to be maintained from 1 through 30 April, 1 through 31 May, and 1 through 14 June, respectively. However, due to the high river flows that occurred this spring, most releases from Conowingo were much higher than the minimum flow requirements.

[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.

## 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 1996 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 ≥100 green or gravid shad were collected in a day, or at the supervisor's discretion if fewer shad were collected. As feasible, 10,000 river herring were scheduled for transport; 5,000 to Conodoguinet Creek (Cumberland County) and 2,500 each into the Conestoga and Little Conestoga rivers (Lancaster County). If possible, river herring were also to be 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 Safe Harbor forebay was utilized twice to release radio tagged American shad for the Safe Harbor telemetry study.

To ensure and enhance transport survival, daily maintenance of all transport equipment was necessary. Transport equipment received excessive amounts of wear and tear, particularly that equipment associated with East lift transports. Some trailer tires and trailer hitch surge brake bolts were 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.

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 1996 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. The second highest number of American shad (37,513) was captured as well as 1,136 river herring (alewife and blueback herring). No new species were collected in 1996 as compared to previous years of operation (RMC 1992).

A combined total of 724,999 fish was collected (Table 1). The East lift accounted for 492,384 fish of 36 taxa while the West lift collected 232,615 fish of 39 taxa. Some 26,040 and 11,473 American shad were captured at the East and West lifts, respectively. Alosids (American shad, blueback herring, and alewife) comprised 5.3% of the total catch. No hickory shad were captured at either lift. Nearly 77% of the river herring were collected at the West lift. Gizzard shad dominated the catch and comprised nearly 90% of the total. Although carp comprised 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 49 days of operation at the East lift, a total of 26,040 American shad was captured (Table 2). The West lift also operated a total of 28 days and captured 11,473 American shad (Table 3). Approximately 90% of the total shad captured were transported. Some 1,735 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, those sacrificed, and those utilized in MD DNR hatchery spawning trials.

The East lift first collected American shad on 15 April and the West lift collected its first shad on 10 May, its first day of operation. About 78% (29,155 shad) of the shad were collected between 19 May and 8 June. The peak day occurred on 22 May when 1,584 shad were captured at the East lift and the West lift collected 1,931 shad on 27 May. During the season, the East and West lifts captured more than 1,000 American shad in a single day on 12 and 5 occasions, respectively. Some 4.9, 70.1, and 25.0% of the shad catch was collected in April, May, and June.

American shad were collected at water temperatures of 53.6°F to 80.1°F and at natural river flows of 16,600 to 93,800 cfs (Figures 3 and 4). Nearly 71% of the shad were collected at water temperatures >65°F (Table 4). River water temperatures generally were less than 65°F until 20 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 (56.5) than on weekends (77.8) (Table 6). Generally, during both periods, catches were greatest between 0700 and 1100 hr. Some relatively high catch rates were observed after 1100 hr for both periods, particularly when discharges ranged from 11,000 to 20,000 cfs on weekends.

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 (221.0) occurred when both large units 10 and 11 were off and generation was between 6,000-10,000 cfs. However, due to the above normal river flows experienced this season, 65% of the shad were captured with discharges >40,000 cfs.

### 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 6,422 shad was sexed. The combined male/female ratio was 1.1:1. Males comprised

72% of the total catch in April, 55% in May, and 41% in June.

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

Scale samples of 354 shad were read (Table 9). Both males and females ranged in age from III to VII years old. Almost all the males (81%) were IV and V years old, while most females (86%) were V and VI years old. The 1992 year class was the most abundant year class of the males sampled and comprised nearly 50% of the total while the 1991 year class comprised 55% of the females sampled.

More than 94% of males and females were virgins (Table 9). Of the 207 males sampled, 10 (4.8%) were single repeat spawners. Of the 147 females, 9 (6.1%) were single repeat spawners. Overall, repeat spawners comprised 5.4% of the total sample. Although, no double repeat spawners were observed from those sacrificed, a small number of MD DNR tagged shad were observed to be double repeat spawners. In addition, one shad tagged by the MD DNR in 1992 was captured in 1996. Assuming it had spawned every season since it was tagged, 1996 was the fifth spawning season for this shad.

Females were larger than males (Table 9). The smallest male measured 303 mm fork length, the smallest female was 334 mm. The average length of males and females were 398 and 460 mm, respectively.

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

Including multiple recaptures, 262 MD DNR tagged American shad were recaptured; 160 at the East lift and 102 at the West lift (Table 10). Of the 262 shad recovered, 31 were tagged by MD DNR in previous years. The MD DNR tagged 835 shad in 1996; 425 from pound nets in the upper Chesapeake Bay and 410 by hook and line in the Conowingo tailrace. Of the 154 first time verified MD DNR recaptures, 129 were tagged in the tailrace and 25 in the pound nets. The shad averaged 17.2 days free before capture. The shortest time before recapture was 1 day while the longest term before recapture was 58 days.

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

A total of 1,132 blueback herring was collected (Tables 1, 2, and 3). Nearly 77% (871) of the blueback herring were captured at the West lift. Of those captured at the East lift, 70% (183) were collected on 9 and 11 June. Due to consistently high river flows, only 4 alewife were captured during spring 1996.

The combined catch of river herring (blueback herring and alewife) from both lifts was

1,136 (Table 1) and was much lower than the total catch observed in recent years (RMC 1995). No hickory shad were captured at either lift in 1996.

Although shad and river herring catches were lower than in 1995, relatively large numbers of river herring and hickory shad were present in the tailrace. The reduced catch of all alosids (particularly blueback herring) was a direct result of high river flows in April and May which delayed the start of lift operations. Anglers reported large schools of herring along the west shoreline as well as strong catches of hickory shad. These observations were confirmed during a creel survey of the Shures Landing shore anglers that NAI conducted for the Maryland DNR. Shad and river herring catches were relatively high in late April with good catches reported through mid-May.

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

Pre-spawned American shad were transported from 25 April through 14 June. Over 91% of the American shad catch was transported to upstream spawning areas with an observed stocking survival of 99.7% (Table 11). A total of 33,825 shad was transported; 22,923 from the East lift, 9,361 from the West lift, and 1,541 in combined transports. Some 15,510 shad were stocked directly to the Susquehanna River at Tri-County Marina. Additionally, 17,807 shad were released at the PFBC Columbia access, 332 shad at PFBC Muddy Creek access, and 176 shad were transported to Safe Harbor for radio telemetry and Turb'N Tag studies. The MD DNR transported 1,058 shad to the Manning Hatchery for spawning purposes. In addition, the New Jersey Aquarium acquired 63 shad for use in a public display.

Transportation of shad occurred on 32 and 19 days from the East and West lifts, respectively, while combined transports occurred on 12 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 11 per day. East transport/load size varied from 83 to 136 shad per trip. The load size of transports originating from the West lift ranged from 20 to 190 shad per trip. Transport survival ranged from 91.1 to 100% from the East lift while West lift transport survival ranged from 93.3 to 100%. Shad were transported at water temperatures of 57.2 to 81.0°F.

A total of 1,541 shad was transported upstream in combined transports. The average transport survival for these trips was 99.9%; load size ranged from 39 to 130 shad per trip. More than 86% 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 2,893 shad was held over at the East lift with 17 (0.6%) holding mortalities, while 681 shad were held over at the West facility with a total of 136

(20.0%) holding mortalities. The West holding facility suffered a pump failure on 24 May resulting in a loss of 83 shad. If this event is not factored in, the holding mortality rate at the West lift would be 7.8%.

### 2.8 River Herring Transport

A total of 410 blueback herring (36.2% of total catch) was transported and released into the mainstem of the Susquehanna River (Table 12). Herring were transported on 11 and 23 May with 100% survival.

### 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 1996. 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 36 days beginning 26 April and continued until after transport ceased from both fish lifts. These efforts resulted in the recovery of 477 dead shad (1.41%) of the total shad transported. When delayed mortalities are included with transport mortalities, the transport survival rate for the season was estimated at 98.2%.

## 3.0 DISCUSSION

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.

The second highest number of American shad (37,513) was captured in 1996. The catch may have been lower than in 1995 due to a decrease in lift operation time caused by high, unstable river flows, particularly in April and early May. Over 69% of the total shad catch was collected at the East lift. In 1995, the East lift captured nearly 75% of the 61,650 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 was probably affected by the loss of operating time due to the high river flows as well as the January flood which delayed the West lift start-up until 10 May. Unlike 1994 and 1995, there was no reduction in the volume of attraction water since both service units were operational in 1996.

Over 91% of the American shad catch was transported to upstream spawning areas with an overall transport survival rate of 99.7%. Careful attention to transport procedures combined with modifications to equipment greatly improved efficiency and survival of American shad. Although several improvements were made since 1991 that enhanced East lift transport operations the trailer units had some tire and surge bolt problems that sporadically hampered transport efficiency. These problems were addressed throughout the season and may not be encountered again at the East lift if lift construction at the upstream facilities is completed prior to spring 1997.

The upgraded West Fish Lift will be able to support restoration efforts as the program begins a new phase in anadromous fish restoration to the Susquehanna River and other Chesapeake Bay tributaries. In 1997, the East Fish Lift will be operated to pass fish into Conowingo Pond.

## LITERATURE CITED


Cating, J. P. 1953. Determining age of American shad from their scales. U.S. Fish Wildl. Service, Fish. Bull. 54(85):187-199.

RMC. 1983. Summary of the operation of the Conowingo Dam Lift in spring 1982. Prepared for Philadelphia Electric Company by RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, PA. 32 pp.

RMC. 1986. Summary of the operation of the Conowingo Dam Lift in spring 1985. Prepared for Philadelphia Electric Company by RMC Environmental Services, Muddy Run Ecological Laboratory, Drumore, PA. 44 pp.

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

RMC. 1993. Summary of operations at the Conowingo Dam fish passage facilities in spring 1993. Prepared for Susquehanna Electric Company by RMC Environmental Services, Inc., Muddy Run Ecological Laboratory, Drumore, PA.

RMC. 1994. Summary of operations at the Conowingo Dam fish passage facilities in spring 1994. Prepared for Susquehanna Electric Company by RMC Environmental Services, Inc., Muddy Run Ecological Laboratory, Drumore, PA.

Table 1

**Comparison of annual catch of fishes at the Conowingo Dam Fish Lifts, 1 April through 14 June 1996.**

| *YEAR* | *1996* | *1996* |
|---|---|---|
| *LOCATION* | *EAST* | *WEST* |
| *NO. OF DAYS* | *49* | *28* |
| *NO. OF LIFTS* | *599* | *464* |
| *OPERATING TIME (HRS)* | *454.1* | *284.6* |
| *FISHING TIME (HRS)* | *420.6* | *259.2* |
| *NO. OF TAXA* | *35* | *38* |
| American eel | 39 | 640 |
| BLUEBACK HERRING | 261 | 871 |
| ALEWIFE | 3 | 1 |
| AMERICAN SHAD | 26,040 | 11,473 |
| GIZZARD SHAD | 455,317 | 196,019 |
| Rainbow trout | 9 | 12 |
| Brown trout | 22 | 27 |
| Brook trout | 2 | 3 |
| Muskellunge | 2 | 4 |
| Common carp | 4,139 | 5,726 |
| Comely shiner | 117 | 2,180 |
| Spottail shiner | 2 | . |
| Quillback | 3,773 | 583 |
| White sucker | 73 | 20 |
| Northern hogsucker | 4 | . |
| Shorthead redhorse | 228 | 754 |
| White catfish | 4 | 293 |
| Brown bullhead | 3 | 54 |
| Channel catfish | 1,037 | 5,487 |
| White perch | 49 | 4,583 |
| STRIPED BASS | 276 | 1,845 |
| Rock bass | 3 | 149 |
| Redbreast sunfish | 17 | 179 |
| Green sunfish | 4 | 18 |
| Pumpkinseed | 1 | 11 |
| Bluegill | 37 | 158 |
| Smallmouth bass | 531 | 232 |
| Largemouth bass | 9 | 23 |
| White crappie | 1 | 25 |
| Yellow perch | 12 | 180 |
| Logperch | 1 | . |
| Walleye | 351 | 964 |
| Sea lamprey | 9 | 10 |
| Striped bass x white bass | 4 | 4 |
| Tiger muskie | 4 | 1 |
| Golden shiner | . | 40 |
| Spotfin shiner | . | 10 |
| Yellow bullhead | . | 22 |
| Black crappie | . | 9 |
| Atlantic needlefish | . | 1 |
| Brook trout x lake trout | . | 4 |
| TOTAL | 492,384 | 232,615 |

*trap96.xls\Table 1 - 12/18/96*

Table 2

Daily summary of selected fishes collected at the Conowingo Dam East Lift, 1 April through 14 June, 1996.

| *DATE* | *01 Apr* | *03 Apr* | *05 Apr* | *08 Apr* | *10 Apr* | *12 Apr* | *15 Apr* | *22 Apr* | *23 Apr* | *24 Apr* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *8* | *8* | *8* | *8* | *8* | *8* | *9* | *9* | *8* | *10* |
| *FIRST LIFT* | *11:47* | *11:03* | *11:20* | *11:12* | *11:27* | *11:02* | *11:23* | *11:02* | *11:02* | *11:15* |
| *LAST LIFT* | *18:02* | *18:00* | *18:25* | *18:15* | *18:10* | *18:30* | *19:00* | *18:30* | *18:05* | *18:50* |
| *OPERATING TIME (HRS)* | *6.2* | *7* | *7.1* | *7* | *6.7* | *7.5* | *7.6* | *7.5* | *7* | *7.6* |
| *FISHING TIME (HRS)* | *5.5* | *6.4* | *6.5* | *6.5* | *6.2* | *6.9* | *7* | *7.6* | *6.5* | *6.8* |
| *AVG WATER TEMP (C)* | *7.5* | *9* | *9.8* | *9.2* | *9.1* | *9.6* | *12* | *12.5* | *13.3* | *14.6* |
| BLUEBACK HERRING | | | | | | | | | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | | | | | | | 141 | | 13 | 81 |
| GIZZARD SHAD | | 26 | 38 | 163 | 19 | 102 | 461 | 7,229 | 3,700 | 9,909 |
| COMMON CARP | | | | 1 | | | 1 | | 13 | 1 |
| STRIPED BASS | | | | | | | | | | |
| OTHER SPP | 10 | 16 | 10 | 15 | 24 | 1 | 73 | 21 | 30 | 45 |
| TOTAL | 10 | 42 | 48 | 179 | 43 | 103 | 676 | 7,250 | 3,756 | 10,036 |

| *DATE* | *25 Apr* | *26 Apr* | *27 Apr* | *28 Apr* | *29 Apr* | *05 May* | *06 May* | *08 May* | *09 May* | *10 May* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *10* | *14* | *15* | *2* | *12* | *10* | *8* | *9* | *12* | *19* |
| *FIRST LIFT* | *11:13* | *11:00* | *11:02* | *11:02* | *12:47* | *11:19* | *11:27* | *11:02* | *7:45* | *7:23* |
| *LAST LIFT* | *18:15* | *18:50* | *19:00* | *11:35* | *18:45* | *18:45* | *18:30* | *17:30* | *18:35* | *18:45* |
| *OPERATING TIME (HRS)* | *7* | *7.8* | *8* | *0.6* | *6* | *7.4* | *7* | *6.5* | *10.8* | *11.4* |
| *FISHING TIME (HRS)* | *6.6* | *6.7* | *6.8* | *0.5* | *5.7* | *6.7* | *6.5* | *6.2* | *10.3* | *10.3* |
| *AVG WATER TEMP (C)* | *14.9* | *15* | *15* | *15.2* | *15* | *13.8* | *14.6* | *14.4* | *14.6* | *14* |
| BLUEBACK HERRING | | 1 | | | | | | | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | 2 | | | | | | | | | |
| AMERICAN SHAD | 400 | 674 | 19 | 3 | 501 | 1 | 2 | 918 | 1,289 | 880 |
| GIZZARD SHAD | 9,200 | 12,600 | 28,650 | 3,002 | 14,000 | 19,605 | 1,305 | 7,206 | 11,430 | 3,962 |
| COMMON CARP | 3 | 14 | 2 | | | 1 | 5 | | 3 | 9 |
| STRIPED BASS | | 1 | | | | 4 | 1 | 1 | | 1 |
| OTHER SPP | 20 | 51 | 35 | 2 | 22 | 252 | 213 | 45 | 69 | 87 |
| TOTAL | 9,625 | 13,341 | 28,706 | 3,007 | 14,523 | 19,863 | 1,526 | 8,170 | 12,791 | 4,939 |

*trap96.xls\Tables 2, 3 - 12/18/96*

Table 2

Continued.

| DATE | 11 May | 12 May | 18 May | 20 May | 21 May | 22 May | 23 May | 24 May | 25 May | 26 May |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *13* | *15* | *9* | *8* | *15* | *13* | *14* | *11* | *12* | *9* |
| *FIRST LIFT* | *7:03* | *7:07* | *11:02* | *11:20* | *7:02* | *7:12* | *7:43* | *7:47* | *7:02* | *7:12* |
| *LAST LIFT* | *15:45* | *18:35* | *18:45* | *19:05* | *18:05* | *18:25* | *18:30* | *19:00* | *18:30* | *18:30* |
| *OPERATING TIME (HRS)* | *8.7* | *11.5* | *7.7* | *7.7* | *11.1* | *11.2* | *10.8* | *11.2* | *11.5* | *11.3* |
| *FISHING TIME (HRS)* | *8.1* | *11.2* | *7.1* | *7.6* | *10.8* | *11.2* | *10.4* | *11.1* | *11.3* | *11.2* |
| *AVG WATER TEMP (C)* | *14.4* | *15* | *13.4* | *16.4* | *18.5* | *19.5* | *21.8* | *22.5* | *24.5* | *23* |
| BLUEBACK HERRING | 1 | | | | 2 | | | | 1 | 2 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | 1 | | | | | | | | | |
| AMERICAN SHAD | 833 | 1,200 | 3 | 1,161 | 1,331 | 1,584 | 1,214 | 1,315 | 1,532 | 1,164 |
| GIZZARD SHAD | 11,002 | 15,305 | 2,754 | 10,500 | 26,920 | 13,600 | 14,926 | 14,008 | 4,380 | 7,552 |
| COMMON CARP | 7 | 6 | | 6 | 209 | 199 | 136 | 205 | 35 | 33 |
| STRIPED BASS | | 3 | | | | | 2 | 2 | | 3 |
| OTHER SPP | 73 | 134 | 401 | 110 | 140 | 222 | 307 | 218 | 91 | 204 |
| **TOTAL** | **11,917** | **16,648** | **3,158** | **11,777** | **28,602** | **15,605** | **16,585** | **15,748** | **6,039** | **8,958** |

| DATE | 27 May | 28 May | 29 May | 30 May | 31 May | 01 Jun | 02 Jun | 03 Jun | 04 Jun | 05 Jun |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *15* | *20* | *17* | *15* | *11* | *15* | *16* | *13* | *15* | *17* |
| *FIRST LIFT* | *7:33* | *7:23* | *7:03* | *7:12* | *8:13* | *7:13* | *7:08* | *7:23* | *7:17* | *7:12* |
| *LAST LIFT* | *18:45* | *18:40* | *19:00* | *19:00* | *18:45* | *19:00* | *18:40* | *18:30* | *18:45* | *18:45* |
| *OPERATING TIME (HRS)* | *11.2* | *11.3* | *12* | *11.8* | *10.5* | *11.8* | *11.5* | *11.1* | *11.5* | *11.6* |
| *FISHING TIME (HRS)* | *11* | *9.7* | *10.4* | *10.7* | *9.8* | *11* | *10.8* | *10.2* | *10.3* | *10.4* |
| *AVG WATER TEMP (C)* | *17.8* | *22.1* | *21.8* | *20.8* | *20* | *19.4* | *19.1* | *19.9* | *19.9* | *21.1* |
| BLUEBACK HERRING | 15 | | | | 1 | 31 | 4 | 3 | 2 | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | 1,177 | 850 | 902 | 361 | 296 | 1,030 | 1,387 | 410 | 544 | 713 |
| GIZZARD SHAD | 6,985 | 24,320 | 5,330 | 5,071 | 5,410 | 3,460 | 1,851 | 10,535 | 19,907 | 29,407 |
| COMMON CARP | 91 | 76 | 49 | 16 | 9 | 21 | | 621 | 19 | 208 |
| STRIPED BASS | 15 | 25 | 14 | 12 | 10 | 12 | | 16 | 9 | 11 |
| OTHER SPP | 73 | 150 | 36 | 21 | 310 | 20 | 19 | 66 | 144 | 148 |
| **TOTAL** | **8,356** | **25,421** | **6,331** | **5,481** | **6,036** | **4,574** | **3,261** | **11,651** | **20,625** | **30,487** |

*trap96.xls\Tables 2, 3 - 12/18/96*

Table 2

Continued.

| DATE | 06 Jun | 07 Jun | 08 Jun | 09 Jun | 10 Jun | 11 Jun | 12 Jun | 13 Jun | 14 Jun | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 19 | 17 | 20 | 18 | 13 | 14 | 11 | 11 | 8 | 599 |
| FIRST LIFT | 7:02 | 7:27 | 7:02 | 7:07 | 7:27 | 7:23 | 7:02 | 7:07 | 7:17 | . |
| LAST LIFT | 18:45 | 18:45 | 18:05 | 18:40 | 18:20 | 18:35 | 16:35 | 17:55 | 12:45 | . |
| OPERATING TIME (HRS) | 11.7 | 11.3 | 11.1 | 11.6 | 10.9 | 11.2 | 9.6 | 10.8 | 5.5 | 454.1 |
| FISHING TIME (HRS) | 10.7 | 10 | 9.5 | 10.2 | 10 | 10.2 | 8.8 | 10 | 4.9 | 420.6 |
| AVG WATER TEMP (C) | 20.7 | 22.1 | 21.7 | 23.1 | 23.8 | 24.9 | 25.7 | 25.2 | 26.7 | . |
| BLUEBACK HERRING | | 1 | 2 | 53 | 12 | 130 | | | | 261 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | 3 |
| AMERICAN SHAD | 315 | 474 | 493 | 451 | 142 | 155 | 33 | 27 | 21 | 26,040 |
| GIZZARD SHAD | 28,300 | 9,455 | 6,060 | 10,550 | 5,921 | 10,440 | 7,051 | 11,000 | 710 | 455,317 |
| COMMON CARP | 337 | 184 | 316 | 80 | 396 | 412 | 159 | 255 | 1 | 4,139 |
| STRIPED BASS | 9 | 17 | 21 | 9 | 22 | 22 | 10 | 10 | 14 | 276 |
| OTHER SPP | 148 | 184 | 941 | 405 | 35 | 371 | 61 | 147 | 128 | 6,348 |
| TOTAL | 29,109 | 10,315 | 7,833 | 11,548 | 6,528 | 11,530 | 7,314 | 11,439 | 874 | 492,384 |

Table 3

Daily summary of selected fishes collected at the Conowingo Dam West Lift, 1 April through 14 June, 1996.

| *DATE* | *10 May* | *11 May* | *20 May* | *21 May* | *22 May* | *23 May* | *24 May* | *25 May* | *26 May* | *27 May* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *8* | *15* | *4* | *24* | *22* | *16* | *1* | *12* | *14* | *14* |
| *FIRST LIFT* | *15:30* | *7:15* | *13:41* | *7:05* | *7:22* | *7:30* | *8:40* | *7:11* | *7:30* | *7:33* |
| *LAST LIFT* | *19:00* | *16:00* | *19:00* | *18:00* | *18:33* | *18:45* | *8:40* | *18:30* | *18:40* | *18:53* |
| *OPERATING TIME (HRS)* | *3.5* | *8.8* | *5.3* | *10.9* | *11.2* | *11.3* | *0* | *11.3* | *11.2* | *11.3* |
| *FISHING TIME (HRS)* | *3.2* | *6.9* | *1.1* | *9.8* | *8.9* | *10.2* | *.* | *11.3* | *10.8* | *10.9* |
| *AVG WATER TEMP (C)* | *14.9* | *15.2* | *17.1* | *18.6* | *19.5* | *20.5* | *22.1* | *22.2* | *21.7* | *21.5* |
| BLUEBACK HERRING | 205 | 336 | 2 | 1 | 7 | 55 | | 6 | 150 | 20 |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | 1 | | | | | | | | | |
| AMERICAN SHAD | 35 | 103 | 16 | 98 | 285 | 1,043 | | 1,155 | 483 | 1,931 |
| GIZZARD SHAD | 7,225 | 10,020 | 5,050 | 23,048 | 30,450 | 8,076 | 3,800 | 3,533 | 17,075 | 5,495 |
| COMMON CARP | 1 | 10 | 531 | 1,007 | 109 | 18 | 2 | 13 | 38 | 53 |
| STRIPED BASS | 5 | 23 | 4 | 29 | 35 | 83 | 10 | 35 | 168 | 91 |
| OTHER SPP | 118 | 509 | 615 | 786 | 2,159 | 1,950 | 483 | 903 | 419 | 520 |
| TOTAL | **7,590** | **11,001** | **6,218** | **24,969** | **33,045** | **11,225** | **4,295** | **5,645** | **18,333** | **8,110** |

| *DATE* | *28 May* | *29 May* | *30 May* | *31 May* | *01 Jun* | *02 Jun* | *03 Jun* | *04 Jun* | *05 Jun* | *06 Jun* |
|---|---|---|---|---|---|---|---|---|---|---|
| *NO OF LIFTS* | *17* | *23* | *23* | *11* | *22* | *23* | *16* | *17* | *17* | *24* |
| *FIRST LIFT* | *7:15* | *7:07* | *7:00* | *7:15* | *7:05* | *7:00* | *7:15* | *7:15* | *7:05* | *7:10* |
| *LAST LIFT* | *18:55* | *18:40* | *18:55* | *19:15* | *19:00* | *18:35* | *18:10* | *18:45* | *18:45* | *18:45* |
| *OPERATING TIME (HRS)* | *11.7* | *11.6* | *11.9* | *12* | *11.9* | *11.6* | *10.9* | *11.5* | *11.7* | *11.6* |
| *FISHING TIME (HRS)* | *11.2* | *10.4* | *10.3* | *12* | *11.7* | *11* | *10* | *10.3* | *11* | *10.8* |
| *AVG WATER TEMP (C)* | *20.2* | *18.5* | *18.2* | *17.5* | *19.3* | *18.3* | *21.4* | *18* | *19.7* | *19.5* |
| BLUEBACK HERRING | 7 | 35 | 8 | 1 | 2 | 10 | | 12 | | |
| HICKORY SHAD | | | | | | | | | | |
| ALEWIFE | | | | | | | | | | |
| AMERICAN SHAD | 1,130 | 739 | 515 | 758 | 276 | 159 | 1,140 | 233 | 370 | 156 |
| GIZZARD SHAD | 4,261 | 2,402 | 3,543 | 6,350 | 8,500 | 1,251 | 1,982 | 9,971 | 1,920 | 12,505 |
| COMMON CARP | 153 | 23 | 48 | 2 | 11 | 1 | 16 | 30 | 84 | 447 |
| STRIPED BASS | 171 | 142 | 136 | 10 | 70 | 14 | 55 | 53 | 21 | 46 |
| OTHER SPP | 640 | 257 | 239 | 100 | 102 | 58 | 118 | 130 | 174 | 249 |
| TOTAL | **6,362** | **3,598** | **4,489** | **7,221** | **8,961** | **1,493** | **3,311** | **10,429** | **2,569** | **13,403** |

*trap96.xls\Tables 2, 3 - 12/18/96*

Table 3

Continued.

| DATE | 07 Jun | 08 Jun | 09 Jun | 10 Jun | 11 Jun | 12 Jun | 13 Jun | 14 Jun | TOTALS |
|---|---|---|---|---|---|---|---|---|---|
| NO OF LIFTS | 19 | 19 | 22 | 24 | 21 | 13 | 13 | 10 | 464 |
| FIRST LIFT | 7:05 | 7:10 | 7:00 | 7:06 | 7:03 | 7:03 | 7:10 | 7:10 | . |
| LAST LIFT | 18:45 | 18:30 | 18:45 | 18:35 | 18:13 | 18:15 | 16:30 | 12:50 | . |
| OPERATING TIME (HRS) | 11.7 | 11.3 | 11.8 | 11.5 | 11.2 | 11.2 | 9.3 | 5.7 | 284.6 |
| FISHING TIME (HRS) | 10.9 | 10.8 | 11.2 | 10.6 | 10.6 | 9.5 | 8.6 | 5.4 | 259.2 |
| AVG WATER TEMP (C) | 21.3 | 22.3 | 22.6 | 24 | 23.9 | 24.7 | 24.9 | 26.3 | . |
| BLUEBACK HERRING | | | 7 | | 7 | | | | 871 |
| HICKORY SHAD | | | | | | | | | |
| ALEWIFE | | | | | | | | | 1 |
| AMERICAN SHAD | 255 | 160 | 126 | 38 | 207 | 47 | 10 | 5 | 11,473 |
| GIZZARD SHAD | 6,505 | 6,535 | 3,515 | 7,050 | 2,624 | 1,458 | 1,440 | 435 | 196,019 |
| COMMON CARP | 218 | 131 | 206 | 749 | 351 | 303 | 1,100 | 71 | 5,726 |
| STRIPED BASS | 124 | 164 | 18 | 47 | 112 | 54 | 35 | 90 | 1,845 |
| OTHER SPP | 521 | 858 | 777 | 1,353 | 780 | 599 | 796 | 467 | 16,680 |
| TOTAL | 7,623 | 7,848 | 4,649 | 9,237 | 4,081 | 2,461 | 3,381 | 1,068 | 232,615 |

Table 4

**Catch of American shad by water temperature at the Conowingo Dam Fish Lifts (East and West), 1 April through 14 June, 1996. Clean-out lifts excluded.**

| WATER TEMP. (F) | HOURS FISHING | NUMBER | CATCH/ EFFORT | PERCENT |
|---|---|---|---|---|
| < 65 | 220.97 | 10,946 | 49.54 | 29.2 |
| > 65 | 458.78 | 26,500 | 57.76 | 70.8 |
| TOTAL | 679.75 | 37,446 | 55.09 | 100 |

*trap96.xls\Table 4 - 12/18/96*

Table 5

**Total catch and catch per hour of American shad by date and weir gate setting at Conowingo Dam East Fish Lift, 1996.**

| | | Weir Gates | | | | |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | TOTAL |
| 01 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 3.5 | 2.1 | 5.5 |
| | Catch / Hr Fishing | | | - | - | - |
| 03 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 6 | 0.4 | 6.4 |
| | Catch / Hr Fishing | | | - | - | - |
| 05 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 5.5 | 1 | 6.5 |
| | Catch / Hr Fishing | | | - | - | - |
| 08 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 5.5 | 1 | 6.5 |
| | Catch / Hr Fishing | | | - | - | - |
| 10 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 5.2 | 1 | 6.2 |
| | Catch / Hr Fishing | | | - | - | - |
| 12 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 6.4 | 0.5 | 6.9 |
| | Catch / Hr Fishing | | | - | - | - |
| 15 Apr | # Shad | | | 119 | 22 | 141 |
| | Hrs Fishing | | | 5 | 2 | 7 |
| | Catch / Hr Fishing | | | 23.8 | 11 | 20.1 |
| 22 Apr | # Shad | | | - | - | - |
| | Hrs Fishing | | | 5.6 | 2 | 7.6 |
| | Catch / Hr Fishing | | | - | - | - |
| 23 Apr | # Shad | | | 11 | 1 | 12 |
| | Hrs Fishing | | | 5.5 | 1 | 6.5 |
| | Catch / Hr Fishing | | | 2 | 1 | 1.8 |
| 24 Apr | # Shad | | | 78 | 3 | 81 |
| | Hrs Fishing | | | 5.8 | 1 | 6.8 |
| | Catch / Hr Fishing | | | 13.4 | 3 | 11.9 |
| 25 Apr | # Shad | | | 400 | | 400 |
| | Hrs Fishing | | | 6.6 | | 6.6 |
| | Catch / Hr Fishing | | | 60.8 | | 60.8 |
| 26 Apr | # Shad | | | 647 | 27 | 674 |
| | Hrs Fishing | | | 6.2 | 0.5 | 6.7 |
| | Catch / Hr Fishing | | | 103.5 | 54 | 99.9 |
| 27 Apr | # Shad | | | 15 | 4 | 19 |
| | Hrs Fishing | | | 5.3 | 1.5 | 6.8 |
| | Catch / Hr Fishing | | | 2.8 | 2.7 | 2.8 |

*trap96.xls\Table 5 - 12/18/96*

Table 5

Continued.

| | | Weir Gates | | | | |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | TOTAL |
| 28 Apr | # Shad | | | 3 | | 3 |
| | Hrs Fishing | | | 0.5 | | 0.5 |
| | Catch / Hr Fishing | | | 6 | | 6 |
| 29 Apr | # Shad | | | 501 | | 501 |
| | Hrs Fishing | | | 5.7 | | 5.7 |
| | Catch / Hr Fishing | | | 87.1 | | 87.1 |
| 05 May | # Shad | | | 1 | - | 1 |
| | Hrs Fishing | | | 6 | 0.8 | 6.7 |
| | Catch / Hr Fishing | | | 0.2 | - | 0.1 |
| 06 May | # Shad | | | 2 | | 2 |
| | Hrs Fishing | | | 6.5 | | 6.5 |
| | Catch / Hr Fishing | | | 0.3 | | 0.3 |
| 08 May | # Shad | | | 516 | 402 | 918 |
| | Hrs Fishing | | | 3.6 | 2.6 | 6.2 |
| | Catch / Hr Fishing | | | 144 | 155.6 | 148.9 |
| 09 May | # Shad | | | 901 | 387 | 1,288 |
| | Hrs Fishing | | | 7.3 | 3 | 10.3 |
| | Catch / Hr Fishing | | | 124.3 | 129 | 125.7 |
| 10 May | # Shad | | | 730 | 150 | 880 |
| | Hrs Fishing | | | 8.2 | 2.1 | 10.3 |
| | Catch / Hr Fishing | | | 89.4 | 72 | 85.9 |
| 11 May | # Shad | | | 710 | 123 | 833 |
| | Hrs Fishing | | | 6.7 | 1.4 | 8.1 |
| | Catch / Hr Fishing | | | 106.5 | 86.8 | 103.1 |
| 12 May | # Shad | | | 1,070 | 130 | 1,200 |
| | Hrs Fishing | | | 8.3 | 2.8 | 11.2 |
| | Catch / Hr Fishing | | | 128.4 | 45.9 | 107.5 |
| 18 May | # Shad | | | 2 | 1 | 3 |
| | Hrs Fishing | | | 5 | 2.1 | 7.1 |
| | Catch / Hr Fishing | | | 0.4 | 0.5 | 0.4 |
| 20 May | # Shad | | | 922 | 237 | 1,159 |
| | Hrs Fishing | | | 4 | 3.6 | 7.6 |
| | Catch / Hr Fishing | | | 230.5 | 66.1 | 152.8 |
| 21 May | # Shad | | | 1,021 | 304 | 1,325 |
| | Hrs Fishing | | | 6.7 | 4.1 | 10.8 |
| | Catch / Hr Fishing | | | 151.3 | 74.4 | 122.3 |

Table 5

Continued.

| | | Weir Gates | | | | |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | TOTAL |
| 22 May | # Shad | | | 1,211 | 347 | 1,558 |
| | Hrs Fishing | | | 8.9 | 2.2 | 11.2 |
| | Catch / Hr Fishing | | | 135.8 | 154.2 | 139.5 |
| 23 May | # Shad | 84 | | 1,110 | 19 | 1,213 |
| | Hrs Fishing | 0.5 | | 9.4 | 0.5 | 10.4 |
| | Catch / Hr Fishing | 168 | | 117.9 | 38 | 116.4 |
| 24 May | # Shad | | | 943 | 370 | 1,313 |
| | Hrs Fishing | | | 9 | 2.1 | 11.1 |
| | Catch / Hr Fishing | | | 104.8 | 177.6 | 118.5 |
| 25 May | # Shad | 10 | | 1,058 | 464 | 1,532 |
| | Hrs Fishing | 0.2 | | 8.4 | 2.6 | 11.2 |
| | Catch / Hr Fishing | 40 | | 125.7 | 179.6 | 136.2 |
| 26 May | # Shad | 249 | | 468 | 447 | 1,164 |
| | Hrs Fishing | 0.5 | | 4.6 | 6.1 | 11.2 |
| | Catch / Hr Fishing | 498 | | 102.1 | 73.5 | 104.2 |
| 27 May | # Shad | 247 | | 645 | 285 | 1,177 |
| | Hrs Fishing | 2.2 | | 5.7 | 3.2 | 11 |
| | Catch / Hr Fishing | 114 | | 113.8 | 90 | 107 |
| 28 May | # Shad | 81 | | 641 | 128 | 850 |
| | Hrs Fishing | 1.6 | | 6 | 2.2 | 9.8 |
| | Catch / Hr Fishing | 51.2 | | 106.8 | 59.1 | 87.2 |
| 29 May | # Shad | 150 | | 300 | 452 | 902 |
| | Hrs Fishing | 0.9 | | 4.6 | 4.9 | 10.4 |
| | Catch / Hr Fishing | 163.6 | | 65.5 | 91.9 | 86.6 |
| 30 May | # Shad | 97 | | 105 | 159 | 361 |
| | Hrs Fishing | 2.2 | | 4.4 | 4 | 10.7 |
| | Catch / Hr Fishing | 43.1 | | 23.8 | 39.7 | 33.8 |
| 31 May | # Shad | | | 190 | 106 | 296 |
| | Hrs Fishing | | | 4.7 | 5.2 | 9.8 |
| | Catch / Hr Fishing | | | 40.7 | 20.5 | 30.1 |
| 01 Jun | # Shad | 145 | | 548 | 336 | 1,029 |
| | Hrs Fishing | 1.1 | | 4.2 | 5.7 | 11 |
| | Catch / Hr Fishing | 133.8 | | 128.9 | 59.3 | 93.5 |
| 02 Jun | # Shad | 1,091 | | 38 | 258 | 1,387 |
| | Hrs Fishing | 8 | | 0.7 | 2.1 | 10.7 |
| | Catch / Hr Fishing | 136.4 | | 57 | 123.8 | 129 |

Table 5

**Continued.**

| | | Weir Gates | | | | |
|---|---|---|---|---|---|---|
| | | A Only Open | B Only Open | Down Only Open | Changing | TOTAL |
| 03 Jun | # Shad | | | 225 | 185 | 410 |
| | Hrs Fishing | | | 6.4 | 3.7 | 10.2 |
| | Catch / Hr Fishing | | | 35.1 | 49.3 | 40.3 |
| 04 Jun | # Shad | 26 | | 345 | 173 | 544 |
| | Hrs Fishing | 0.5 | | 7.1 | 2.7 | 10.3 |
| | Catch / Hr Fishing | 52 | | 48.7 | 62.9 | 52.6 |
| 05 Jun | # Shad | 92 | | 181 | 440 | 713 |
| | Hrs Fishing | 0.9 | | 6.1 | 3.4 | 10.4 |
| | Catch / Hr Fishing | 100.4 | | 29.8 | 128.8 | 68.4 |
| 06 Jun | # Shad | 60 | | 203 | 52 | 315 |
| | Hrs Fishing | 1.5 | | 6.7 | 2.5 | 10.7 |
| | Catch / Hr Fishing | 40 | | 30.5 | 20.8 | 29.5 |
| 07 Jun | # Shad | 234 | | 94 | 146 | 474 |
| | Hrs Fishing | 2.2 | | 4.7 | 3.1 | 10 |
| | Catch / Hr Fishing | 108 | | 19.8 | 47.4 | 47.4 |
| 08 Jun | # Shad | 168 | | 85 | 240 | 493 |
| | Hrs Fishing | 3 | | 3.5 | 3 | 9.5 |
| | Catch / Hr Fishing | 56 | | 24.3 | 80 | 51.9 |
| 09 Jun | # Shad | 396 | | 8 | 47 | 451 |
| | Hrs Fishing | 6.7 | | 1 | 2.4 | 10.2 |
| | Catch / Hr Fishing | 58.7 | | 8 | 19.4 | 44.4 |
| 10 Jun | # Shad | 67 | | 20 | 55 | 142 |
| | Hrs Fishing | 3.4 | | 3.8 | 2.7 | 10 |
| | Catch / Hr Fishing | 19.6 | | 5.3 | 20 | 14.2 |
| 11 Jun | # Shad | 82 | | 38 | 35 | 155 |
| | Hrs Fishing | 3.5 | | 4.7 | 2 | 10.2 |
| | Catch / Hr Fishing | 23.4 | | 8.1 | 17.5 | 15.2 |
| 12 Jun | # Shad | | | 27 | 6 | 33 |
| | Hrs Fishing | | | 6.7 | 2 | 8.8 |
| | Catch / Hr Fishing | | | 4 | 3 | 3.8 |
| 13 Jun | # Shad | | | 14 | 13 | 27 |
| | Hrs Fishing | | | 4 | 6 | 10 |
| | Catch / Hr Fishing | | | 3.5 | 2.2 | 2.7 |
| 14 Jun | # Shad | | | 21 | | 21 |
| | Hrs Fishing | | | 4.9 | | 4.9 |
| | Catch / Hr Fishing | | | 4.3 | | 4.3 |
| TOTAL | # Shad | 3,279 | | 16,167 | 6,554 | 26,000 |
| | Hrs Fishing | 39 | | 270.8 | 110.7 | 420.6 |
| | Catch / Hr Fishin | 84.1 | | 59.7 | 59.2 | 61.8 |

Table 6

Comparison of catch per effort (hr) of American shad on weekdays *vs* weekend days by generation (cfs) at the Conowingo Dam East Fisht Lift, 1 April through 14 June, 1996.

| | | 5,000 cfs | | 6-10,000 cfs | | 11-20,000 cfs | | 21-40,000 cfs | | >40,000 cfs | | Varying cfs | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lift Time | Catch/H | Effort | Catch/H | Effort | Catch/H | Effort | Catch/H | Effort | Catch/H | Effort | Catch/H | Effort | Catch/H | Effort |
| WEEKDAYS | 07:00-11:00 | 61.5 | 9.2 | 162.7 | 5.3 | 55.8 | 8.7 | 23.4 | 23.1 | 108.3 | 19.8 | 54 | 15.4 | 66.7 | 81.5 |
| WEEKDAYS | 11:01-15:00 | - | - | - | - | 42.3 | 4.7 | 30.4 | 23.3 | 51.3 | 104.1 | 77.5 | 2.2 | 47.8 | 134.2 |
| WEEKDAYS | 15:01-20:00 | - | - | - | - | - | - | 45.7 | 12.8 | 62.3 | 86 | 48.6 | 1.8 | 60 | 100.6 |
| *MEAN* | | *61.5* | *9.2* | *162.7* | *5.3* | *51.1* | *13.4* | *31* | *59.1* | *61.2* | *210* | *56.1* | *19.3* | *56.5* | *316.3* |
| WEEKEND | 07:00-11:00 | 71.2 | 8.6 | 498 | 0.5 | 103.4 | 3.5 | 112.6 | 1.1 | 86.2 | 10.8 | 67 | 8.2 | 86.5 | 32.7 |
| WEEKEND | 11:01-15:00 | 65.8 | 2.9 | - | - | 96.3 | 8.8 | 58.3 | 2.4 | 79.7 | 27.8 | 136 | 1 | 82.3 | 43 |
| WEEKEND | 15:01-20:00 | - | - | - | - | 89.1 | 3.3 | 47 | 7 | 52.6 | 17.3 | 220 | 1 | 61.3 | 28.6 |
| *MEAN* | | *69.8* | *11.5* | *498* | *0.5* | *96.4* | *15.7* | *56.4* | *10.5* | *72.6* | *55.9* | *88.8* | *10.2* | *77.8* | *104.2* |
| TOTAL | | 66.1 | 20.7 | 191.5 | 5.8 | 75.5 | 29.1 | 34.8 | 69.6 | 63.6 | 265.9 | 67.4 | 29.5 | 61.8 | 420.6 |

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, 1 Arpil through 14 June, 1996.**

| Total Discharge | Unit 11 | Unit 10 | Number of Lifts | Time (hours) | Total Shad | Shad/Hour |
|---|---|---|---|---|---|---|
| 5,000 cfs | OFF | OFF | 39 | 20.7 | 1,367 | 66.1 |
| *TOTAL* | | | *39* | *20.7* | *1,367* | *66.1* |
| 6-10,000 cfs | OFF | OFF | 8 | 4.8 | 1,068 | 221 |
| *TOTAL* | | | *8* | *4.8* | *1,068* | *221* |
| 11-20,000 cfs | OFF | OFF | 22 | 16.7 | 1,406 | 84.4 |
| 11-20,000 cfs | ON | OFF | 3 | 1.6 | 202 | 127.6 |
| *TOTAL* | | | *25* | *18.2* | *1,608* | *88.1* |
| 21-40,000 cfs | CHG | CHG | 1 | 1 | 31 | 31 |
| 21-40,000 cfs | OFF | OFF | 4 | 2.1 | 95 | 45.6 |
| 21-40,000 cfs | OFF | ON | 4 | 3.5 | 94 | 26.9 |
| 21-40,000 cfs | ON | OFF | 77 | 54.5 | 1,916 | 35.2 |
| *TOTAL* | | | *86* | *61.1* | *2,136* | *35* |
| > 40,000 cfs | OFF | OFF | 1 | 1.3 | 113 | 84.7 |
| ≥ 40,000 cfs | ON | CHG | 1 | 1 | 69 | 69 |
| > 40,000 cfs | ON | OFF | 35 | 27.2 | 1,108 | 40.8 |
| > 40,000 cfs | ON | ON | 302 | 236.4 | 15,620 | 66.1 |
| *TOTAL* | | | *339* | *265.9* | *16,910* | *63.6* |
| VARYING | CHG | CHG | 7 | 8.2 | 523 | 64 |
| VARYING | CHG | OFF | 15 | 15.8 | 758 | 47.9 |
| VARYING | CHG | ON | 1 | 1 | 43 | 43 |
| VARYING | OFF | OFF | 9 | 5.2 | 586 | 111.6 |
| VARYING | ON | CHG | 7 | 6.7 | 570 | 84.4 |
| VARYING | ON | OFF | 8 | 7.8 | 121 | 15.4 |
| VARYING | ON | ON | 6 | 5.1 | 310 | 61 |
| *TOTAL* | | | *53* | *49.9* | *2,911* | *58.3* |
| **TOTAL** | | | **550** | **420.6** | **26,000** | **61.8** |

Table 8

Daily sex ratio of American shad at the Conowingo Dam Fish Lifts, 1996.

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 Apr | 0 | 0 | 0 | 0 | - | 18 May | 3 | 3 | 3 | 0 | - |
| 03 Apr | 0 | 0 | 0 | 0 | - | 20 May | 1,177 | 119 | 76 | 43 | 1.8 to 1 |
| 05 Apr | 0 | 0 | 0 | 0 | - | 21 May | 1,429 | 211 | 111 | 100 | 1.1 to 1 |
| 08 Apr | 0 | 0 | 0 | 0 | - | 22 May | 1,869 | 201 | 116 | 85 | 1.4 to 1 |
| 10 Apr | 0 | 0 | 0 | 0 | - | 23 May | 2,257 | 223 | 132 | 91 | 1.5 to 1 |
| 12 Apr | 0 | 0 | 0 | 0 | - | 24 May | 1,315 | 100 | 52 | 48 | 1.1 to 1 |
| 15 Apr | 141 | 141 | 110 | 31 | 3.5 to 1 | 25 May | 2,687 | 243 | 132 | 111 | 1.2 to 1 |
| 16 Apr | 0 | 0 | 0 | 0 | - | 26 May | 1,647 | 204 | 99 | 105 | 0.9 to 1 |
| 22 Apr | 0 | 0 | 0 | 0 | - | 27 May | 3,108 | 202 | 98 | 104 | 0.9 to 1 |
| 23 Apr | 13 | 13 | 9 | 4 | 2.2 to 1 | 28 May | 1,980 | 272 | 140 | 132 | 1.1 to 1 |
| 24 Apr | 81 | 81 | 60 | 21 | 2.9 to 1 | 29 May | 1,641 | 219 | 108 | 111 | 1 to 1 |
| 25 Apr | 400 | 400 | 283 | 117 | 2.4 to 1 | 30 May | 876 | 212 | 98 | 114 | 0.9 to 1 |
| 26 Apr | 674 | 100 | 71 | 29 | 2.4 to 1 | 31 May | 1,054 | 247 | 96 | 151 | 0.6 to 1 |
| 27 Apr | 19 | 19 | 10 | 9 | 1.1 to 1 | 01 Jun | 1,306 | 213 | 101 | 112 | 0.9 to 1 |
| 28 Apr | 3 | 3 | 2 | 1 | 2 to 1 | 02 Jun | 1,546 | 205 | 97 | 108 | 0.9 to 1 |
| 29 Apr | 501 | 120 | 87 | 33 | 2.6 to 1 | 03 Jun | 1,550 | 216 | 111 | 105 | 1.1 to 1 |
| 05 May | 1 | 1 | 0 | 1 | 0 to 1 | 04 Jun | 777 | 236 | 100 | 136 | 0.7 to 1 |
| 06 May | 2 | 2 | 2 | 0 | - | 05 Jun | 1,083 | 216 | 90 | 126 | 0.7 to 1 |
| 07 May | 0 | 0 | 0 | 0 | - | 06 Jun | 471 | 200 | 74 | 126 | 0.6 to 1 |
| 08 May | 918 | 100 | 68 | 32 | 2.1 to 1 | 07 Jun | 729 | 215 | 89 | 126 | 0.7 to 1 |
| 09 May | 1,289 | 100 | 64 | 36 | 1.8 to 1 | 08 Jun | 653 | 219 | 76 | 143 | 0.5 to 1 |
| 10 May | 915 | 149 | 102 | 47 | 2.2 to 1 | 09 Jun | 577 | 205 | 87 | 118 | 0.7 to 1 |
| 11 May | 936 | 203 | 146 | 57 | 2.6 to 1 | 10 Jun | 180 | 142 | 54 | 88 | 0.6 to 1 |
| 12 May | 1,200 | 100 | 79 | 21 | 3.8 to 1 | 11 Jun | 362 | 224 | 82 | 142 | 0.6 to 1 |
| 13 May | 0 | 0 | 0 | 0 | - | 12 Jun | 80 | 80 | 19 | 61 | 0.3 to 1 |
| 14 May | 0 | 0 | 0 | 0 | - | 13 Jun | 37 | 37 | 14 | 23 | 0.6 to 1 |
| | | | | | | 14 Jun | 26 | 26 | 6 | 20 | 0.3 to 1 |
| | | | | | | **TOTAL** | **37,513** | **6,422** | **3,354** | **3,068** | **1.1 to 1** |



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**Table 9**

**Age and spawning history of American shad collected and sacrificed at the Conowingo Dam Fish Lifts, 1996.**

| | | Spawning History | | | Fork Length (mm) | | |
|---|---|---|---|---|---|---|---|
| Sex | Age | N | Virgins | Repeats Once | Mean | Min | Max |
| MALE | III | 25 | 25 | - | 356 | 303 | 384 |
| | IV | 103 | 102 | 1 | 383 | 335 | 435 |
| | V | 65 | 59 | 6 | 424 | 379 | 473 |
| | VI | 13 | 10 | 3 | 457 | 427 | 498 |
| | VII | 1 | 1 | - | 557 | 557 | 557 |
| | *Total* | *207* | *197* | *10* | *398* | *303* | *557* |
| FEMALE | III | 2 | 2 | - | 370 | 334 | 405 |
| | IV | 17 | 17 | - | 427 | 367 | 473 |
| | V | 81 | 74 | 7 | 454 | 405 | 500 |
| | VI | 45 | 43 | 2 | 485 | 443 | 526 |
| | VII | 2 | 2 | - | 499 | 485 | 513 |
| | *Total* | *147* | *138* | *9* | *460* | *334* | *526* |
| Grand Total | | 354 | 335 | 19 | 424 | 303 | 557 |

Table 10

Summary of American shad tagged by Maryland DNR and recaptured at the Conowingo Fish Lifts, 1996.

| | Daily Catch | | Number of MD DNR Recaptures | | | Daily Catch | | Number of MD DNR Recaptures | |
|---|---|---|---|---|---|---|---|---|---|
| Date | East | West | East | West | Date | East | West | East | West |
| 01 Apr | 0 | - | - | - | 18 May | 3 | - | - | - |
| 03 Apr | 0 | - | - | - | 20 May | 1,161 | 16 | 3 | - |
| 05 Apr | 0 | - | - | - | 21 May | 1,331 | 98 | 5 | - |
| 08 Apr | 0 | - | - | - | 22 May | 1,584 | 285 | 7 | - |
| 10 Apr | 0 | - | - | - | 23 May | 1,214 | 1,043 | 5 | 4 |
| 12 Apr | 0 | - | - | - | 24 May | 1,315 | - | 7 | - |
| 15 Apr | 141 | - | - | - | 25 May | 1,532 | 1,155 | 9 | 3 |
| 16 Apr | - | - | - | - | 26 May | 1,164 | 483 | 7 | 3 |
| 22 Apr | 0 | - | - | - | 27 May | 1,177 | 1,931 | 15 | 16 |
| 23 Apr | 13 | - | - | - | 28 May | 850 | 1,130 | 9 | 9 |
| 24 Apr | 81 | - | - | - | 29 May | 902 | 739 | 5 | 8 |
| 25 Apr | 400 | - | - | - | 30 May | 361 | 515 | 8 | 6 |
| 26 Apr | 674 | - | - | - | 31 May | 296 | 758 | 3 | 6 |
| 27 Apr | 19 | - | - | - | 01 Jun | 1,030 | 276 | 10 | 4 |
| 28 Apr | 3 | - | - | - | 02 Jun | 1,387 | 159 | 13 | 2 |
| 29 Apr | 501 | - | 2 | - | 03 Jun | 410 | 1,140 | 4 | 15 |
| 05 May | 1 | - | - | - | 04 Jun | 544 | 233 | 5 | 1 |
| 06 May | 2 | - | - | - | 05 Jun | 713 | 370 | 9 | 5 |
| 07 May | - | - | - | - | 06 Jun | 315 | 156 | 5 | 3 |
| 08 May | 918 | - | - | - | 07 Jun | 474 | 255 | 10 | 3 |
| 09 May | 1,289 | - | 2 | - | 08 Jun | 493 | 160 | 7 | 3 |
| 10 May | 880 | 35 | 1 | - | 09 Jun | 451 | 126 | 3 | 2 |
| 11 May | 833 | 103 | 1 | - | 10 Jun | 142 | 38 | 2 | 2 |
| 12 May | 1,200 | - | 1 | - | 11 Jun | 155 | 207 | 1 | 4 |
| 13 May | - | - | - | - | 12 Jun | 33 | 47 | 1 | 3 |
| 14 May | - | - | - | - | 13 Jun | 27 | 10 | - | 1 |
| | | | | | 14 Jun | 21 | 5 | - | - |
| | | | | | TOTAL | 26,040 | 11,473 | 160 | 103 |

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Table 11

Summary of American shad transported from the Conowingo Dam Fish Lifts, 1996.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from both locations* | | | | | |
| 11 May | - | 15.6 | 100 | Tri-County Marina | 0 | 100 | 18.7 | 10.4 | 16.9 |
| 01 Jun | - | 19 | 120 | Columbia PFC | 1 | 99.2 | 10 | 9 | 19.2 |
| 02 Jun | - | 19.5 | 104 | Columbia PFC | 0 | 100 | 15.8 | 11 | 20 |
| 02 Jun | - | 20 | 122 | Columbia PFC | 0 | 100 | 13.2 | 12 | 21 |
| 04 Jun | - | 21 | 120 | Columbia PFC | 0 | 100 | 13 | 10.4 | 21 |
| 04 Jun | - | 21.2 | 130 | Columbia PFC | 0 | 100 | 12.6 | 13 | 21.6 |
| 04 Jun | - | 20.5 | 107 | Tri-County Marina | 0 | 100 | 11 | 9 | 19.5 |
| 06 Jun | - | 23 | 107 | Columbia PFC | 0 | 100 | 14.6 | 10 | 23.5 |
| 07 Jun | - | 22.5 | 119 | Columbia PFC | 0 | 100 | 11.6 | 10 | 24.5 |
| 08 Jun | - | 25 | 97 | Columbia PFC | 0 | 100 | 13 | 10.8 | 26 |
| 09 Jun | - | 24.6 | 95 | Columbia PFC | 0 | 100 | 12.6 | 10.5 | 25.5 |
| 09 Jun | - | 25 | 82 | Columbia PFC | 0 | 100 | 15.4 | 13.6 | 25.1 |
| 10 Jun | - | 26 | 53 | Columbia PFC | 0 | 100 | 12.2 | 8.8 | 26 |
| 11 Jun | - | 26 | 90 | Columbia PFC | 0 | 100 | 15 | 8.6 | 25.5 |
| 12 Jun | - | 27 | 56 | Columbia PFC | 0 | 100 | 12.4 | 8.5 | 25 |
| 14 Jun | - | 27.2 | 39 | Columbia PFC | 0 | 100 | 12.2 | 9 | 25.2 |
| TOTAL, COMBINED | | | 1,541 | | 1 | | | | |
| | | | | *Transported from the East Lift* | | | | | |
| 25 Apr | 400 | 16 | 130 | Tri-County Marina | 0 | 100 | 14 | 14.6 | 17 |
| 25 Apr | 400 | 16 | 130 | Tri-County Marina | 1 | 99.2 | 11.7 | 11.3 | 16.5 |
| 25 Apr | 400 | 15 | 130 | Tri-County Marina | 0 | 100 | 13 | 11.8 | 15 |
| 26 Apr | 674 | 15.5 | 125 | Tri-County Marina | 0 | 100 | 11.6 | 11.4 | 14.5 |
| 26 Apr | 674 | 15.5 | 125 | Tri-County Marina | 0 | 100 | 12.8 | 11.8 | 15 |
| 26 Apr | 674 | 15.1 | 134 | Tri-County Marina | 4 | 97 | 13.4 | 11.2 | 14.1 |
| 26 Apr | 674 | 15.5 | 135 | Tri-County Marina | 0 | 100 | 15.4 | 13 | 14.5 |
| 27 Apr | 19 | 16.5 | 123 | Tri-County Marina | 0 | 100 | 12 | 12.2 | 17 |
| 29 Apr | 501 | 15.8 | 125 | Tri-County Marina | 0 | 100 | 13 | 11.6 | 15.8 |
| 29 Apr | 501 | 16 | 130 | Tri-County Marina | 0 | 100 | 12.5 | 12.3 | 16.7 |
| 29 Apr | 501 | 15.5 | 130 | Tri-County Marina | 0 | 100 | 13.2 | 10 | 15 |
| 29 Apr | 501 | 15.5 | 97 | Tri-County Marina | 0 | 100 | 11.2 | 10 | 15 |

*trap96.xls\Table 11 - 12/18/96*

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued* | | | | | |
| 08 May | 918 | 14.5 | 130 | Tri-County Marina | 0 | 100 | 13.2 | 11 | 14 |
| 08 May | 918 | 15 | 130 | Tri-County Marina | 0 | 100 | 14.5 | 11.1 | 14 |
| 08 May | 918 | 14.5 | 130 | Tri-County Marina | 0 | 100 | 14.5 | 10.4 | 14 |
| 08 May | 918 | 14.5 | 130 | Tri-County Marina | 0 | 100 | 12 | 11 | 13 |
| 08 May | 918 | 14.5 | 130 | Tri-County Marina | 0 | 100 | 10.8 | 10.6 | 14 |
| 09 May | 1,289 | 15 | 106 | Tri-County Marina | 0 | 100 | 13 | 10.8 | 14 |
| 09 May | 1,289 | 14.9 | 130 | Tri-County Marina | 0 | 100 | 13.2 | 10.2 | 14.1 |
| 09 May | 1,289 | 14.8 | 130 | Tri-County Marina | 0 | 100 | 12 | 11 | 13.9 |
| 09 May | 1,289 | 15.1 | 130 | Tri-County Marina | 1 | 99.2 | 16 | 10.7 | 14.5 |
| 09 May | 1,289 | 15 | 130 | Tri-County Marina | 0 | 100 | 11 | 13.6 | 15.2 |
| 09 May | 1,289 | 14.8 | 131 | Tri-County Marina | 0 | 100 | 12.3 | 11.2 | 14 |
| 09 May | 1,289 | 14.5 | 130 | Tri-County Marina | 0 | 100 | 13.2 | 11.4 | 13.9 |
| 09 May | 1,289 | 15 | 104 | Tri-County Marina | 0 | 100 | 11.2 | 11 | 14 |
| 09 May | 1,289 | 15.1 | 130 | Tri-County Marina | 0 | 100 | 12 | 10.3 | 14.2 |
| 10 May | 880 | 14.9 | 123 | Tri-County Marina | 0 | 100 | 13.4 | 9.8 | 14 |
| 10 May | 880 | 14 | 113 | Tri-County Marina | 0 | 100 | 12 | 10.4 | 14.5 |
| 10 May | 880 | 15.1 | 131 | Tri-County Marina | 0 | 100 | 13.4 | 10.1 | 16 |
| 10 May | 880 | 15 | 136 | Tri-County Marina | 0 | 100 | 9.5 | 11 | 16 |
| 10 May | 880 | 14.5 | 131 | Tri-County Marina | 0 | 100 | 13.6 | 10.5 | 15.5 |
| 10 May | 880 | 15 | 134 | Tri-County Marina | 0 | 100 | 11.2 | 10.2 | 16.1 |
| 10 May | 880 | 15 | 135 | Tri-County Marina | 0 | 100 | 10.8 | 11.6 | 15.5 |
| 11 May | 833 | 15 | 118 | Tri-County Marina | 0 | 100 | 14.9 | 10 | 15.7 |
| 11 May | 833 | 16.5 | 130 | Tri-County Marina | 0 | 100 | 12.9 | 10.8 | 17.5 |
| 11 May | 833 | 16 | 130 | Tri-County Marina | 0 | 100 | 12.4 | 13 | 16 |
| 11 May | 833 | 16 | 130 | Tri-County Marina | 0 | 100 | 14 | 10.2 | 17.5 |
| 11 May | 833 | 16.5 | 130 | Tri-County Marina | 0 | 100 | 10.4 | 9.4 | 17.1 |
| 12 May | 1,200 | 15 | 130 | Tri-County Marina | 0 | 100 | 15.8 | 9.6 | 15 |
| 12 May | 1,200 | 15.5 | 130 | Tri-County Marina | 0 | 100 | 14.8 | 10.4 | 15.5 |
| 12 May | 1,200 | 15 | 130 | Tri-County Marina | 0 | 100 | 14.4 | 8.8 | 15.1 |
| 12 May | 1,200 | 15.5 | 130 | Tri-County Marina | 0 | 100 | 12.4 | 9.8 | 15.5 |
| 12 May | 1,200 | 15.5 | 130 | Tri-County Marina | 1 | 99.2 | 13.4 | 10.8 | 14.5 |
| 12 May | 1,200 | 16 | 130 | Tri-County Marina | 0 | 100 | 11.2 | 10.5 | 16 |

*trn96.xls\Table 11 - 12/18/96*

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued* | | | | | |
| 12 May | 1,200 | 15.1 | 130 | Tri-County Marina | 0 | 100 | 9.8 | 12.8 | 15.1 |
| 12 May | 1,200 | 15.5 | 130 | Tri-County Marina | 0 | 100 | 13.8 | 9.8 | 15 |
| 12 May | 1,200 | 15 | 130 | Tri-County Marina | 0 | 100 | 12 | 9.8 | 14.9 |
| 20 May | 1,161 | 17 | 130 | Tri-County Marina | 0 | 100 | 10.6 | 8.4 | 20 |
| 20 May | 1,161 | 16.8 | 121 | Tri-County Marina | 0 | 100 | 17 | 10 | 21 |
| 20 May | 1,161 | 18 | 113 | Tri-County Marina | 0 | 100 | 20 | 7.7 | 22 |
| 20 May | 1,161 | 17 | 130 | Tri-County Marina | 0 | 100 | 16 | 12.1 | 22 |
| 20 May | 1,161 | 17.5 | 130 | Tri-County Marina | 0 | 100 | 12.4 | 8.2 | 22 |
| 20 May | 1,161 | 17 | 130 | Tri-County Marina | 0 | 100 | 12.2 | 10 | 21.5 |
| 21 May | 1,331 | 18 | 130 | Tri-County Marina | 0 | 100 | 11.8 | 8.6 | 21.5 |
| 21 May | 1,331 | 18.8 | 130 | Tri-County Marina | 0 | 100 | 12.5 | 7.5 | 22 |
| 21 May | 1,331 | 19.8 | 130 | Tri-County Marina | 0 | 100 | 12.8 | 9.8 | 22.8 |
| 21 May | 1,331 | 20.5 | 130 | Tri-County Marina | 0 | 100 | 13 | 10.4 | 23 |
| 21 May | 1,331 | 19.5 | 130 | Tri-County Marina | 0 | 100 | 10.2 | 9.8 | 22 |
| 21 May | 1,331 | 20.1 | 130 | Tri-County Marina | 0 | 100 | 12 | 8 | 22.9 |
| 21 May | 1,331 | 20.3 | 130 | Tri-County Marina | 0 | 100 | 16 | 9.2 | 22.6 |
| 21 May | 1,331 | 20.8 | 130 | Tri-County Marina | 2 | 98.5 | 14 | 8.8 | 22.2 |
| 21 May | 1,331 | 19.5 | 130 | Tri-County Marina | 0 | 100 | 13.2 | 8.5 | 22.5 |
| 21 May | 1,331 | 19 | 130 | Tri-County Marina | 0 | 100 | 12 | 8 | 22.4 |
| 22 May | 1,584 | 21 | 129 | Tri-County Marina | 1 | 99.2 | 13.2 | 8.2 | 21 |
| 22 May | 1,584 | 20.4 | 130 | Columbia PFC | 0 | 100 | 14.4 | 7 | 21 |
| 22 May | 1,584 | 20 | 129 | Columbia PFC | 0 | 100 | 18.3 | 9.4 | 20.8 |
| 22 May | 1,584 | 20 | 129 | Columbia PFC | 0 | 100 | 10.9 | 7.5 | 21 |
| 22 May | 1,584 | 22 | 129 | Columbia PFC | 0 | 100 | 11 | 8.2 | 22.5 |
| 22 May | 1,584 | 20.5 | 129 | Columbia PFC | 0 | 100 | 13 | 8 | 20.5 |
| 22 May | 1,584 | 22.5 | 130 | Columbia PFC | 1 | 99.2 | 20 | 8.5 | 22.2 |
| 22 May | 1,584 | 22 | 130 | Columbia PFC | 0 | 100 | 16.7 | 8.3 | 22 |
| 22 May | 1,584 | 21 | 130 | Columbia PFC | 1 | 99.2 | 11 | 7.2 | 21.8 |
| 22 May | 1,584 | 20.5 | 130 | Tri-County Marina | 0 | 100 | 14 | 7.7 | 21 |
| 22 May | 1,584 | 22 | 130 | Tri-County Marina | 2 | 98.5 | 11.4 | 7.4 | 22 |
| 23 May | 1,214 | 20.5 | 129 | Columbia PFC | 0 | 100 | 13.6 | 9.2 | 20 |
| 23 May | 1,214 | 20.5 | 103 | Columbia PFC | 0 | 100 | 13.8 | 9.2 | 20.4 |

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| *Transported from the East Lift, continued* | | | | | | | | | |
| 23 May | 1,214 | 22 | 130 | Columbia PFC | 1 | 99.2 | 13 | 10 | 22.3 |
| 23 May | 1,214 | 22 | 130 | Columbia PFC | 0 | 100 | 12.6 | 8.8 | 22 |
| 23 May | 1,214 | 22 | 130 | Columbia PFC | 0 | 100 | 14 | 9.5 | 21.5 |
| 23 May | 1,214 | 23 | 130 | Columbia PFC | 0 | 100 | 13.4 | 12.4 | 23 |
| 23 May | 1,214 | 12 | 130 | Columbia PFC | 1 | 99.2 | 23 | 10.8 | 23.5 |
| 23 May | 1,214 | 22 | 130 | Columbia PFC | 2 | 98.5 | 10.8 | 10 | 21.5 |
| 23 May | 1,214 | 22.8 | 130 | Columbia PFC | 2 | 98.5 | 11.2 | 11.4 | 22.7 |
| 23 May | 1,214 | 25.5 | 120 | Columbia PFC | 0 | 100 | 10.8 | 10.8 | 23 |
| 24 May | 1,315 | 23 | 120 | Columbia PFC | 2 | 98.3 | 17 | 9.6 | 22.2 |
| 24 May | 1,315 | 23 | 98 | Columbia PFC | 0 | 100 | 18.6 | 10.2 | 21.5 |
| 24 May | 1,315 | 22.2 | 120 | Columbia PFC | 1 | 99.2 | 13.7 | 11.2 | 22.2 |
| 24 May | 1,315 | 24 | 120 | Columbia PFC | 0 | 100 | 12.8 | 9.4 | 22.8 |
| 24 May | 1,315 | 24 | 120 | Columbia PFC | 1 | 99.2 | 16.2 | 7.8 | 22.8 |
| 24 May | 1,315 | 23 | 109 | Columbia PFC | 1 | 99.1 | 16 | 10.4 | 22.6 |
| 24 May | 1,315 | 23.7 | 120 | Columbia PFC | 1 | 99.2 | 16.5 | 11.5 | 23 |
| 24 May | 1,315 | 23.5 | 119 | Columbia PFC | 0 | 100 | 13.5 | 11.8 | 22.8 |
| 24 May | 1,315 | 23 | 120 | Columbia PFC | 0 | 100 | 14 | 11.5 | 22 |
| 24 May | 1,315 | 23.8 | 120 | Columbia PFC | 1 | 99.2 | 15.4 | 11.5 | 22.6 |
| 25 May | 1,532 | 21.5 | 117 | Columbia PFC | 0 | 100 | 13.6 | 8 | 20 |
| 25 May | 1,532 | 22 | 115 | Columbia PFC | 0 | 100 | 15.2 | 10 | 20.5 |
| 25 May | 1,532 | 22.8 | 110 | Columbia PFC | 0 | 100 | 13 | 9.5 | 21.8 |
| 25 May | 1,532 | 22 | 110 | Columbia PFC | 0 | 100 | 13 | 10 | 21 |
| 25 May | 1,532 | 22 | 110 | Columbia PFC | 0 | 100 | 16 | 10.2 | 22 |
| 25 May | 1,532 | 22.5 | 110 | Columbia PFC | 0 | 100 | 13.2 | 11 | 22 |
| 25 May | 1,532 | 23 | 110 | Columbia PFC | 0 | 100 | 13.6 | 10.6 | 22.3 |
| 25 May | 1,532 | 22.5 | 110 | Columbia PFC | 0 | 100 | 11.8 | 11.2 | 21.5 |
| 25 May | 1,532 | 24.2 | 110 | Columbia PFC | 4 | 96.4 | 11.3 | 11.3 | 21.9 |
| 25 May | 1,532 | 24 | 110 | Columbia PFC | 0 | 100 | 15.4 | 10.1 | 22 |
| 25 May | 1,532 | 24 | 110 | Columbia PFC | 0 | 100 | 11.2 | 10.2 | 22 |
| 25 May | 1,532 | 23.2 | 110 | Columbia PFC | 0 | 100 | 12 | 10.6 | 21 |
| 26 May | 1,164 | 22.5 | 110 | Columbia PFC | 0 | 100 | 16.6 | 9.8 | 20 |
| 26 May | 1,164 | 22 | 120 | Columbia PFC | 1 | 99.2 | 8.6 | 12.4 | 22.2 |

trap96.xls\Table 11 - 12/18/96

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued* | | | | | |
| 26 May | 1,164 | 22.2 | 120 | Columbia PFC | 1 | 99.2 | 14.1 | 10.3 | 20 |
| 26 May | 1,164 | 23 | 120 | Columbia PFC | 1 | 99.2 | 12.5 | 10 | 19.5 |
| 26 May | 1,164 | 22 | 120 | Columbia PFC | 0 | 100 | 10.2 | 10.8 | 19 |
| 26 May | 1,164 | 22.2 | 120 | Columbia PFC | 0 | 100 | 13.6 | 10.8 | 19.4 |
| 26 May | 1,164 | 22.5 | 120 | Columbia PFC | 0 | 100 | 13.4 | 10.4 | 19.5 |
| 26 May | 1,164 | 22 | 120 | Columbia PFC | 0 | 100 | 11.8 | 10 | 18.6 |
| 27 May | 1,177 | 22.5 | 120 | Columbia PFC | 0 | 100 | 12.5 | 8.5 | 18.5 |
| 27 May | 1,177 | 20.8 | 120 | Columbia PFC | 0 | 100 | 10 | 8.6 | 18 |
| 27 May | 1,177 | 21.9 | 120 | Columbia PFC | 0 | 100 | 11.5 | 11.7 | 18 |
| 27 May | 1,177 | 23 | 120 | Columbia PFC | 0 | 100 | 11.5 | 10 | 18 |
| 27 May | 1,177 | 21 | 120 | Columbia PFC | 0 | 100 | 11 | 9.8 | 17.2 |
| 27 May | 1,177 | 22 | 115 | Columbia PFC | 0 | 100 | 14 | 10 | 18 |
| 27 May | 1,177 | 15.7 | 120 | Columbia PFC | 0 | 100 | 23 | 10.2 | 18 |
| 27 May | 1,177 | 21 | 120 | Columbia PFC | 0 | 100 | 11.4 | 10.4 | 16.8 |
| 27 May | 1,177 | 22 | 120 | Columbia PFC | 0 | 100 | 13 | 11 | 17.5 |
| 27 May | 1,177 | 22.5 | 120 | Columbia PFC | 0 | 100 | 12 | 9.8 | 19 |
| 27 May | 1,177 | 20.9 | 120 | Columbia PFC | 0 | 100 | 12.4 | 9.8 | 16.2 |
| 28 May | 850 | 21.2 | 99 | Tri-County Marina | 0 | 100 | 16 | 11 | 18.5 |
| 28 May | 850 | 21 | 120 | Columbia PFC | 0 | 100 | 13.5 | 9 | 16 |
| 28 May | 850 | 21.5 | 120 | Tri-County Marina | 3 | 97.5 | 14.2 | 10 | 14.8 |
| 28 May | 850 | 21.5 | 120 | Tri-County Marina | 0 | 100 | 19.4 | 9.8 | 14.5 |
| 28 May | 850 | 21 | 88 | Tri-County Marina | 0 | 100 | 9 | 8.2 | 14 |
| 28 May | 850 | 21 | 110 | Tri-County Marina | 1 | 99.1 | 18.4 | 10.6 | 14.2 |
| 28 May | 850 | 21 | 125 | Tri-County Marina | 0 | 100 | 20 | 12.6 | 14.5 |
| 29 May | 902 | 20.4 | 83 | Tri-County Marina | 1 | 98.8 | 11.4 | 9.7 | 15 |
| 29 May | 902 | 20.8 | 108 | Columbia PFC | 0 | 100 | 13 | 10.8 | 14.8 |
| 29 May | 902 | 20 | 120 | Columbia PFC | 0 | 100 | 13.2 | 9.8 | 15 |
| 29 May | 902 | 20.1 | 120 | Columbia PFC | 0 | 100 | 12.5 | 10.2 | 15 |
| 29 May | 902 | 21 | 120 | Columbia PFC | 1 | 99.2 | 14 | 10.5 | 16 |
| 29 May | 902 | 21 | 120 | Columbia PFC | 0 | 100 | 14.2 | 13.8 | 21.2 |
| 29 May | 902 | 20.2 | 119 | Columbia PFC | 1 | 99.2 | 7.6 | 11.8 | 16 |
| 29 May | 902 | 21 | 125 | Tri-County Marina | 0 | 100 | 12.5 | 10.8 | 14.9 |

*trap96.xls\Table 11 - 12/18/96*

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued* | | | | | |
| 30 May | 361 | 20 | 120 | Columbia PFC | 0 | 100 | 9.8 | 10.6 | 16 |
| 30 May | 361 | 21 | 120 | Columbia PFC | 0 | 100 | 12 | 10 | 17 |
| 31 May | 296 | 20 | 119 | Tri-County Marina | 1 | 99.2 | 14 | 9.8 | 17.5 |
| 31 May | 296 | 21.5 | 119 | Tri-County Marina | 0 | 100 | 10 | 10.4 | 17.5 |
| 31 May | 296 | 19.6 | 120 | Tri-County Marina | 3 | 97.5 | 9.8 | 11.4 | 17 |
| 01 Jun | 1,030 | 20.1 | 120 | Columbia PFC | 0 | 100 | 10.6 | 9.3 | 19.2 |
| 01 Jun | 1,030 | 19.2 | 120 | Columbia PFC | 0 | 100 | 12.8 | 9.2 | 18.5 |
| 01 Jun | 1,030 | 20 | 120 | Columbia PFC | 0 | 100 | 12 | 10.8 | 21 |
| 01 Jun | 1,030 | 20.2 | 120 | Columbia PFC | 3 | 97.5 | 11.6 | 10.6 | 21 |
| 01 Jun | 1,030 | 19.8 | 120 | Columbia PFC | 1 | 99.2 | 12.8 | 9.6 | 19.9 |
| 01 Jun | 1,030 | 20.5 | 120 | Columbia PFC | 0 | 100 | 17.4 | 11 | 22 |
| 01 Jun | 1,030 | 20 | 120 | Columbia PFC | 2 | 98.3 | 16.6 | 11 | 21 |
| 01 Jun | 1,030 | 20.5 | 120 | Tri-County Marina | 0 | 100 | 11.8 | 10 | 20.3 |
| 02 Jun | 1,387 | 19.3 | 101 | Columbia PFC | 0 | 100 | 10.4 | 9.2 | 18.6 |
| 02 Jun | 1,387 | 19 | 120 | Columbia PFC | 0 | 100 | 12.5 | 9.5 | 20.5 |
| 02 Jun | 1,387 | 20.5 | 124 | Columbia PFC | 0 | 100 | 12.4 | 13.2 | 20.9 |
| 02 Jun | 1,387 | 20.5 | 130 | Columbia PFC | 0 | 100 | 15.2 | 11.1 | 21.5 |
| 02 Jun | 1,387 | 20 | 120 | Columbia PFC | 0 | 100 | 18.6 | 11.4 | 21.5 |
| 02 Jun | 1,387 | 19 | 120 | Columbia PFC | 0 | 100 | 19.8 | 10 | 21.8 |
| 02 Jun | 1,387 | 18 | 130 | Columbia PFC | 0 | 100 | 12.5 | 9.6 | 20.5 |
| 02 Jun | 1,387 | 18.5 | 130 | Tri-County Marina | 0 | 100 | 16.8 | 11 | 20.5 |
| 02 Jun | 1,387 | 19 | 125 | Columbia PFC | 1 | 99.2 | 12 | 10 | 21 |
| 02 Jun | 1,387 | 21 | 120 | Tri-County Marina | 0 | 100 | 16 | 9.6 | 21.5 |
| 03 Jun | 410 | 20 | 115 | Columbia PFC | 1 | 99.1 | 14.9 | 9.6 | 20.5 |
| 03 Jun | 410 | 18.7 | 126 | Tri-County Marina | 0 | 100 | 9.2 | 11.4 | 19 |
| 03 Jun | 410 | 20 | 130 | Columbia PFC | 0 | 100 | 12.2 | 9.1 | 20.6 |
| 04 Jun | 544 | 20.5 | 120 | Tri-County Marina | 7 | 94.2 | 10.4 | 10.8 | 19.5 |
| 04 Jun | 544 | 20.8 | 120 | Tri-County Marina | 2 | 98.3 | 14 | 11.8 | 20.2 |
| 04 Jun | 544 | 21 | 120 | Columbia PFC | 0 | 100 | 11 | 8.4 | 21 |
| 05 Jun | 713 | 20.5 | 120 | Columbia PFC | 0 | 100 | 11 | 8.3 | 21.8 |
| 05 Jun | 713 | 21.2 | 120 | Columbia PFC | 0 | 100 | 12.4 | 9 | 22 |
| 05 Jun | 713 | 20.5 | 120 | Columbia PFC | 0 | 100 | 12 | 9.8 | 20.5 |

*trap96.xls\Table 11 - 12/18/96*

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the East Lift, continued* | | | | | |
| 05 Jun | 713 | 22 | 118 | Columbia PFC | 0 | 100 | 8.8 | 8.3 | 22.8 |
| 05 Jun | 713 | 23 | 114 | Columbia PFC | 1 | 99.1 | 12.2 | 8 | 22 |
| 05 Jun | 713 | 22.8 | 122 | Columbia PFC | 0 | 100 | 12 | 10 | 22 |
| 06 Jun | 315 | 22.5 | 120 | Columbia PFC | 2 | 98.3 | 12.9 | 9.6 | 23 |
| 06 Jun | 315 | 22.5 | 118 | Columbia PFC | 0 | 100 | 10.8 | 9.6 | 22.5 |
| 07 Jun | 474 | 22.2 | 120 | Columbia PFC | 0 | 100 | 10.8 | 9.4 | 23 |
| 07 Jun | 474 | 23.5 | 120 | Columbia PFC | 0 | 100 | 11 | 13 | 24 |
| 07 Jun | 474 | 25 | 112 | Columbia PFC | 0 | 100 | 15.4 | 10.2 | 25 |
| 08 Jun | 493 | 23.2 | 100 | Columbia PFC | 0 | 100 | 10.6 | 9.6 | 24.8 |
| 08 Jun | 493 | 23.1 | 111 | Columbia PFC | 0 | 100 | 8.3 | 10.2 | 24.1 |
| 08 Jun | 493 | 25 | 110 | Columbia PFC | 0 | 100 | 9 | 10.8 | 26 |
| 08 Jun | 493 | 25 | 93 | Columbia PFC | 5 | 94.6 | 14 | 10.5 | 25.5 |
| 09 Jun | 451 | 24.3 | 101 | Columbia PFC | 9 | 91.1 | 12.7 | 8.9 | 24.5 |
| 09 Jun | 451 | 25 | 110 | Columbia PFC | 1 | 99.1 | 8.8 | 8.6 | 27.5 |
| 09 Jun | 451 | 24.5 | 110 | Columbia PFC | 3 | 97.3 | 9.2 | 13.4 | 25 |
| 10 Jun | 142 | 25.5 | 90 | Columbia PFC | 1 | 98.9 | 12.8 | 9.3 | 27.5 |
| 11 Jun | 155 | 25.9 | 88 | Columbia PFC | 0 | 100 | 8.4 | 9.3 | 26 |
| TOTAL, EAST LIFT | | | 22,923 | | 84 | | | | |
| | | | | *Transported from the West Lift* | | | | | |
| 11 May | 103 | 16 | 96 | Tri-County Marina | 0 | 100 | 10.8 | 8.8 | 16.5 |
| 22 May | 285 | 21.5 | 167 | Tri-County Marina | 3 | 98.2 | 12 | 8.4 | 22.5 |
| 22 May | 285 | 21 | 190 | Columbia PFC | 0 | 100 | 10.6 | 8 | 21.5 |
| 23 May | 1,043 | 22 | 170 | Columbia PFC | 0 | 100 | 12.2 | 9.8 | 21.5 |
| 23 May | 1,043 | 20.5 | 158 | PFC Muddy Cr. | 0 | 100 | 12.6 | 11.8 | 20.5 |
| 23 May | 1,043 | 22 | 174 | PFC Muddy Cr. | 0 | 100 | 12.2 | 13 | 23 |
| 23 May | 1,043 | 22.5 | 60 | Safe Harbor Forebay | 4 | 93.3 | 11.5 | 9.3 | 22.5 |
| 23 May | 1,043 | 22 | 176 | Columbia PFC | 0 | 100 | 10 | 13 | 22.5 |
| 24 May | - | 23 | 120 | Columbia PFC | 0 | 100 | 14.6 | 8.6 | 22 |
| 25 May | 1,155 | 22.2 | 150 | Columbia PFC | 1 | 99.3 | 8.8 | 12 | 22.5 |
| 25 May | 1,155 | 23 | 134 | Columbia PFC | 1 | 99.3 | 13.8 | 13.6 | 23 |
| 25 May | 1,155 | 23 | 147 | Columbia PFC | 0 | 100 | 12 | 12.2 | 23 |

*trap96.xls\Table 11 - 12/18/96*

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the West Lift, continued* | | | | | |
| 25 May | 1,155 | 23 | 137 | Columbia PFC | 0 | 100 | 15.4 | 11.2 | 22.2 |
| 25 May | 1,155 | 23.2 | 150 | Columbia PFC | 0 | 100 | 12.6 | 11.4 | 21.1 |
| 25 May | 1,155 | 23.2 | 150 | Columbia PFC | 0 | 100 | 13.2 | 12 | 21.7 |
| 25 May | 1,155 | 23.4 | 170 | Columbia PFC | 0 | 100 | 13 | 10 | 21.5 |
| 26 May | 483 | 22.2 | 173 | Columbia PFC | 0 | 100 | 11.8 | 10.2 | 19.5 |
| 26 May | 483 | 13.7 | 166 | Columbia PFC | 1 | 99.4 | 22.2 | 9.6 | 12 |
| 26 May | 483 | 21.5 | 115 | Columbia PFC | 0 | 100 | 14.6 | 9.6 | 18.5 |
| 27 May | 1,931 | 22.8 | 150 | Columbia PFC | 1 | 99.3 | 13.4 | 9 | 10 |
| 27 May | 1,931 | 22.2 | 150 | Columbia PFC | 0 | 100 | 11.4 | 10.4 | 16.9 |
| 27 May | 1,931 | 22 | 150 | Columbia PFC | 0 | 100 | 9.6 | 9 | 18 |
| 27 May | 1,931 | 22.5 | 158 | Columbia PFC | 0 | 100 | 10.4 | 11 | 18 |
| 27 May | 1,931 | 22.5 | 155 | Columbia PFC | 0 | 100 | 10.2 | 10 | 18 |
| 27 May | 1,931 | 22 | 156 | Columbia PFC | 1 | 99.4 | 13 | 11 | 17.5 |
| 27 May | 1,931 | 22 | 140 | Columbia PFC | 2 | 98.6 | 11.6 | 9.8 | 17.8 |
| 27 May | 1,931 | 23 | 160 | Columbia PFC | 0 | 100 | 12.6 | 10.4 | 18 |
| 27 May | 1,931 | 22.5 | 158 | Columbia PFC | 1 | 99.4 | 12.2 | 9.8 | 17.5 |
| 27 May | 1,931 | 22 | 150 | Columbia PFC | 0 | 100 | 12.2 | 9.8 | 18 |
| 27 May | 1,931 | 22 | 170 | Columbia PFC | 0 | 100 | 11 | 9.8 | 17.5 |
| 28 May | 1,130 | 20.2 | 173 | Tri-County Marina | 0 | 100 | 12.8 | 10.2 | 14.2 |
| 28 May | 1,130 | 22 | 165 | Tri-County Marina | 0 | 100 | 11.6 | 13.8 | 22 |
| 28 May | 1,130 | 21 | 143 | Tri-County Marina | 0 | 100 | 10 | 10.2 | 14 |
| 28 May | 1,130 | 20.5 | 163 | Tri-County Marina | 1 | 99.4 | 12 | 10 | 18.8 |
| 28 May | 1,130 | 21.5 | 170 | Columbia PFC | 0 | 100 | 12.6 | 10.6 | 14.5 |
| 28 May | 1,130 | 20 | 115 | Tri-County Marina | 0 | 100 | 12 | 10.2 | 13.8 |
| 29 May | 739 | 20.5 | 151 | Columbia PFC | 0 | 100 | 10.6 | 9 | 15.5 |
| 29 May | 739 | 20.5 | 150 | Tri-County Marina | 0 | 100 | 13.2 | 9 | 13.8 |
| 29 May | 739 | 20.1 | 149 | Columbia PFC | 0 | 100 | 12.4 | 11.4 | 15.3 |
| 29 May | 739 | 20.2 | 160 | Tri-County Marina | 1 | 99.4 | 10.8 | 10.2 | 14.4 |
| 29 May | 739 | 20 | 81 | Tri-County Marina | 0 | 100 | 9 | 9.8 | 14 |
| 30 May | 515 | 20 | 118 | Tri-County Marina | 0 | 100 | 12.6 | 10.2 | 14 |
| 30 May | 515 | 20 | 157 | Tri-County Marina | 0 | 100 | 9.8 | 12.8 | 20.5 |
| 30 May | 515 | 20 | 148 | Tri-County Marina | 1 | 99.3 | 12 | 10.2 | 16 |

tr~~96.xls\Table 11 - 12/18/96

Table 11

Continued.

| DATE | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Transported from the West Lift, continued* | | | | | |
| 30 May | 515 | 19.9 | 67 | Tri-County Marina | 0 | 100 | 12.2 | 10.8 | 15.9 |
| 31 May | 758 | 19.8 | 147 | Tri-County Marina | 2 | 98.6 | 10.7 | 11 | 16 |
| 31 May | 758 | 20 | 178 | Columbia PFC | 0 | 100 | 11 | 11 | 17.5 |
| 31 May | 758 | 19.9 | 32 | Safe Harbor Forebay | 0 | 100 | 19.5 | 14.2 | 20 |
| 31 May | 758 | 20 | 29 | Safe Harbor Forebay | 0 | 100 | 14 | 12.2 | 20 |
| 31 May | 758 | 19.5 | 169 | Columbia PFC | 1 | 99.4 | 10.2 | 12.3 | 18.2 |
| 31 May | 758 | 19 | 174 | Tri-County Marina | 0 | 100 | 10 | 18.5 | 18 |
| 01 Jun | 276 | 19 | 170 | Columbia PFC | 0 | 100 | 11.5 | 10.4 | 19.8 |
| 03 Jun | 1,140 | 19.2 | 145 | Tri-County Marina | 0 | 100 | 11.2 | 10.2 | 20 |
| 03 Jun | 1,140 | 19.2 | 173 | Tri-County Marina | 0 | 100 | 13.8 | 13.6 | 19.6 |
| 03 Jun | 1,140 | 19.8 | 167 | Tri-County Marina | 5 | 97 | 13.4 | 10.2 | 19 |
| 03 Jun | 1,140 | 20 | 170 | Columbia PFC | 0 | 100 | 14 | 9 | 21 |
| 03 Jun | 1,140 | 20.7 | 184 | Tri-County Marina | 1 | 99.5 | 12.5 | 10.5 | 20 |
| 03 Jun | 1,140 | 20.2 | 170 | Columbia PFC | 0 | 100 | 12.2 | 8 | 20 |
| 04 Jun | 233 | 19 | 131 | Columbia PFC | 1 | 99.2 | 12.8 | 13.4 | 19 |
| 05 Jun | 370 | 21 | 150 | Columbia PFC | 1 | 99.3 | 10.8 | 8.5 | 22 |
| 05 Jun | 370 | 20 | 150 | Columbia PFC | 0 | 100 | 10.4 | 9.1 | 21 |
| 07 Jun | 255 | 22 | 128 | Columbia PFC | 0 | 100 | 11.6 | 10.6 | 24.3 |
| 08 Jun | 160 | 23.1 | 123 | Columbia PFC | 0 | 100 | 12.4 | 8 | 24.5 |
| 10 Jun | 38 | 23.5 | 35 | Safe Harbor Forebay | 0 | 100 | 10.5 | 10.3 | 23.8 |
| 11 Jun | 207 | 24.5 | 106 | Columbia PFC | 1 | 99.1 | 13.2 | 13.6 | 24.9 |
| 11 Jun | 207 | 24.5 | 20 | Safe Harbor Forebay | 0 | 100 | 11 | 9.4 | 25 |
| TOTAL, WEST LIFT | | | 9,361 | | 30 | | | | |
| | | | 33,825 | | 115 | | | | |



trap96.xls\Table 11 - 12/18/96

Table 12

Summary of transports of river herring from the Conowingo Dam Fish Lifts, 1 April through 14 June, 1996.

| DATE | SPECIES | NO. COLLECTED | WATER TEMP (C) | NO. TRANSPORTED | LOCATION | OBSERVED MORTALITY | PERCENT SURVIVAL | D.O. (ppm) START | D.O. (ppm) FINISH | WATER TEMP (C) AT STOCKING LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Transported from both locations* | | | | | |
| 11 May | Blueback herring | - | 15.6 | 79 | Tri-County Marina | 0 | 100 | 18.7 | 10.4 | 16.9 |
| | TOTAL, COMBINED | | | 79 | | 0 | | | | |
| | | | | | *Transported from the West Lift* | | | | | |
| 11 May | Blueback herring | 336 | 16.0 | 276 | Tri-County Marina | 0 | 100 | 10.8 | 8.8 | 16.5 |
| 23 May | Blueback herring | 55 | 22.0 | 55 | Columbia PFC | 0 | 100 | 12.2 | 9.8 | 21.5 |
| | TOTAL, WEST LIFT | | | 331 | | 0 | | | | |
| | | | | 410 | | 0 | | | | |

*trap96.xls\Table 12 - 12/18/96*

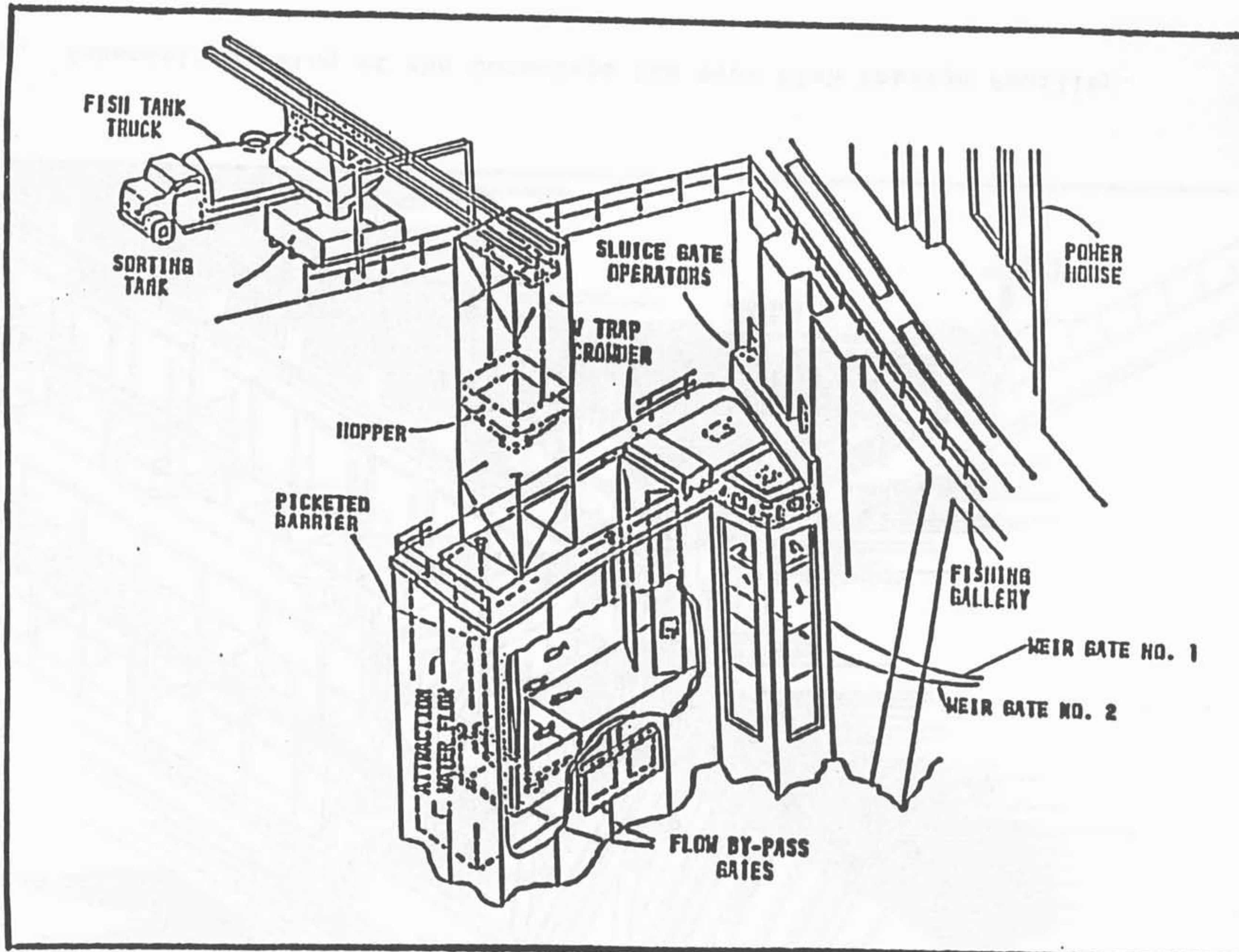


Figure 1. Schematic drawing of Conowingo Dam West Fish Passage Facility, Anonymous (1972).

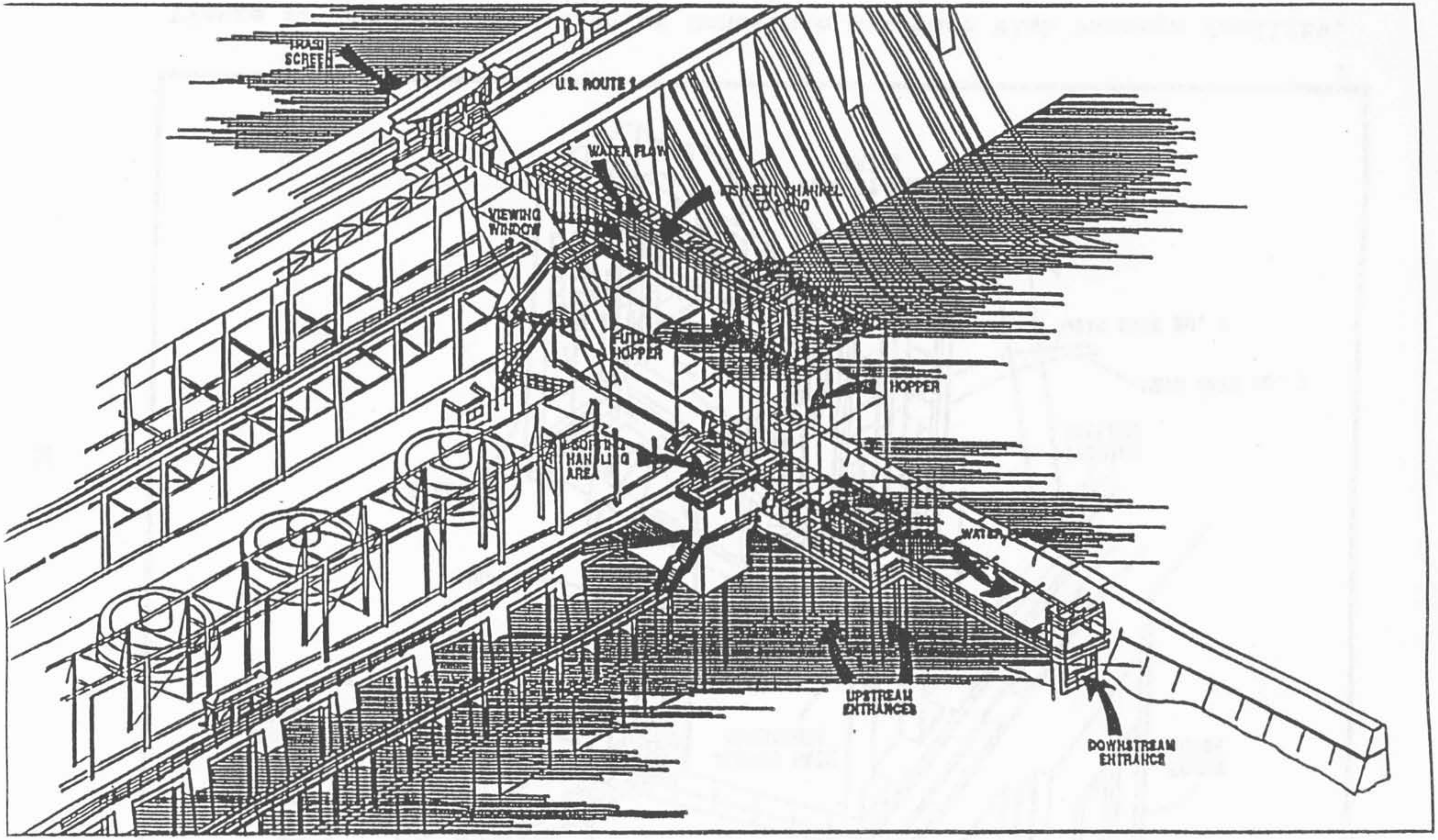


Figure 2. Schematic drawing of the Conowingo Dam East Fish Passage Facility.

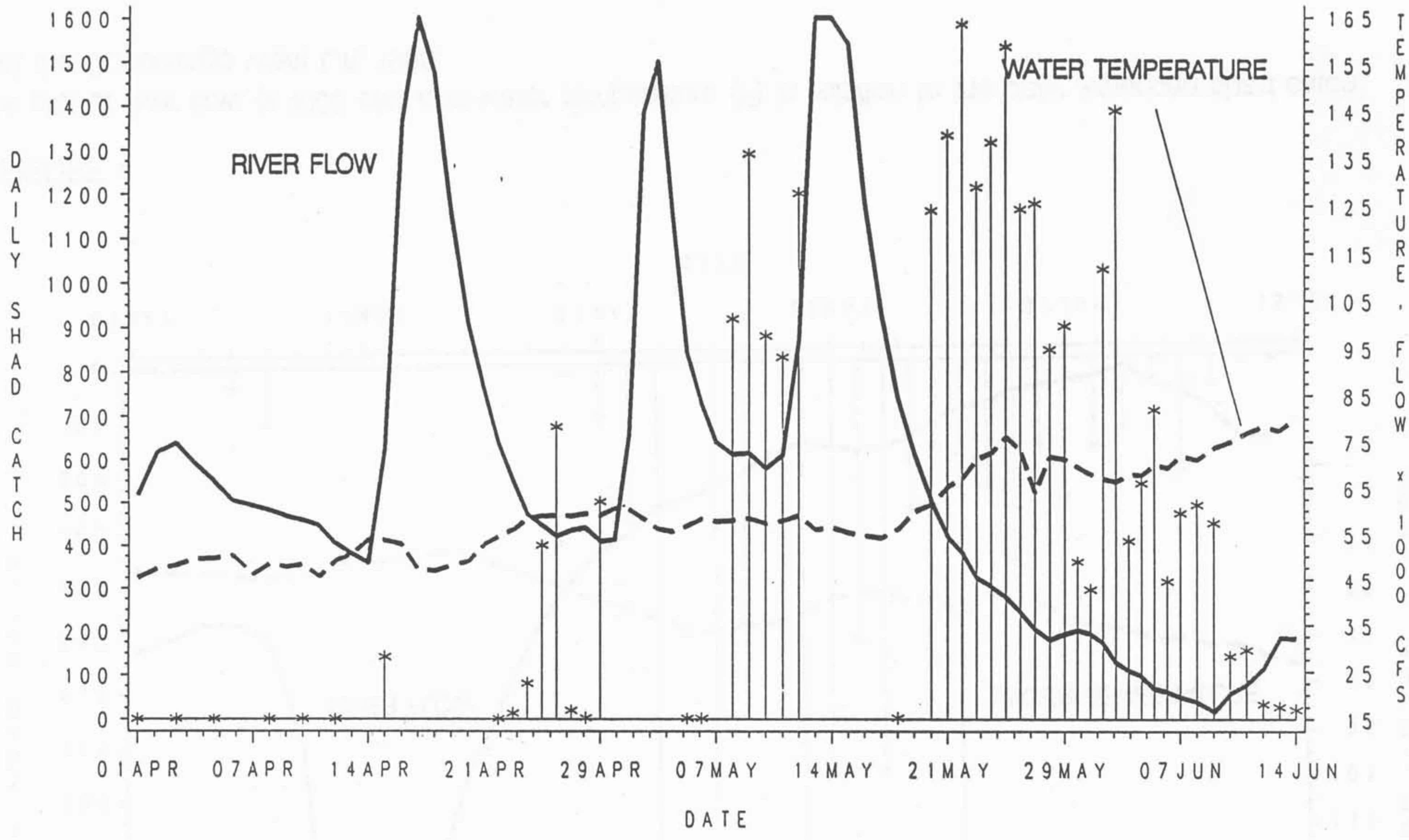


FIGURE 3

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, 1996.

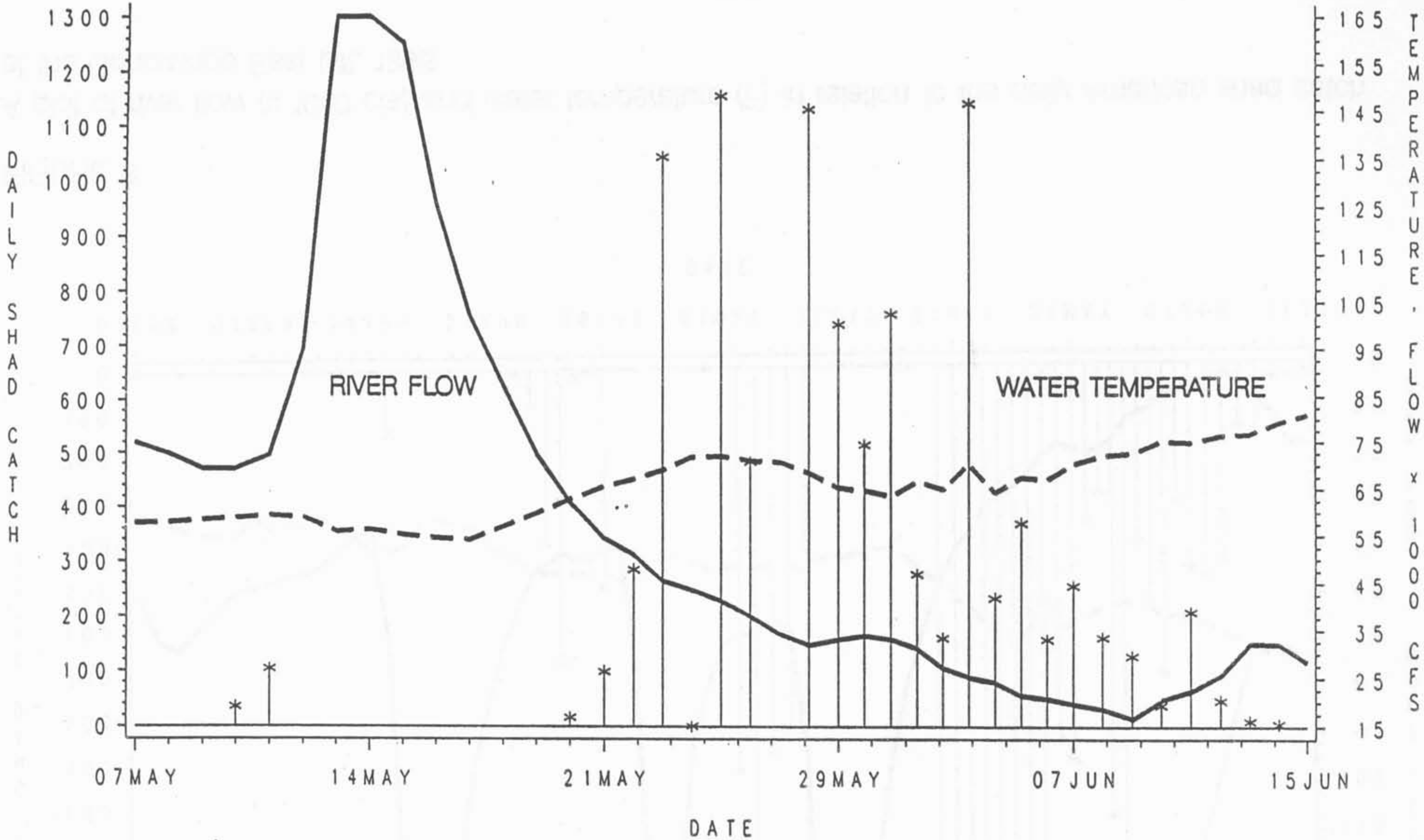


FIGURE 4

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, 1996.

JOB II - Part 1

# AMERICAN SHAD EGG COLLECTION PROGRAM ON THE HUDSON RIVER, 1996

THE WYATT GROUP, INC.
1853 William Penn Way
P.O. Box 4423
Lancaster, PA 17604

## I. INTRODUCTION

The Pennsylvania Fish and Boat Commission (PFBC) is cooperating with other state and federal agencies and hydropower companies to restore the American shad to the Susquehanna River. One component of that effort is production of hatchery-reared American shad larvae at the Commission's Van Dyke Hatchery for stocking in the Susquehanna River. Fertilized American shad eggs are required to initiate the hatchery activities. Since 1980 about 453 million eggs have been obtained in support of the Susquehanna River anadromous fish restoration program. Annual production ranged from 11 to 52 million eggs per year. The highest production was from the Columbia River, Oregon, which was discontinued after the 1989 season. All subsequent egg collection efforts have been made on the East Coast. The primary rivers used in recent years have been the Delaware and Hudson, though some effort was made on the Connecticut River from 1991-1994 (Table 1).

The Hudson River has been an important source of viable eggs in support of the hatchery effort. The Wyatt Group, Inc. (Lancaster, Pennsylvania) was contracted to capture ripe adult shad on the spawning grounds, to strip and artificially fertilize the eggs, and to deliver them to the hatchery. The objective was to deliver up to 20 million fertilized American shad eggs, with a viability of 60-70 percent. This report provides the results of the 1996 collection program on the Hudson River.

## II. METHODS

### A. General Conditions and Procedures

The Wyatt Group used procedures that it has employed on the Hudson River since 1989. This included regular contact with commercial fishermen and resource agency personnel beginning on 1 April. Contacts were made weekly until 15 April and then every two days until conditions showed that it was time to start the project. Persons contacted included commercial shad fishermen at Claverack and Wappinger Falls, NY, and New York Department of Environmental Conservation (NYDEC) fishery biologists at New Paltz, NY.

The project commenced when water temperature and local conditions on the Hudson River showed that ripe shad were available for capture. In 1996, this occurred in the last week of April when the water temperature reached 53°F. The selection of days that were suitable for fishing (from project start-up to end) was the decision of the PFBC Project Officer, following consultation with The Wyatt Group field supervisor.

Ripe shad were captured by gill net and haul seine in areas of the river where it has been shown that they can be captured with consistency. Gill netting was not conducted from Friday at 6:00 PM to Saturday at 6:00 PM, in observance of a NYDEC designated lift day. Haul seining was conducted each day of the week when tidal conditions were suitable. A scientific collecting permit for this work was provided by the NYDEC.

The PFBC Project Officer decided when field work would begin and end and the daily level of effort expanded (one or two field crews). These determinations were based on availability of funds, water temperatures, success of the collection efforts to date, trends in numbers and viability of eggs collected, and other factors. Wyatt field biologists provided daily reports to PFBC to advise on success of egg collection efforts, estimated time of arrival of eggs, and prospects for egg collection efforts for the next nights fishing.

The Wyatt Group provided two collecting crews. Each was assigned to a boat equipped with gill nets and the gear required for artificial fertilization and packing of shad eggs. As warranted the two crews fished simultaneously. When eggs were collected in the haul seine operation, the contracted commercial fisherman, Mr. Everett Nack, provided two boats and six people. A Wyatt Group collecting crew helped in the operation but was mainly responsible for the processing of ripe shad.

**B. Collection Gear**

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

The Nack haul seine fishery was conducted in the first three weeks of May, when tidal conditions were appropriate. The haul seine was 500-feet long, 12-feet deep and had 2-inch meshes. Seine operations were conducted on an ebb tide between late afternoon and dusk. With this tidal condition, a landing site was available where the catch could be beached and the catch processed. When ripe shad were being caught a Wyatt Group crew was assigned to obtain eggs.

Gill-netting and haul seining alternated with the changing tidal conditions; the haul seine was used during periods of low water and gill-nets were used at all other times. The effectiveness of gill netting is influenced by water depth and nets are fished in depths of 4-8 feet.

**C. Collecting Locations**

The Wyatt Group gill netted and haul seined for ripe adult American shad between Kingston (River Mile 95) and the Troy Dam at Albany (RM 151) from 1988-1995. Ripe shad concentrated, and could be consistently captured in large numbers, between Barrytown (RM 99) and Castleton-on-Hudson (RM 137). They were captured regularly near Cheviot (RM 106) by gill-net and off Rogers Island (RM 114) by haul seine. Two new sites were added during the 1996 sampling program at Coxsackie (RM 123) and Athens (RM 117).

The sampling schedule was organized in an order of priority that reflected probability of success based on past experience. It was governed by water temperature, tidal conditions, time of day, and weather. Each variable has an influence on the success of capturing ripe shad.

**D. Processing of Ripe Shad and Eggs**

Ripe females were strip-spawned using the dry method and eggs were fertilized with sperm from several ripe males when possible. A small amount of water was added to activate the sperm. After several minutes, eggs were washed to remove excess sperm, scales and blood, and they were water hardened for at least one hour before packaging. Hardened eggs were packaged in double plastic bags (five liters of eggs with five liters of fresh water). At least two liters of pure oxygen was injected into each bag and it was secured with castrating rings. The bags were then be placed into appropriate sized coolers and labeled as to site, date, quantity and water temperature.

Eggs from each night of collection were brought to Catskill, NY for loading. When the volume of eggs was five liters or more, they were delivered by automobile to the PFBC Van Dyke hatchery located on SR 333, five miles west of Thompsontown, PA. The goal was to have the eggs arrive at the hatchery between 10:00 and 11:30 a.m. All shipments were to arrive before 3:00 p.m. the next day. The Wyatt field supervisor (or a designate) notified the hatchery regarding the number of liters of eggs shipped and their estimated arrival time.

## III. FACTORS AFFECTING EGG COLLECTION SUCCESS

### A. Water Temperature

Water temperature was important in deciding the time to commence and end efforts to collect ripe shad. Experience has shown that ripe shad are usually available at a water temperature of 51°F, and that large numbers of eggs can be collected when water temperature is 54-64°F. Some spawning activity may occur up to a temperature of 68° F. Collections start-up is planned for when water temperature reaches 52°F because a sudden warm spell can raise temperatures quickly.

### B. Tidal Conditions

All netting in the Hudson River is done in tidal areas. The impact of tidal conditions, although mostly affecting netting efficiency at certain sites, influences the availability of ripe shad. Shad tend to move toward shallow water on the rising tide to spawn. On the Hudson River, spawning is most predominant during the period when the tide changes from ebb to flood. At this time, shad are especially vulnerable to gill netting on the flats and along the shore where the water is 4-8 feet deep.

Tide tables were used to decide when gill netting would be most effective at selected sites. At Cheviot and Glasco, the depth at the shoreline prevents the setting of gill nets at ebb tide. Therefore, sampling must be coordinated with use of the tide chart to decide when sampling will be efficient. At Castleton-on-Hudson, the water depth is variable (4-10 feet) and gill-nets could be set at any tide.

### C. Time of Day

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

## IV. RESULTS AND DISCUSSION

The first crew began gill netting on 30 April and the second crew was added on 13 May. The second effort was initiated because ripe shad were consistently available as demonstrated by collection of more than 0.5 million eggs at Castleton during 8-12 May. Once the second boat began operations it was used consistently until egg collection efforts ceased. Egg collection ended on 3 June after three consecutive days of not obtaining eggs. Sampling occurred on 27 dates during this period and included 43 boat-days of gill-netting and two boat-days of haul seining.

A total of 6.06 million eggs was shipped to the Van Dyke hatchery (Table 2). All were collected through gill net efforts. Van Dyke kept 5.69 million eggs for culture and provided 362,000 eggs to Maryland DNR's Manning hatchery. Egg production on the Hudson River was 54% lower than in

1995 when 12.9 million eggs were collected. Egg viability averaged 68% and ranged from 5% to 92% in individual shipments. Egg viabilities were very low at water temperatures of 50-52°F, but averaged 75% once collecting water temperature reached 57°F and above. The 1996 egg viability results were comparable with those obtained in 1995 (71.4%) and earlier years.

Most Hudson River shad eggs taken in 1996 came from two sites - 2.47 million (43.3%) from Cheviot and 2.18 million (38.4%) from Coxsackie (Table 3). The Castleton site was not nearly as productive in 1996 (13.5% of total) as in 1995 (59.7%). The haul seine effort at Rodgers Island took many adult shad but resulted in no eggs. Negative results from haul seining are attributed to water temperature and tidal conditions in 1996. When the tidal conditions were appropriate, the water temperature was too low for spawning. By the time tidal conditions were appropriate, spawning had ceased. Few eggs have been obtained from the haul seine in the last several years, however, increased knowledge of the river has resulted in addition of more sites suitable for gill netting.

Egg collection in 1996 was highly influenced by weather conditions and water temperature. Rain produced turbid water conditions which may have affected spawning activity and distribution of shad. Collecting began on 8 May when water temperature was 50°F and remained at or below 52°F until 19 May. This is very unusual for the Hudson River as data from 1989 through 1994 indicates that water temperatures were at least 52°F by 1 May each year and quickly increased to 54°F, the temperature at which spawning activity is consistent. Thus, there were more than two weeks in the beginning of the 1996 effort when conditions for shad spawning was not optimal. Collecting conditions by site and date are given in Table 4.

## V. SUMMARY

A total of 6.06 million American shad eggs was collected from the Hudson River and delivered to the PFBC Van Dyke hatchery in 1996. The number of eggs was approximately 54% of that collected in 1995. This reduction is attributed in great part to weather and water temperature conditions. Suitable water temperature for spawning occurred two weeks later than in any year since Hudson River egg collections began (1989). Rain created turbid conditions that may have affected spawning activity or locations. Egg viability (68%) was within the goal established by the PFBC. The use of two boat crews provided the flexibility needed on the Hudson River for maximizing numbers of eggs collected.

TABLE 1. Total number (millions) of American shad eggs collected from the Delaware, Hudson, and Connecticut Rivers and delivered to theVan Dyke Hatchery, 1983-1996.

| Year | Delaware | Hudson | Connecticut | Totals |
|---|---|---|---|---|
| 1983 | 2.40 | 1.17 | - | 3.57 |
| 1984 | 2.64 | - | - | 2.64 |
| 1985 | 6.16 | - | - | 6.16 |
| 1986 | 5.86 | - | - | 5.86 |
| 1987 | 5.01 | - | - | 5.01 |
| 1988 | 2.91 | - | - | 2.91 |
| 1989 | 5.96 | 11.18 | - | 17.14 |
| 1990 | 13.15 | 14.53 | - | 27.68 |
| 1991 | 10.74 | 17.66 | 1.10 | 29.50 |
| 1992 | 9.60 | 3.00 | 5.71 | 18.31 |
| 1993 | 9.30 | 2.97 | 7.44 | 19.71 |
| 1994 | 10.27 | 6.29 | 4.10 | 20.66 |
| 1995 | 10.75 | 11.85 | - | 22.60 |
| 1996 | 8.31 | 5.69 | - | 14.00 |
| Totals | 103.06 | 74.34 | 18.35 | 195.75 |

TABLE 2. Collection data for American shad eggs taken on the Hudson River, New York, 1996.

| Date | Volume Eggs (liters) | Number of Eggs | PFC Shipment Number | Water Temperature ( F) | Percent Viability | Gear |
|---|---|---|---|---|---|---|
| 8-May | 2.5 | 69,734 | 1 | 50 | 5.0 | Gill |
| 9-May | 14.4 | 425,014 | 2 | 51 | 12.0 | Gill |
| 12-May | 1.0 | 33,660 | 3 | 51 | 16.2 | Gill |
| 13-May | 2.7 | 73,918 | 4 | 51 | 10.5 | Gill |
| 15-May | 6.4 | 186,789 | 5 | 52 | 39.2 | Gill |
| 16-May | 2.7 | 73,918 | 6 | 51 | 45.3 | Gill |
| 19-May | 2.1 | 59,923 | 7 | 57 | 70.1 | Gill |
| 20-May | 1.6 | 52,143 | 8 | 57 | 30.7 | Gill |
| 20-May | 3.8 | 108,432 | 9 | 57 | 55.3 | Gill |
| 21-May | 33.1 | 933,848 | 12 | 57 | 75.6 | Gill |
| 22-May | 28.7 | 945,481 | 14 | 56 | 80.0 | Gill |
| 23-May | 5.1 | 145,527 | 16 | 59 | 91.9 | Gill |
| 23-May | 12.4 | 361,903 | 17 | 59 | 77.3 | Gill |
| 25-May | 1.4 | 39,051 | 18 | 60 | 60.8 | Gill |
| 27-May | 9.8 | 273,357 | 20 | 61 | 83.1 | Gill |
| 28-May | 27.6 | 861,060 | 22 | 61 | 76.9 | Gill |
| 29-May | 34.8 | 1,050,285 | 24 | 62 | 75.1 | Gill |
| 30-May* | 12.0 | 362,167 | 26 | 61 | NA | Gill |
| Total | 202.1 | 6,056,210 | 18 | 56 | 68.0 | |
| Van Dyke | 190.1 | 5694043 | | | | |
| Manning | 12.0 | 362,167 | | | | |

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

TABLE 3. American shad egg totals by site on the Hudson River, New York, 1996.

| Site | Number of Shipments | Volume of Eggs (liters) | Number of Eggs Received | Number of Viable Eggs | Percent Viability |
|---|---|---|---|---|---|
| Kingston | 0 | 0.0 | 0 | 0 | 0.0 |
| Cheviot | 5 | 82.0 | 2,467,072 | 1,839,135 | 74.5 |
| Castleton | 6 | 26.5 | 770,681 | 169,651 | 22.0 |
| Rogers Island | 0 | 0.0 | 0 | 0 | 0.0 |
| Glasco | 3 | 9.4 | 271,589 | 183,229 | 67.5 |
| Coxsackie | 4 | 84.2 | 2,184,702 | 1,678,120 | 76.8 |
| Total | 18 | 202.1 | 5,694,044 | 3,870,135 | 68.0 |

TABLE 4 . Summary of American shad egg collections on the Hudson River, New York, 1996.

| | | Water | | Eggs Shipped | | | Shad Collected | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | Date | Temp (F) | Weather | Liters | Number | Viability(%) | Roe | Males | Ripe |
| Castleton | 30-Apr | 49 | Rain | - | - | - | 0 | 0 | 0 |
| Castleton | 1-May | 49 | Overcast | - | - | - | 1 | 0 | 0 |
| Castleton | 4-May | 50 | Fog | - | - | - | 2 | 0 | 0 |
| Castleton | 5-May | 50 | Overcast | - | - | - | 9 | 0 | 0 |
| Castleton | 7-May | 50 | Windy | - | - | - | 12 | 0 | 0 |
| Castleton | 8-May | 50 | Clear | 2.5 | 69,734 | 5.0 | 78 | 11 | 3 |
| Castleton | 9-May | 51 | Clear | 14.4 | 425,014 | 12.0 | 71 | 28 | 23 |
| Castleton | 12-May | 51 | Overcast | 1.0 | 33,660 | 16.2 | 18 | 5 | 3 |
| Castleton | 13-May | 50 | Overcast | 2.7 | 73,918 | 10.5 | 7 | 5 | 1 |
| Castleton | 15-May | 50 | Clear | - | - | - | 7 | 13 | 0 |
| Castleton | 18-May | 53 | Severe Storms | - | - | - | 7 | 3 | 0 |
| Castleton | 19-May | 57 | Clear | 2.1 | 59,923 | 70.1 | 28 | 5 | 4 |
| Castleton | 20-May | 57 | Clear | 3.8 | 108,432 | 55.3 | 31 | 13 | 7 |
| Castleton | 21-May | 57 | Clear | - | - | - | 21 | 8 | 0 |
| Castleton | 26-May | 60 | Clear | - | - | - | 3 | 2 | 2 |
| Castleton | 30-May | 61 | Clear | - | - | - | 24 | 8 | 9 |
| Cheviot | 4-May | 50 | Clear | - | - | - | 6 | 5 | 0 |
| Cheviot | 13-May | 51 | Clear | - | - | - | 8 | 24 | 2 |
| Cheviot | 14-May | 52 | Clear | - | - | - | 25 | 15 | 0 |
| Cheviot | 15-May | 52 | Clear | 6.4 | 186,789 | 39.2 | 27 | 22 | 9 |
| Cheviot | 19-May | 54 | Clear | - | - | - | 9 | 24 | 0 |
| Cheviot | 21-May | 57 | Clear | 33.1 | 933,848 | 75.6 | 55 | 29 | 27 |
| Cheviot | 22-May | 56 | Clear | 28.7 | 945,481 | 80.0 | 79 | 25 | 24 |
| Cheviot | 22-May | 56 | Clear | - | - | - | 38 | 14 | 20 |
| Cheviot | 23-May | 59 | Clear | 12.4 | 361,903 | 77.3 | 31 | 12 | 18 |
| Cheviot | 25-May | 60 | Clear | 1.4 | 39,051 | 60.8 | 18 | 14 | 3 |

TABLE 4. (Continued) Summary of American shad egg collections on the Hudson River, New York, 1996.

| Site | Date | Water Temp (F) | Weather | Eggs Shipped Liters | Eggs Shipped Number | Eggs Shipped Viability(%) | Shad Collected Roe | Shad Collected Males | Shad Collected Ripe |
|---|---|---|---|---|---|---|---|---|---|
| Cheviot | 26-May | 60 | Clear | - | - | - | 17 | 5 | 3 |
| Cheviot | 28-May | 61 | Clear | - | - | - | 15 | 8 | 0 |
| Cheviot | 3-Jun | 62 | Rain | - | - | - | 5 | 1 | 1 |
| Coxsackie | 26-May | 60 | Clear | - | - | - | 27 | 0 | 7 |
| Coxsackie | 27-May | 61 | Clear | 9.8 | 273,357 | 83.1 | 61 | 26 | 20 |
| Coxsackie | 28-May | 61 | Clear | 27.6 | 861,060 | 76.9 | 108 | 47 | 46 |
| Coxsackie | 29-May | 62 | Clear | 34.8 | 1,050,285 | 75.1 | 68 | 35 | 27 |
| Coxsackie | 29-May | 62 | Clear | - | - | - | 54 | 29 | 25 |
| Coxsackie | 30-May | 61 | Clear | 12.0 | 362,167 | | 46 | 10 | 19 |
| Coxsackie | 1-Jun | 60 | Clear | - | - | - | 24 | 3 | 3 |
| Coxsackie | 2-Jun | 62 | Rain | - | - | - | 16 | 5 | 3 |
| Coxsackie | 2-Jun | 62 | Rain | - | - | - | 6 | 0 | 4 |
| Coxsackie | 3-Jun | 63 | Rain | - | - | - | 14 | 5 | 3 |
| Glasco | 16-May | 51 | Clear | 2.7 | 73,918 | 45.3 | 10 | 6 | 0 |
| Glasco | 16-May | 51 | Clear | - | - | - | 27 | 38 | 2 |
| Glasco | 18-May | 53 | Severe Storms | - | - | - | 12 | 7 | |
| Glasco | 20-May | 57 | Clear | 1.6 | 52,143 | 30.7 | 4 | 5 | 2 |
| Glasco | 23-May | 59 | Clear | 5.1 | 145,527 | 91.9 | 23 | 10 | 10 |
| Rogers Island | 14-May | 51 | Clear | - | - | - | 285 | 183 | 0 |
| Rogers Island | 27-May | 61 | Clear | - | - | - | 90 | 50 | 0 |
| Athens | 1-Jun | 62 | Clear | - | - | - | 6 | 2 | 2 |
| Totals | | 56 | | 202.1 | 6,056,210 | 64.6 | 1,533 | 760 | 332 |

## JOB II - Part 2
## COLLECTION OF AMERICAN SHAD EGGS FROM THE DELAWARE RIVER, 1996

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**Introduction**

The goal of this activity in 1996, as in past years, was to collect and ship up to 15 million eggs taken from American shad captured in gill nets set in Delaware River spawning waters in the vicinity of Smithfield Beach within the Delaware Water Gap National Recreation Area near Bushkill, PA. Immediately after netting ripe shad, eggs were stripped and fertilized and allowed to harden in river water. Water-hardened eggs were then to be sealed in plastic bags containing river water and pure oxygen, and driven 150 miles to the Pennsylvania Fish and Boat Commission (PFBC) Van Dyke hatchery near Thompsontown, PA.

**Methods**

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

Both male and female shad were placed into water filled tubs and returned to shore. Eggs were stripped from ripe female shad and fertilized in dry pans with sperm from ripe males. Once gametes were mixed a small amount of fresh water was added and they were allowed to stand for five minutes, followed by several washings. Cleaned fertilized eggs were then placed into newly designed floating boxes with fine mesh sides which promote a continuous flushing with fresh river water. Eggs were water hardened for about one hour. The combination of allowing eggs to stand prior to washing and use of the new water hardening boxes appeared to improve egg viability compared with prior years.

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

Most adult shad did not survive the rigors of netting and artificial spawning and it was necessary to properly dispose of the carcasses. They could not be sold for profit or placed back into the river, but, in past years, some fish were provided to non-profit groups as raptor food. The National Park Service provided a disposal pit on park property and shad carcasses were delivered there each night and covered with hydrated lime. Prior to disposal, representative samples of each night's catch (both sexes) were measured and weighed and scale and otolith samples were removed for analysis.

**Results and Discussion**

All Delaware River shad egg collections in 1996 are shown in Table 1. The notably cool weather in the spring delayed gill netting for shad until 20 May when the river temperature reached 17°C. This was the latest starting date for egg collection on the Delaware River since collections began over 20 years ago. The shad catch during the first week ranged from 35 to 59 fish each night resulting in shipments of 7.2 to 11.5 liters of eggs (0.32 to 0.40 million). Although egg viability from the first nights catch was only 54.5% it increased to over 70% for each of the last three nights as water temperature warmed to 18-19°C.

Netting resumed on 27 May following the Memorial Day weekend and weather remained cool throughout the second week. With water temperature reduced by about 3°C, the shad catch was almost double that of the first week averaging 87 fish per night. Up to 20 gill nets were fished each night and egg shipments ranged from 20.6 to 33.6 liters (0.68 to 1.0 million) with viabilities ranging from 71% to 81%. The entire shipment of about one million eggs from 30 May was transferred to Maryland DNR's Joseph Manning Hatchery.

The third week of netting began on 2 June and river temperature increased back to 19°C. Catch was not hampered however as 168 shad were taken that first night and provided almost 2 million eggs. Weather cooled the next day and for the remainder of the week the average nightly catch decreased to 58 shad producing 10 to 22 liters of eggs (0.45-0.79 million). Egg viability during the third week was down considerably from prior shipments, ranging from 18 to 66%.

Following a warm weekend, river temperature increased to 23°C and only 22 shad were netted with 6 liters of eggs (0.34 million) shipped on 10 June. None of these eggs were viable and netting was terminated for the season.

**Summary**

Shad eggs were collected on 13 nights between 20 May and 10 June, 1996. Two scheduled fishing nights were cancelled due to thunderstorms. A total of 885 adult shad were captured and 253.5 liters were shipped for a hatchery count of 9.3 million eggs with an average viability of 62%. This effort was an improvement over 1995 when the Delaware River produced 12.1 million shad eggs on 13 nights during 14-31 May, but with only 45% viability.

# TABLE 1

## Delaware River Shad Egg Collection Data
## 20 May - 10 Jun 1996

| Date | Water Temp (C) | No. of Nets Set | No. of Shad Captured | Eggs Shipped (liters) | | Eggs (million) | Percent Viability |
|---|---|---|---|---|---|---|---|
| | | | | Field Count | Van Dyke Count | | |
| 20 May | 17 | 12 | 35 | 7 | 7.8 | 0.346 | 54.5 |
| 21 May | 19 | 14 | 59 | 14 | 9.2 | 0.344 | 73.6 |
| 22 May | 18 | 17 | 45 | 10 | 7.2 | 0.323 | 71.5 |
| 23 May | 18 | 16 | 35 | 15 | 11.5 | 0.404 | 76.7 |
| 24 May | | | | | | | |
| 25 May | | | | | | | |
| 26 May | | | | | | | |
| 27 May | 16 | 17 | 86 | 40 | 31.0 | 0.946 | 80.9 |
| 28 May | 15 | 20 | 105 | 40 | 31.8 | 1.014 | 71.3 |
| 29 May | 15 | 20 | 67 | 21 | 20.6 | 0.679 | 81.1 |
| 30 May | 15 | 20 | 89 | 41 | 33.6 | 1.000* | Incubated at Manning |
| 31 May | | | | | | | |
| 01 Jun | | | | | | | |
| 02 Jun | 19 | 20 | 168 | 54 | 49.6 | 1.992 | 55.2 |
| 03 Jun | 18 | 20 | 46 | 12 | 10.0 | 0.448 | 17.6 |
| 04 Jun | 17 | Did not fish - severe thunderstorms | | | | | |
| 05 Jun | 19 | 20 | 63 | 24 | 22.4 | 0.787 | 66.1 |
| 06 Jun | 19 | 20 | 65 | 21 | 16.6 | 0.687 | 62.5 |
| 07 Jun | | | | | | | |
| 08 Jun | | | | | | | |
| 09 Jun | 23 | Did not fish - thunderstorms | | | | | |
| 10 Jun | 23 | 20 | 22 | 6 | 2.2 | 0.339 | 0.0 |
| TOTAL | | 236 | 885 | 305 | 253.5 | 9.309 | 62.0** |

*Estimated for Manning Hatchery shipment.
**Mean percent viability.

## JOB III. AMERICAN SHAD HATCHERY OPERATIONS, 1996
PART 1

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### INTRODUCTION

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

Production goals for 1996 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.

Most eggs received at Van Dyke were disinfected to prevent the spread of infectious diseases from out-of-basin sources. Some eggs were maintained as un-disinfected controls or disinfected at varying concentrations and durations to determine the effect of egg disinfection on egg survival (Appendix 1). Research conducted in 1996 focused on development of techniques to mark American shad otoliths by five hour immersion of eggs in 2,000, 3,000, or 4,000 mg/L oxytetracycline (Appendix 2).

## EGG SHIPMENTS

A total of 14.4 million eggs (460 L) were received in 33 shipments in 1996 (Table 1). This represented the smallest number of eggs received since 1981, and was well below the average of 32.7 million from 1982 to 1995 (Table 2). The poor egg collections in 1996 are thought to be due to decreased shad abundance on the Hudson River and an extremely late Spring characterized by high water and low temperatures. Overall egg viability (which we define as the percentage which ultimately hatches) was 62.7%.

Thirteen shipments of eggs were received at Van Dyke from the Delaware River (8.3 million eggs) with a viability of 62.0%. Four different sites were fished on the Hudson River, producing a total of 18 shipments (5.7 million eggs) with an overall viability of 68.0%. Low viability at the Castleton site is related to low water temperatures at the time of collection and will be discussed in Appendix 1. Two shipments of eggs were delivered to MDNR's Manning Hatchery for culture there.

## SURVIVAL

Overall survival of fry was 93.8%, compared to 91.2% in 1995, 78% in 1994, 66% in 1993, 41% in 1992 and a range of 70% to 90% for the period 1984 through 1991. The high survival was due to two factors: (1) 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; and, (2) mortality due to fry laying on top of each other and smothering each other was minimal.

Survival of individual tanks followed three patterns (Figure 1). Twenty-nine tanks exhibited 7d survival averaging 95.5%. Ten tanks, reared to 13 or more days of age, exhibited survival of 94.1%, typical of high survival tanks in the past. Only one tank (H11) suffered high mortality due to smothering of fry when they lay on the bottom of the tank the day after hatch. This has been an ongoing problem (Hendricks, 1996). All the mortality problems noted in 1995 were also associated with fry laying on the bottom of the tank, beginning the morning after hatch. In the past, this was thought to be related to decreases in water temperature or force-hatching the larvae too early, when the yolk-sac is too large. This year, we attempted to feed the larvae earlier, beginning at 3 days of age. Fry laying on the bottom were fed immediately, regardless of age and forced off the bottom using water jets, a squeegee, or by positioning pieces of black rubber on the bottom in the areas where the fry tended to lay. These strategies were all successful to some extent. Once forced off the bottom, the fry tended to remain swimming in the water column. The presence of food appeared to help in keeping the fry swimming. In addition, we continued to plumb tanks with temporary "double down" influent pipes which direct a flow of water into the center "well" to prevent larvae from laying there and smothering each other. This procedure is absolutely essential to preventing severe mortalities.

## FRY PRODUCTION

Production and stocking of American shad fry, summarized in Tables 2, 3 and 4, totaled 8.5 million. A total of 4.8 million was released in the Juniata River and 943 thousand in the Susquehanna River at Montgomery Ferry. American shad fry were also stocked in other main stem areas and in tributaries: 172 thousand in Conodoguinet Creek, 277 thousand in the Conestoga River, 43 thousand in Standing Stone Creek, 561 thousand in the West Branch Susquehanna River, and 682 thousand in the North Branch Susquehanna River. In addition, 993 thousand fry were stocked in the Lehigh River to support restoration efforts there.

Some eight thousand were transferred to raceways at Benner Spring for mark retention analysis. Five thousand were given to St. Dominick's School for experimental classroom culture as part of a Chesapeake Bay Foundation public education initiative. Five hundred were transferred to the City University of New York 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 256 ppm oxytetracycline hydrochloride for 4h duration. All fry were marked according to stocking site. Fry stocked in the Juniata River or the Susquehanna River at Montgomery Ferry were marked at 3 days of age and stocked at 6-8 days of age. Fry stocked in the Conodoguinet Creek were given a triple mark at 9, 12, and 15 days of age and stocked at 16 days of age. Fry stocked in the Conestoga River were given a quadruple mark at 3, 9, 12, and 15 days of age and stocked at 17 days of age. Fry stocked in Standing Stone Creek and the Lehigh River were given a triple mark at 3, 6, and 9 days of age and stocked at 21 and 13 days of age, respectively. Fry stocked in the North Branch Susquehanna River were given a quadruple mark at 3, 6, 9, and 12 days of age and stocked at 13 days of age. Fry stocked in the West Branch Susquehanna River were given a triple mark at 3, 9, and 12 days of age and stocked at 17 days of age. Small lots of eggs were experimentally marked by 5 hour immersion in 2000, 3000 or 4000 mg/L oxytetracycline immediately after arrival at Van Dyke (Appendix 2). They received additional marks by 4h immersion in 256 mg/L at 3 days of age.

Verification of mark retention was accomplished by stocking groups of marked fry in tanks or raceways and examining otolith samples collected later. Retention of tetracycline marks for American shad was 100% for all groups analyzed except some egg marked groups (Table 6, Appendix 2).

While no problems in the tetracycline marks were noted in the mark retention samples, analysis of otoliths of juvenile American shad collected in the wild revealed a number of confusing marks. Three problems were identified. 1.) Single, day three marks

(Juniata River release) appeared dull and diffuse and two to three increments wide, sometimes appearing to be two or three separate but consecutive marks (24 specimens, representing 14% of the single marked specimens). 2.) Triple, day 3, 6, and 9 (Lehigh River release) marks appeared to have a diffuse day 3 mark and bright day 6 and 9 marks with no space between them (5 specimens, representing 2% of the Lehigh River specimens). 3.) Double marks (release below Conowingo Dam) appeared to have a normal day 3 mark and a bright double mark where the day 6 mark should be or a blur of fluorescence increasing in intensity from day 3 to day 6 where a definitive mark stood out from the diffuse glow (total 12 specimens, representing 57% of the double marked specimens). Thus, numbers 2 and 3 above can appear to be almost identical. Fortunately, most of the triple (3,6,9) marked fish were released in the Lehigh River with only a small number released in the Susquehanna River (Standing Stone Creek). As a result, we were able to identify the origin of all but three specimens collected above Conowingo Dam and all the specimens collected below Conowingo Dam.

We have noted these types of problematic marks in the past but never with the frequency encountered in 1996. This probably relates to changes in the marking regime as recommended by the Tetracycline Marking Task Force of the Chesapeake Bay Program's Fish Passage Workgroup. This group recommended decreasing the spacing between marks by one day from three unmarked days between marks to two. This was done to provide more unique mark combinations for the many jurisdictions desiring unique marks while permitting early release of larvae.

The cause of these anomalous marks is unknown. The lack of spacing between day 6 and 9 marks on Lehigh River fish may be due to poor otolith growth for a short time during the rearing period, exacerbated by the decision to shorten the interval between marks. This does not explain why day 6 marks produced at Manning appear to be two bright adjacent marks, or why day 3 marks produced at Van Dyke appear to be two or three dull marks.

These anomalies were not detected in mark retention groups because mark retention specimens were selected from one tank of larvae representing each unique mark. Other tanks receiving that mark were not analyzed for mark retention. Thus, of the forty tanks of larvae reared at Van Dyke, only six tanks were sampled for mark retention. Whatever caused the anomalous marks may have occurred in only a few tanks, none of which happened to be sampled for mark retention analysis.

These problems suggest cause for concern when adults begin returning three years from now. We are quite confident we would not be able to distinguish between numbers 2 and 3 above. Number 1 above will likely cause confusion as well. In light of the fact that 7 day old larvae stocked in the Juniata River are not surviving as well as older larvae stocked at distant sites (see Appendix 3), returning to 3 unmarked days between marks may be advisable.

## SUMMARY

A total of 33 shipments (14.4 million eggs) was received at

Van Dyke in 1996. Total egg viability was 62.7% and survival to stocking was 93.8%, resulting in production of 8.5 million fry. The majority of the fry were stocked in the Juniata River (4.8 million). Fry were also released in the Susquehanna River at Montgomery Ferry (943 thousand), Standing Stone Creek (43 thousand), Conodoguinet Cr. (172 thousand), Conestoga River (277 thousand), The West Branch Susquehanna River (561 thousand), the North Branch Susquehanna River (683 thousand), and the Lehigh River (993 thousand).

Overall survival of fry was 93.8. The high survival was largely due to stocking at an earlier age (7 days) and preventing smothering of fry when they lay on the bottom in the first few days after hatch.

All American shad fry cultured at Van Dyke were marked by 4 hour immersion in 256 ppm oxytetracycline. Marks were assigned based on release site, regardless of egg source. Retention of tetracycline marks was 100% for all production marks, however, we experienced problems in determining the origin of multiple marked fish collected in the wild. Single marks often appeared as closely spaced double marks and double marks sometimes to have no unmarked space between them.

Marking of embryos by five hour immersion in 2,000, 3,000 and 4,000 ppm oxytetracycline was successful, but further research is needed to determine the extent of egg mortality or deformities, if any, caused by the marking and at what age multiple marks can be applied and be distinguishable from the egg mark.

## RECOMMENDATIONS FOR 1996

1. Disinfect all egg shipments at 50 ppm free iodine.
2. Slow temper eggs collected at river temperatures below 55F.
3. Routinely feed all fry beginning at 2 days of age.
4. Continue to utilize Maryland's Manning Hatchery for production of marked fry and fingerlings for release below Conowingo Dam.
5. Continue to hold egg jars on the incubation battery until eggs begin hatching, before sunning and transferring to the tanks.
6. Continue to siphon egg shells from the rearing tank within hours of egg hatch.
7. Continue to utilize left over AP-100 only if freshly manufactured supplies run out.
8. Construct new foam bottom screens for Van Dyke jars each year.
9. Do not disinfect foam bottom screens prior to use.
10. Continue to hold Delaware River eggs until 8:00AM before processing.
11. Design and conduct a study to determine if repeated stocking at a site results in decreased survival.
12. Return to three unmarked days between marks for multiple marks.

## LITERATURE CITED

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

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

Hendricks, M. L. and T. R. Bender, Jr. 1995. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L. 1996. Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Figure 1. Survival of American shad fry, Van Dyke, 1996.

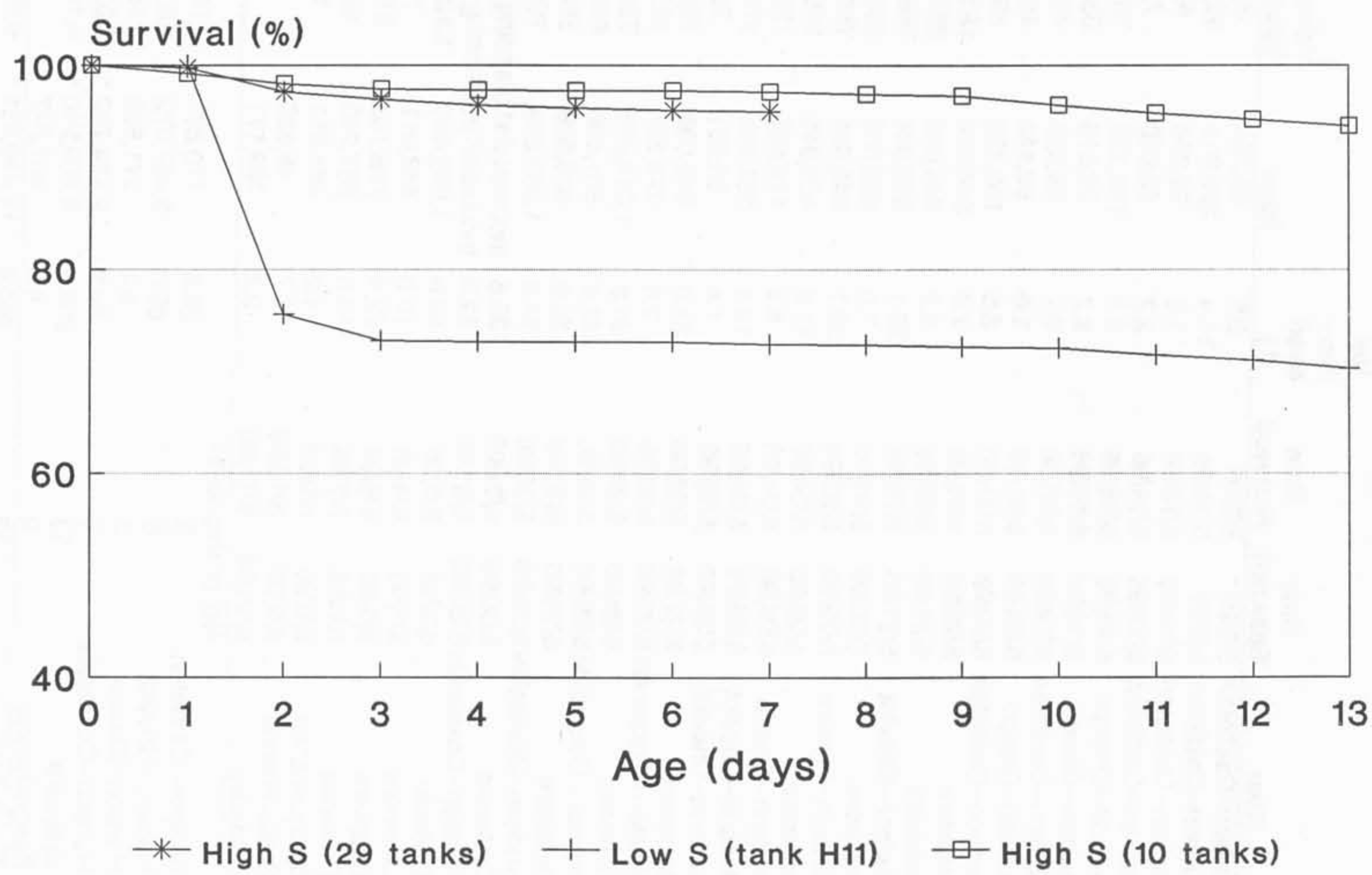

Table 1. American shad egg shipments recieved at Van Dyke, 1996.

| Ship-ment No. | River | Date Spawned | Date Recieved | Vol. Rec-eived (L) | Eggs | Viable Eggs | Percent Viable |
|---|---|---|---|---|---|---|---|
| 1 | Hudson–Castleton | 5/8/96 | 5/9/96 | 2.5 | 69,734 | 3,500 | 5.0% |
| 2 | Hudson–Castleton | 5/9/96 | 5/10/96 | 14.4 | 425,014 | 50,962 | 12.0% |
| 3 | Hudson–Castleton | 5/12/96 | 5/13/96 | 1.0 | 33,660 | 5,455 | 16.2% |
| 4 | Hudson–Castleton | 5/13/96 | 5/14/96 | 2.7 | 73,918 | 7,737 | 10.5% |
| 5 | Hudson–Cheviot | 5/15/96 | 5/16/96 | 6.4 | 186,789 | 73,217 | 39.2% |
| 6 | Hudson–Glasco | 5/16/96 | 5/17/96 | 2.7 | 73,918 | 33,458 | 45.3% |
| 7 | Hudson–Castleton | 5/19/96 | 5/20/96 | 2.1 | 59,923 | 42,005 | 70.1% |
| 8 | Hudson–Glasco | 5/20/96 | 5/21/96 | 1.6 | 52,143 | 16,020 | 30.7% |
| 9 | Hudson–Castleton | 5/20/96 | 5/21/96 | 3.8 | 108,432 | 59,993 | 55.3% |
| 10 | Delaware | 5/20/96 | 5/21/96 | 7.8 | 346,056 | 188,535 | 54.5% |
| 11 | Delaware | 5/21/96 | 5/22/96 | 9.2 | 344,048 | 253,259 | 73.6% |
| 12 | Hudson–Cheviot | 5/21/96 | 5/22/96 | 33.1 | 933,848 | 706,214 | 75.6% |
| 13 | Delaware | 5/22/96 | 5/23/96 | 7.2 | 322,568 | 230,506 | 71.5% |
| 14 | Hudson–Cheviot | 5/22/96 | 5/23/96 | 28.7 | 945,481 | 756,388 | 80.0% |
| 15 | Delaware | 5/23/96 | 5/24/96 | 11.5 | 403,915 | 309,800 | 76.7% |
| 16 | Hudson–Glasco | 5/23/96 | 5/24/96 | 5.1 | 145,527 | 133,751 | 91.9% |
| 17 | Hudson–Cheviot | 5/23/96 | 5/24/96 | 12.4 | 361,903 | 279,575 | 77.3% |
| 18 | Hudson–Cheviot | 5/25/96 | 5/26/96 | 1.4 | 39,051 | 23,741 | 60.8% |
| 19 | Delaware | 5/27/96 | 5/28/96 | 31.0 | 946,033 | 765,150 | 80.9% |
| 20 | Hudson–Coxsackie | 5/27/96 | 5/28/96 | 9.8 | 273,357 | 227,072 | 83.1% |
| 21 | Delaware | 5/28/96 | 5/29/96 | 31.8 | 1,014,056 | 723,197 | 71.3% |
| 22 | Hudson–Coxsackie | 5/28/96 | 5/29/96 | 27.6 | 861,060 | 662,375 | 76.9% |
| 23 | Delaware | 5/29/96 | 5/30/96 | 20.6 | 678,638 | 550,330 | 81.1% |
| 24 | Hudson–Coxsackie | 5/29/96 | 5/30/96 | 34.8 | 1,050,285 | 788,673 | 75.1% |
| 25 | Delaware | 5/30/96 | 5/31/96 | 33.6 | Incubated at Manning | | |
| 26 | Hudson–Coxsackie | 5/30/96 | 5/31/96 | 12.0 | Incubated at Manning | | |
| 27 | Delaware | 6/2/96 | 6/3/96 | 49.6 | 1,992,451 | 1,100,038 | 55.2% |
| 28 | Delaware | 6/3/96 | 6/4/96 | 10.0 | 448,011 | 79,037 | 17.6% |
| 29 | Delaware | 6/5/96 | 6/6/96 | 22.4 | 786,755 | 519,670 | 66.1% |
| 30 | Delaware | 6/6/96 | 6/7/96 | 16.6 | 687,240 | 429,450 | 62.5% |
| 31 | Susquehanna | 6/9/96 | 6/9/96 | 4.2 | 361,811 | 18,689 | 5.2% |
| 32 | Susquehanna | 6/9/96 | 6/10/96 | 0.7 | 45,836 | 0 | 0.0% |
| 33 | Delaware | 6/10/96 | 6/11/96 | 2.2 | 339,171 | 0 | 0.0% |
| Totals | | No. of shipments | | | | | |
| | Hudson–Castleton | 6 | | 26.5 | 770,681 | 169,651 | 22.0% |
| | Hudson–Cheviot | 5 | | 82.0 | 2,467,072 | 1,839,135 | 74.5% |
| | Hudson–Glasco | 3 | | 9.4 | 271,588 | 183,229 | 67.5% |
| | Hudson–Coxsackie | 4 | | 84.2 | 2,184,702 * | 1,678,120 * | 76.8% * |
| | Delaware | 13 | | 253.5 | 8,308,940 * | 5,148,970 * | 62.0% * |
| | Susquehanna | 2 | | 4.9 | 407,647 | 18,689 | 4.6% |
| | Grand Total | 33 | | 460.4 | 14,410,631 * | 9,037,794 * | 62.7% * |

*Does not include eggs incubated at Manning.

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

| 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 |
| 1996 | 460 | 14.4 | 62.7 | 9.0 | 8,466 * | – | 8,466 | 0.588 | 0.941 |

*Includes fry reared at Manning.

| | |
|---|---|
| Total | 162,963 |
| Total since 1985 (OTC marked) | 131,566 |

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

| Date | Tank | Number | Mark (days) | Location | Origin | Age | Size |
|---|---|---|---|---|---|---|---|
| 5/22/96 | A11 | 5,000 | 3 | St. Dominick's School | Hudson | 4 | Fry |
| 5/24/96 | A11 | 39,700 | 3 | Millerstown | Hudson | 6 | Fry |
| 5/28/96 | A21 | 1,000 | 3 | Millerstown | Hudson | 7 | Fry |
| 5/30/96 | A31 | 105,400 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/4/96 | A41 | 112,200 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/5/96 | B41 | 328,000 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/6/96 | C11 | 229,900 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/6/96 | C21 | 368,400 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/6/96 | C31 | 352,000 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/7/96 | D11 | 50,000 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/7/96 | D21 | 271,600 | 3 | Millerstown | Hudson | 6 | Fry |
| 6/10/96 | D31 | 186,500 | 3 | Millerstown | Delaware | 6 | Fry |
| 6/10/96 | D41 | 155,200 | 3 | Millerstown | Delaware | 6 | Fry |
| 6/10/96 | E11 | 186,300 | 3 | Millerstown | Delaware | 6 | Fry |
| 6/11/96 | E21 | 183,600 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/11/96 | E31 | 226,100 | 3 | Millerstown | Hudson | 7 | Fry |
| 6/12/96 | E41 | 240,100 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/12/96 | F11 | 239,600 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/12/96 | F21 | 236,800 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/13/96 | F31 | 219,200 | 3 | Millerstown | Hudson | 8 | Fry |
| 6/13/96 | F41 | 220,200 | 3 | Millerstown | Hudson | 8 | Fry |
| 6/13/96 | G11 | 217,100 | 3 | Millerstown | Hudson | 8 | Fry |
| 6/14/96 | B11 | 171,700 | 9,12,15 | Condoguinet Cr. | Delaware | 16 | Fry |
| 6/14/96 | B11 | 2,000 | 9,12,15 | Benner Spring Raceway F1 | Delaware | 16 | Fry |
| 6/14/96 | G21 | 275,500 | 3 | Millerstown | Delaware | 8 | Fry |
| 6/14/96 | G31 | 265,300 | 3 | Millerstown | Delaware | 8 | Fry |
| 6/15/96 | B21 | 240,000 | 3,9,12 | West Br. Susq. R. | Delaware | 17 | Fry |
| 6/15/96 | B31 | 321,100 | 3,9,12 | West Br. Susq. R. | Hudson | 17 | Fry |
| 6/15/96 | B31 | 2,000 | 3,9,12 | Benner Spring Raceway F2 | Hudson | 17 | Fry |
| 6/17/96 | C41 | 277,100 | 3,9,12,15 | Conestoga R. | Delaware | 17 | Fry |
| 6/17/96 | C41 | 2,000 | 3,9,12,15 | Benner Spring Raceway F3 | Delaware | 17 | Fry |
| 6/18/96 | I31 | 77,200 | 3 | Millerstown | Delaware | 7 | Fry |
| 6/19/96 | G41 | 248,700 | 3,6,9,12 | North Br. Susq. R. | Hudson | 13 | Fry |
| 6/19/96 | H11 | 185,600 | 3,6,9,12 | North Br. Susq. R. | Hudson | 13 | Fry |
| 6/19/96 | H21 | 248,200 | 3,6,9,12 | North Br. Susq. R. | Hudson | 13 | Fry |
| 6/19/96 | H21 | 2,000 | 3,6,9,12 | Benner Spring Raceway F4 | Hudson | 13 | Fry |
| 6/20/96 | I41 | 266,500 | 3 | Montgomery Ferry | Delaware | 7 | Fry |
| 6/20/96 | A12 | 234,100 | 3 | Montgomery Ferry | Delaware | 7 | Fry |
| 6/20/96 | A22 | 215,100 | 3 | Montgomery Ferry | Delaware | 6 | Fry |
| 6/20/96 | A32 | 500 | 3 | City Univ. of NY | Delaware | 6 | Fry |
| 6/21/96 | A32 | 212,700 | 3 | Montgomery Ferry | Delaware | 7 | Fry |
| 6/24/96 | H31 | 263,500 | 3,6,9 | Lehigh River | Delaware | 13 | Fry |
| 6/24/96 | H31 | 2,000 | 3,6,9 | Benner Spring Raceway E1 | Delaware | 13 | Fry |
| 6/24/96 | H41 | 257,200 | 3,6,9 | Lehigh River | Delaware | 13 | Fry |
| 6/24/96 | I11 | 272,300 | 3,6,9 | Lehigh River | Delaware | 13 | Fry |
| 6/24/96 | I21 | 200,000 | 3,6,9 | Lehigh River | Delaware | 13 | Fry |
| 6/24/96 | A42 | 14,900 | 3 | Montgomery Ferry | Susquehanna | 8 | Fry |
| 7/2/96 | I21 | 42,900 | 3,6,9 | Standing Stone Cr. | Delaware | 13 | Fry |

Table 4. Production and utilization of juvenile American shad, Van Dyke, 1996.

| | Site | Fry |
|---|---|---|
| Releases | Juniata R.– Millerstown | 4,786,900 |
| | Susquehanna R.– Montgomery Ferry | 943,300 |
| | Conodoguinet Cr. | 171,700 |
| | Conestoga River | 277,100 |
| | West Br. Susquehanna River | 561,100 |
| | North Br. Susquehanna River | 682,500 |
| | Standing Stone Cr. | 42,900 |
| | Sub–Total | 7,465,500 |
| | Lehigh River | 993,000 |
| Transfers | Benner Spring Raceways | 8,000 |
| | St. Dominick's School | 5,000 |
| | City Univ. of NY | 500 |
| | Sub–Total | 13,500 |
| | Total Production | 8,472,000 |
| | Viable eggs | 9,037,800 |
| | Survival of fry (%) | **93.7%** |

Table 5. Tetracycline marking regime for Alosids stocked in the Chesapeake Bay watershed, 1996.

| Hatchery | Size | Egg Source | Stocking Location | Immersion Mark (days) | Feed mark | No. Stocked |
|---|---|---|---|---|---|---|
| **American Shad:** | | | | | | |
| King & Queen | Fry | York R. | James R. | Single (6) | – | 4,507,000 |
| King & Queen | Fry | York R. | York R. | Double (3,6) | – | 1,999,000 |
| Harrsion Lake | Fry | York R. | James R. | Single (6) | – | 1,267,000 |
| Harrsion Lake | Fry | Potomac R. | Potomac R. | Double (3,9) | – | 1,990,000 |
| Van Dyke | Fry | Delaware | Conodoguinet Cr. | Triple (9,12,15) | – | 171,700 |
| Van Dyke | Fry | Delaware | Conestoga R. | Quadruple (3,9,12,15) | – | 277,100 |
| Van Dyke | Fry | Delaware | Standing Stone Cr. | Triple (3,6,9) | – | 42,900 |
| Van Dyke | Fry | Hudson/ Delaware | Juniata R. (Millerstown) | Single (3) | – | 4,786,900 |
| Van Dyke | Fry | Delaware | Susquehanna R. (Montgomery Ferry) | Single (3) | – | 943,300 |
| Van Dyke | Fry | Hudson/ Delaware | West Br. Susquehanna R. | Triple (3,9,12) | – | 561,100 |
| Van Dyke | Fry | Hudson | North Br. Susquehanna R. | Quadruple (3,6,9,12) | – | 682,500 |
| Manning | Fry | Hudson/ Delaware | Below Conowingo | Double (3,6) | – | 800,000 |
| Manning | Fry | Susq. | Below Conowingo | Double (3,6) | – | 200,000 |
| Manning | Fry | Susq. | Patuxent R. | Double (9,12) | – | 800,000 |
| Manning | Fing. | Susq. | Patuxent R. | – | Single* | 100,000 |
| Manning | Fry | Susq. | Choptank R. | Double (6,12) | – | 625,000 |
| Manning | Fing. | Susq. | Choptank R. | – | Single* | 100,000 |
| **Hickory Shad:** | | | | | | |
| Manning | Fry | Susq. | Patuxent R. | Single (3) | – | 745,000 |
| Manning | Fing. | Susq. | Patuxent R. | – | – | 25,000 |
| Manning | Fry | Susq. | Choptank R. | Single (3) | – | 125,000 |
| Manning | Fing. | Susq. | Choptank R. | – | – | 25,000 |

*Also coded wire tagged

Table 6. Tetracycline mark retention for American shad reared in 1996

| Tank/ Raceway | Mark (days) | Mark (days) | Exhibiting Mark | Number Stocked | Disposition |
|---|---|---|---|---|---|
| Race F1 | 9,12,15 | 9,12,15 | 19/19 (100%) | 171,700 | Stocked Conodoguinet Cr. |
| Race F3 | 3,9,12,15 | 3,9,12,15 | 19/19 (100%) | 277,100 | Stocked Conestoga R. |
| Race E1 | 3,6,9 | 3,6,9 | 18/18 (100%) | 42,900 | Stocked Standing Stone Cr. |
| Race F2 | 3,9,12 | 3,9,12 | 19/19 (100%) | 561,100 | Stocked West Br. Susq. R. |
| Race F4 | 3,6,9,12 | 3,6,9,12 | 19/19 (100%) | 682,500 | Stocked North Br. Susq. R. |
| Not sampled | 3 | 3 | – | 5,730,200 | Stocked Juniata R.– Millerstown or Susq. R.– Montgomery Ferry |
| Tank J41 | control, 3 | control, 3 | 17/17 (100%)* | – | not Stocked |
| Race E4 | egg,3 (2000ppm) | egg,3<br>0,3<br>egg,** | 14/17 (82%)<br>2/17 (12%)<br>1/17 (6%) | – | not Stocked |
| Race E3 | egg,3 (3000ppm) | egg,3<br>0,3<br>egg,0<br>egg,** | 9/18 (50%)<br>2/18 (11%)<br>1/18 (6%)<br>6/18 (33%) | – | not Stocked |
| Race E2 | egg (4000ppm) | egg,3<br>egg,** | 15/20 (75%)<br>5/20 (25%) | – | not Stocked |

*Sampled @ 28d of age, otoliths veiwed un–ground
**Exhibited a massive blur of OTC fluorescence which as far as day 5 and obscures the day 3 mark.

## Appendix 1.

# American Shad Egg Disinfection Trials, 1996

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## Introduction

Disinfection of all American shad eggs has been standard practice at Van Dyke since 1984. The purpose of disinfection is to prevent the spread of diseases to the hatchery and to the Susquehanna River system. The initial impetus for disinfection was to prevent the spread of the IHN virus from the Columbia River to East Coast rivers. IHN has the potential to cause significant mortality to salmonids in hatcheries and in the wild.

Initial disinfection procedures involved a 10 min. bath at 100ppm. Errors in calculation of concentrations and lack of proper buffering caused egg mortalities in 1985 (Hendricks et al., 1986) and led to research in 1986 and 1987 (Hendricks et al., 1987, Hendricks et al., 1988) to determine the extent of egg mortality associated with disinfection. In 1986, we compared survival of eggs disinfected for 10 min. at 100ppm to untreated controls. The experiment was replicated 5 times with three pairs of jars from one shipment and two pairs of jars from another shipment. Overall viability for the disinfected jars (50.4%) was significantly lower (a= .05, Wilcoxin's Sign Rank Test) than for the controls (76.3%). In a second experiment, we compared survival of eggs treated at 100 (6 replicates), 75 (6 replicates) and 50ppm (5 replicates). Mean survival was 40.8%, 42.5% and 41.4% for the 100, 75 and 50ppm treatments, respectively. There was no significant difference in survival between treatments (ANOVA, F= .278, d.f.= 2,11).

In 1987, we disinfected eggs from each of five shipments at 100, 75, 50, 25, and 0ppm (control). There was an apparent difference (although not significant, F= 1.82, a= .05) between survival at 100ppm (50.0%), 75 ppm (61.2%), and 50, 25, and 0ppm (68.5%, 68.8%, and 69.4% respectively). A second experiment in

1987 exhibited little difference in survival between treatments. Mean survival of eggs from 4 shipments was 65.2% for 100ppm , 64.8% for 75ppm and 67.4% for untreated controls.

Although the results were inconsistent, these four trials suggested that disinfection did have an impact on survival. Since organic iodine compounds are viricidal at 30ppm and bactericidal at 75 to 100ppm (Wood, 1979) we modified our disinfection protocol to a 10 min. bath at 80ppm, beginning in 1988.

The first two egg shipments received in 1996 exhibited viabilities between 5 and 14%. In an attempt to determine the cause of these low viabilities, we tested different iodine concentrations, durations and manufacturers and different tempering regimes. This report summarizes the experiments conducted in 1996.

## Materials and Methods

American shad eggs were strip-spawned at collection sites on the Hudson and Delaware Rivers. Eggs were water hardened and placed in plastic bags, approximately 5L of eggs with 5L of water. Bags were filled with a pure oxygen atmosphere and driven to Van Dyke in styrofoam or plastic coolers.

At Van Dyke, the bags were placed in a tempering trough to temper. "Quick tempered" eggs were placed in the trough at Van Dyke egg incubation temperatures (range of 57 to 60F). Heat is transferred readily through the bags and eggs typically temper within 10 minutes. For "slow tempered" eggs, we measured the temperature of the water in the bags and filled the trough with water at that temperature. Warmer water was added to the trough each hour to raise the temperature one degree Fahrenheit.

After tempering, eggs were poured into a submerged net. The net was lifted, excess water drained, and the net was placed in a solution of iodine disinfectant. Iodine disinfectants were buffered to a pH of 7.0 by the manufacturer. Ph was measured for each batch of disinfectant using a Whatman pH pen. After the required treatment duration, the net was lifted to drain off disinfectant and the eggs poured into an incubation jar.

Eggs were enumerated after disinfection for production lots and before disinfection for test lots. Egg volume was measured by the dry volume method using a graduated cylinder with window screen on the bottom. Volume was converted to numbers of eggs using methods of von Bayer (1910).

For production lots, egg viability was determined using standard Van Dyke protocols (Hendricks et al., 1987). For test lots, three samples of at least 100 eggs were collected 3 to 4 days after fertilization. Viability was determined by counting live and dead eggs under a dissecting microscope.

## Results and Discussion

The first two egg shipments received in 1996 were handled by standard Van Dyke protocols. They were disinfected for 10 minutes at 80ppm, using Argentyne disinfectant purchased in 1995 (Table 1). Egg viability ranged from 5 to 14% for these shipments. These eggs were collected from the Hudson River at temperatures of 50 and 51F. In the past, first Hudson River egg shipments were generally taken at water temperatures of 55F.

In an attempt to determine the cause of these low viabilities, we initiated a series of tests, beginning with shipment 3. The shipment 3 control exhibited viability of 81%, compared to 0% viability for the test lots with batches of disinfectant purchased in two different years from two different manufacturers (Table 1). This eliminated the possibility that we had gotten a "bad batch" of disinfectant, or that it had somehow "spoiled."

With shipment 4, we tested 80ppm disinfection for 10 min against an untreated control and 50ppm disinfection for 30 min. Controls exhibited 43 to 47% viability, while the disinfected batches suffered complete mortality.

With shipment 5, we tested "quick tempering" against "slow tempering" for a control and for a 10 min. treatment at 80ppm. Control groups exhibited similar survival (53 -56%) for both "quick" and "slow" tempering trials. The disinfected groups exhibited higher survival when "slow tempered" (38%) than when "quick tempered" (14%). This suggests some sort of synergism between disinfection and tempering or water temperature at the time of collection.

Shipment 6 trials tested egg viability for an undisinfected control against disinfection at 25, 50 and 80ppm. Viability for the 25ppm treatment (81%) was similar to the control (85%). Viability was much lower for treatment at higher concentrations (50ppm- 17%, 80ppm- 1%).

Shipment 7 trials tested egg viability for an undisinfected control against disinfection at 50 and 80ppm. Viability for the control (74%) was similar to the 50ppm treatment (76%), while the 80ppm treatment exhibited viability of 60%. These eggs were delivered to Van Dyke with the box left in the sun instead of being placed in the egg shed like all the other shipments. Consequently, the bag temperature had risen from 57 at the river to 65F. The impact on viability, if any, is not known. River temperatures for this and all subsequent shipments were in the range normally conducive to collection of large numbers of viable shad eggs.

Shipment 8 was disinfected by standard production protocol at 80ppm for 10 min, with viability of 31%.

Trials in shipments 9 and 10 tested undisinfected controls against disinfection at 50ppm for 10 min. Viability for disinfected groups was 7 to 8% lower than untreated controls (Table 1).

Trials in shipments 11 and 12 tested egg viability for undisinfected controls against disinfection at 50 and 80ppm. Viability was lowest for the 80ppm treatments and highest for the controls.

These experiments, coupled with the ones in 1985 and 1986, demonstrate that disinfection of American shad eggs with iodine compounds does result in egg mortality. Mortality rates increase with higher concentrations of iodine. In addition, temperature appears to play a role as well. Eggs collected at water temperatures below 55F suffer higher mortality when disinfected than do eggs collected at water temperatures of 55F or above. It is not clear whether this is due to poorer quality of the eggs when collected at lower temperatures or tempering too quickly. In the last three production years, 7.3 to 23.7% of the total Hudson River eggs have been collected when river temperature was below 55F. In order to minimize the impact of disinfection on hatchery production, I recommend disinfection at 50ppm for 10 min and slow tempering of egg shipments collected when river temperature is below 55F.

## Literature Cited

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1986. Job III. American shad hatchery operations. In: Restoration of the American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1987. Job III. American shad hatchery operations. In: Restoration of the American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1988. Job III. American shad hatchery operations. In: Restoration of the American shad to the Susquehanna River, Annual Progress Report, 1987. Susquehanna River Anadromous Fish Restoration Committee.

Wood, J. W. 1979. Diseases of Pacific salmon, their prevention and treatment. Washington Dept. of Fisheries. 82p.

von Bayer, H. 1910. A method of measuring fish eggs. Bull. U. S. Fish. 18 (1908) (2): 1011-1014.

Table A1-1. Survival of American shad eggs disinfected with iodine at various concentrations, 1996.

| Ship. No. | Egg Source | Egg Jar | Eggs (L) | Eggs No. | Temperature (F) River | Temperature (F) Bag | Temperature (F) Van Dyke | Disinfection Iodine Conc. (ppm) | Disinfection Duration (min) | Disinfection Disin-fectant | Egg Survival (%) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hudson | 1 | 2.50 | 69,700 | 50 | 56 | 59 | 80 | 10 | Argentyne (95) | 5% | Production lots |
| 2 | Hudson | 301 | 7.20 | 212,500 | 51 | 56 | 59 | 80 | 10 | Argentyne (95) | 10% | Production lots |
| | | 302 | 7.20 | 212,500 | | | | 80 | 10 | Argentyne (95) | 14% | Production lots |
| 3 | Hudson | 2 | 0.20 | 6,700 | 54 | 53 | 57 | Control | – | – | 81% | |
| | | 3 | 0.20 | 6,700 | | | | 80 | 10 | Aurudyne (95) | 0% | |
| | | 4 | 0.20 | 6,700 | | | | 80 | 10 | Aurudyne (96) | 0% | |
| | | 5 | 0.20 | 6,700 | | | | 80 | 10 | Argentyne (95) | 0% | |
| | | 6 | 0.20 | 6,700 | | | | 80 | 10 | Argentyne (96) | 0% | |
| 4 | Hudson | 7 | 0.45 | 12,600 | 51 | 52 | 58 | Control | 30 | – | 43% | |
| | | 8 | 0.45 | 12,600 | | | | 50 | 30 | Argentyne (96) | 0% | |
| | | 9 | 0.45 | 12,600 | | | | 80 | 10 | Argentyne (96) | 0% | |
| | | 10 | 0.40 | 11,200 | | | | Control | 10 | – | 47% | |
| | | 11 | 0.45 | 12,600 | | | | 50 | 30 | Argentyne (96) | 0% | |
| | | 12 | 0.45 | 12,600 | | | | 80 | 10 | Argentyne (96) | 0% | |
| 5 | Hudson | 9 | 1.60 | 46,900 | 52 | 53 | 57 | Control | – | – | 53% | Quick tempered |
| | | 10 | 1.80 | 52,500 | | | | 80 | 10 | Argentyne (96) | 14% | Quick tempered |
| | | 11 | 1.50 | 43,800 | | | | Control | – | – | 56% | Slow tempered |
| | | 12 | 1.50 | 43,800 | | | | 80 | 10 | Argentyne (96) | 38% | Slow tempered |
| 6 | Hudson | 3 | 0.60 | 16,700 | 51 | 56 | 59 | Control | – | – | 85% | |
| | | 6 | 0.65 | 18,100 | | | | 25 | 10 | Argentyne (96) | 81% | |
| | | 5 | 0.70 | 19,500 | | | | 50 | 10 | Argentyne (96) | 17% | |
| | | 4 | 0.70 | 19,500 | | | | 80 | 10 | Argentyne (96) | 1% | |

Table A1–1. (continued).

| Ship. No. | Egg Source | Egg Jar | Eggs (L) | Eggs No. | Temperature (F) River | Temperature (F) Bag | Temperature (F) Van Dyke | Disinfection Iodine Conc. (ppm) | Disinfection Duration (min) | Disinfection Disin–fectant | Egg Survival (%) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Hudson | 13 | 0.70 | 20,000 | 57 | 65 | 60 | Control | – | – | 74% | box left in sun |
| | | 14 | 0.70 | 20,000 | | | | 50 | 10 | Argentyne (96) | 76% | box left in sun |
| | | 15 | 0.70 | 20,000 | | | | 80 | 10 | Argentyne (96) | 60% | box left in sun |
| 8 | Hudson | 21 | 1.60 | 52,100 | 57 | 64 | 60 | 80 | 10 | Argentyne (96) | 31% | |
| 9 | Hudson | 18 | 2.00 | 57,100 | 57 | 64 | 60 | Control | – | – | 59% | |
| | | 19 | 1.80 | 51,400 | | | | 50 | 10 | Argentyne (96) | 51% | |
| 10 | Delaware | 16 | 1.00 | 44,400 | 62 | 64 | 60 | Control | – | – | 52% | |
| | | 17 | 1.00 | 44,400 | | | | 50 | 10 | Argentyne (96) | 45% | |
| 11 | Delaware | 1 | 0.50 | 18,700 | 66 | 64 | 59 | Control | – | – | 81% | |
| | | 29 | 0.50 | 18,700 | | | | 50 | 10 | Argentyne (96) | 76% | |
| | | 40 | 0.50 | 18,700 | | | | 80 | 10 | Argentyne (96) | 62% | |
| 12 | Hudson | 43 | 0.50 | 14,100 | 57 | 62 | 60 | Control | – | – | 88% | |
| | | 20 | 0.50 | 14,100 | | | | 50 | 10 | Argentyne (96) | 80% | |
| | | 22 | 0.50 | 14,100 | | | | 80 | 10 | Argentyne (96) | 78% | |

Note: Quick tempered = tempered within 15 min.
Slow tempered = 1 degree F per hour; shipment 5, jars 11 and 12 only.

## Appendix 2

**Efficacy of marking otoliths of American shad embryos by five hour immersion in 2000, 3000 or 4000mg/L oxytetracycline hydrochloride.**

**by**
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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.

In research conducted at Van Dyke in 1995, American shad embryos were experimentally marked by 5 hour immersion in 1,000 and 2,000 mg/L oxytetracycline (Hendricks, 1996). Marks were visible in only 2 of 20 specimens from the 1000 mg/L group, but all of the specimens in the 2000 mg/L group exhibited marks. These marks were viewed in unground otolith specimens from larvae sampled at 29 days of age. Unfortunately, larvae from these groups were not retained in raceways or ponds for sampling at a later date, when the otoliths would be larger and grinding would be required. Subsequent to that, we observed autofluorescence in the nucleus in a number of otolith specimens taken from larger juvenile shad which required grinding. As a result, we sampled ground otoliths from larger, wild-caught juvenile shad and examined them for autofluorescence. Forty-four percent of the otoliths examined, exhibited autofluorescence at the nucleus which the reader felt would have masked a mark, if it were present. Since the marks observed in egg-treated otoliths were from 29 day old fry, viewed without grinding, we could not be sure that the OTC fluorescence would be distinguishable from auto-fluorescence commonly found in the nucleus.

The purpose of this research was to repeat the experiments from 1995, to determine if otoliths can be marked by immersion during the embryonic stage and if the OTC fluorescence can be distinguished from auto-fluorescence in ground specimens, taken from older fish.

## Materials and Methods

Plastic bags were placed in 5 gal. buckets and filled with 2.0L of 2000, 3000 or 4000mg/L OTC, with a fourth bag as an unmarked control. Buffers were added to the bags to return pH to pre-treatment levels. For the 2000 mg/L solution, 2.5g potassium phosphate plus 9.0g sodium phosphate was added to return pH to pre-treatment levels of 6.5. For the 3000 mg/L solution, 3.0g potassium phosphate plus 15.0g sodium phosphate was added to return pH to pre-treatment levels of 6.7. For the 4000 mg/L solution, 3.5g potassium phosphate plus 20.0g sodium phosphate was added to return pH to pre-treatment levels of 6.5.

Four small groups of eggs from shipment 29, Delaware River egg source, were used for the experiment. Eggs were disinfected and enumerated as per standard practice. Each bag received 0.25L of eggs (7,025). Oxygen was added to each bag and the bags sealed. Marking began at 09:45AM, 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 (102-289 eggs/sample) from each jar and counting the number of live eggs in each sample.

At hatch, the four incubation jars were moved to separate rearing tanks and reared as per standard practice. Larvae in the control tank and in tanks treated with 2000 and 3000 mg/L received additional marks by 4h immersion in 256mg/L OTC at 3d of age.

At 28 or 29 days of age, larvae were sampled for mark analysis from each tank and the remaining larvae transferred to raceways at Benner Spring for grow-out and later mark analysis. Otoliths were extracted under a dissecting microscope. Otoliths from 28-29 day old larvae were viewed whole in immersion oil, while those from raceway reared fish were ground on both sides according to the procedures of Hendricks et al. (1991). 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 A2-1) was 58.0% in the untreated control, 54.9% in the 2000ppm treatment, 25.85 in the 3000ppm treatment, and 29.9% in the 4000ppm treatment. This suggests that treatment at 3000ppm or above results in higher mortality. Specimens from all three treatment concentrations exhibited a high frequency of deformities, including gill, jaw, mouth and nose deformities. For the 2000 and 4000ppm treatment groups, 12 of 20 (60%) exhibited deformities while 9 of 20 (45%) of the 3000ppm treatment group exhibited deformities. Two observations should be noted which may be related to these phenomena. First, buffers (particlularly in higher concentrations) are extremely difficult to dissolve in Van

Dyke's extremely soft water. During treatment, undissolved buffer was observed on the bottom of the bags in close proximity to the eggs. The undissolved buffer may have created a pH chemocline which adversely affected the eggs. Second, the pH pen in use at the time of the experiment may have been unreliable. On the morning of the experiment, the pH pen which had been in use and was known to be reliable was dropped and broken. It was replaced with an older model, which had not been used for several years and which took long to stabilize and gave questionable readings.

With regard to the high frequency of deformities, another possible explanation exists. Shad grown out to fingerling size at Van Dyke have typically exhibited a high frequency of deformities, possibly related to nutritional deficiencies. Shad transferred to ponds, raceways or stocked in the wild at 21d of age do not experience the same high rates of deformities as those retained at Van Dyke. The egg marked fish were transferred to Benner Spring raceways at the relatively young age of 28 or 29 days. However, due to the low fish densities maintained in the tanks, these fish grew extremely fast and were much larger and more well developed for their age than fish cultured at high densities. Thus, the deformities may have been due to nutritional deficiencies which occur at a particular developmental stage, regardless of age.

Twenty-day survival of larvae was 61.5% for the untreated control, 69.1% for the 2000ppm treatment group, 56.1% for the 3000ppm treatment group, and 63.9% for the 4000ppm treatment group. These are slightly lower than normal for fish reared to 20 days of age. This may be due to errors in daily mortality estimates associated with very low densities in the rearing tanks.

Tetracycline marks (Table A2-1) were visible in all of the specimens examined. Autofluorescence did not cause problems in identifying marks as suggested by Hendricks (1996). In some cases, marks were characterized by extremely bright fluorescence, creating a yellow blur which extended out as far as 5 days of age. This was more prevalent at the higher concentrations (8 of 20 for 4000ppm and 9 of 20 for 3000ppm), but was also observed at 2000ppm (2 of 17). At times, this blur masked the fry immersion mark at 3 days of age. In contrast, the group treated at 4000ppm did not recieve a fry immersion mark at 3 days of age. However, fifteeen of twenty (75%) of the specimens treated at 4000ppm exhibited what appeared to be a second mark at day 3. This mark was characterized by a brighter yellow ring within the diffuse OTC "glow" which extended from the nucleus out to approximately day 5. This must have been a false mark produced by some anomaly in calcium metabolism on day 3.

In conclusion, 2000ppm appears to be sufficient to mark American shad eggs by 5h immersion in oxytetracycline. Additional testing is required to determine: 1) at what age multiple marks can be applied and be distinguishable from the egg mark, 2) the extent of egg mortality caused by the marking, and 3) the frequency of deformities caused by the marking.

## Literature Cited


Brooking, T. E., A. J. VanDe Valk. D. M. Green, and L. G. Rudstam. 1994. Comparative survival of fry, pond-reared, and advanced fingerling walleye in New York lakes. Completion report, N. Y. Federal Aid Study VII, Job 102, 4/93 - 3/94. Warmwater Fisheries Unit, Cornell University Bio. Field Station, Bridgeport, N. Y. 47p.

Dabrowski, K. and K. Tsukamoto. 1986. Tetracycline tagging in coregonid embryos and larvae. Journal of Fish Biology 29: 691-698.

Hendricks, M. L. 1996. Job III. American shad hatchery operations. In: Restoration of the American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1988. Job III. American shad hatchery operations. In: Restoration of the American shad to the Susquehanna River, Annual Progress Report, 1987. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management 11:212-219.

Lorson, R. D. and V. A. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. North American Journal of Fisheries Management 7: 453-455.

Muth, R. T. and T. P. Nesler. 1989. Marking Colorado squawfish embryos and newly hatched larvae with tetracycline. The Southwestern Naturalist 34(3): 432-436.

Ruhle, C. and C. Winecki-Kuhn. 1992. Tetracycline marking of coregonids at the time of egg fertilization. Aquatic Sciences 54(2): 165-175.

Tsukamoto, K. 1985. Mass-marking of Ayu eggs and larvae by tetracycline-tagging. Bulletin of the Japanese Society of Scientific Fisheries 51(6): 903-911.

Table A2–1. Efficacy of marking otoliths of Delaware River source American shad embryos by 5h immersion in oxytetracycline, 1996.

| Egg Ship. | Jar | Eggs | Egg Survival (%) | 20d larval Survival (%) | OTC Concen– tration (mg/L) | Egg mark intensity: un marked | Egg mark intensity: + | Egg mark intensity: ++ | Egg mark intensity: +++ | Fry mark intensity: masked by egg mark | Fry mark intensity: un marked | Fry mark intensity: + | Fry mark intensity: ++ | Fry mark intensity: +++ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 1 | 7,025 | 58.0 | 61.5% | Control | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 17 |
| 29 | 11 | 7,025 | 54.9 | 69.1% | 2000 | 2 | 0 | 7 | 8 | 1 | 0 | 3 | 8 | 5 | 17 |
| 29 | 3 | 7,025 | 25.8 | 56.1% | 3000 | 1 | 0 | 3 | 14 | 6 | 1 | 2 | 5 | 4 | 18 |
| 29 | 4 | 7,025 | 29.9 | 63.9% | 4000 | 0 | 0 | 2 | 18 | 5 | 0 | 5 | 3 | 7 | 20 |

\+ Faint mark
++ Moderate mark intensity
+++ Bright mark
Note: Marks administered beginning at 09:45AM, 12 to 15 hours post fertilization.

## Appendix 3.

# Relative survival of American shad larvae released in tributaries vs. those released in the main stem Susquehanna River, 1996.

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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, beginning in 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, the PFBC began stocking adult pre-spawn river herring and hatchery-reared American shad larvae in selected tributaries and previously un-stocked river reaches in 1995. This paper reports on, and evaluates the success of, the American shad larval releases in these waters in 1996.

## Materials and Methods

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 13 to 21d of age to accommodate the tetracycline marks.

Specific release sites were as follows:

1. Conodoguinet Cr., at North Middleton Township Park, .25 miles downstream from the Rt. 74 bridge.
2. Conestoga R., at Conestoga Pines Park, .25 miles above Lancaster Water Authority Dam.
3. Standing Stone Cr., at Blair Park in Huntington, PA.
4. West Branch Susquehanna R., at Greevy Access Area, in Montoursville, PA.
5. North Branch Susquehanna R., at Test Track Park, in Berwick, PA.

Juvenile American shad were recaptured during the Fall out-migration by cast net at Holtwood Dam, in intakes at Peach Bottom Atomic Power Station, and in strainers at Conowingo Dam. Samples from sites upstream from the mouth of the Conestoga River, including the productive Columbia/Marietta area, were not used in the analysis.

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 A3-1. Over 5.7 million larvae (75%) were stocked at the main release sites in the Juniata River (Millerstown) and Susquehanna River (Montgomery Ferry). Of these, 943 thousand were stocked at Montgomery Ferry and 4.8 million were stocked in the Juniata River at Millerstown. These larvae were stocked at 6-8 days of age and, based on the results of Hendricks (1995), would be expected to experience higher survival than the larvae released at 13 to 21 days of age in the tributaries.

Lesser numbers of larvae were released at the other sites: Conodoguinet Cr.- 171,700, Conestoga R.- 277,100, Standing Stone Cr.- 42,900, West Br. Susquehanna R.- 561,100, North Br. Susquehanna R.- 682,500.

A total of 93 juvenile shad were collected at and downstream from Holtwood Dam in 1996. Of these, 45 were recovered from the production stockings in the Juniata and Susquehanna Rivers, resulting in a recovery rate of 0.08 and relative survival of 0.33. Two fish were recovered from the Conodoguinet Cr. release for a recovery rate of 0.12 and relative survival of 0.50. No fish were recovered from the Conestoga R. or Standing Stone Creek releases. Five fish were recovered from the West Branch Susquehanna R. release for a recovery rate of 0.09 and relative survival of 0.38. Sixteen fish were recovered from the North Branch Susquehanna R. release for a recovery rate of 0.23 and relative survival of 1.00.

This study was hampered by our inability to collect specimens in the forebay of Holtwood Dam by lift net. The platform traditionally used for lift net collections in the Holtwood forebay was damaged by floodwaters in January, 1996. Cast netting was substituted for lift netting, however, high river flows either made cast netting ineffective or excluded shad from the forebay. In any case, only 7 shad were collected at Holtwood in 1996, compared to 245 in 1995.

The capture of no Conestoga River shad in 1996 is puzzling, particularly since this group had the highest relative survival in 1995. Possible explanations include low survival due to the high flows experienced in 1996 or movement of the Conestoga River stocking site 15 miles downstream. Another possibility may relate to the fact that these remote stockings generally involve a single tank of fish from a single egg shipment, stocked on a single day. If survival can vary based upon some subtle environmental factor, fish culture practice or occurrence during culture or stocking, then reliance on a single stocking of fish may produce varied results.

Data from juvenile shad collected above Holtwood Dam was analyzed for comparison (Table A3-2). A total of 163 hatchery shad were identified as to stocking site from collections above Holtwood Dam. This data is somewhat similar to the data from shad collected below Holtwood Dam. The highest recovery rate for both groups was for those stocked in the North Branch Susquehanna River. West Branch fish were better represented in the sample below Holtwood (relative survival 0.38) than in the sample above Holtwood (relative survival 0.25). In contrast, Juniata River fish were better represented in the sample collected above Holtwood (relative survival 0.65 above vs 0.33 below Holtwood). Conodoguinet Creek fish were present in both samples with an identical relative survival of 0.50, but this was based on very low sample sizes (2 or 3 fish, depending upon the site). One Standing Stone Creek fish was identified in the upstream sample.

In both 1995 and 1996, three of the remote stocking sites exhibited greater relative survival than the production stocking site at Millerstown. This is surprising for two reasons. First, Hendricks (1995) demonstrated higher survival for larvae released at younger ages, yet larvae released at remote sites had to be held longer to accomplish unique marking. Second, it is reasonable to assume that longer stocking trips to distant sites should result in additional stress to larvae when compared to the short trip to the Millerstown site. As was noted in 1995, 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. If this is true, the improved survival of larvae stocked at 7 days of age, documented by Hendricks (1995), may have been due to the fact that those larvae were stocked at the site before predators were attracted to that site, not age at stocking. In addition, it implies that maximum survival can be achieved by choosing stocking sites to spread the larvae out as much as possible.

## Literature Cited

Hendricks, M. L., T. R. Bender, Jr. and V. A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management 11:212-219.

Hendricks, M. L. 1995. Relative survival of Hudson River American shad larvae released at 7 days of age vs. those released at 19 days of age. Appendix 4, Job III. American shad hatchery operations. In: Restoration of American shad to the Susquehanna River. Annual progress report, 1994. Susquehanna River Anadromous Fish Restoration Committee.

Johnson, J. H. 1993. Biotic factors affecting the survival of recently released American shad larvae in the Susquehanna River Basin. Doctoral Dissertation, State University of New York, Syracuse. 124p.

Wiggins, T. A., T. R. Bender, Jr., V. A. Mudrak, and J. A. Coll. 1985. The development, feeding, growth, and survival of cultured American shad larvae through the transition from endogenous to exogenous nutrition. Progressive Fish-Culturist 47(2): 87-93.

Table A3–1. 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, 1996.

| Year | Stocking Site | Age at Release (days) | Release Dates | Fry Released Number | Fry Released % | Juveniles Recovered Number | Juveniles Recovered % | Recovery Rate | Relative Survival |
|---|---|---|---|---|---|---|---|---|---|
| 1996 | Juniata R./ Susq. R. @ Mont. Ferry | 6–8 | 5/24–6/24 | 5,730,200 | 77% | 45 | 66 | 0.08 | 0.33 |
| | Conodoguinet Cr. | 16 | 6/14 | 171,700 | 2% | 2 | 3 | 0.12 | 0.50 |
| | Conestoga R. | 17 | 6/17 | 277,100 | 4% | 0 | 0 | 0.00 | 0.00 |
| | Standing Stone Cr. | 21 | 7/2 | 42,900 | 1% | 0 | 0 | 0.00 | 0.00 |
| | W. Br. Susq. R. | 17 | 6/15 | 561,100 | 8% | 5 | 7 | 0.09 | 0.38 |
| | N. Br. Susq. R. | 13 | 6/19 | 682,500 | 9% | 16 | 24 | 0.23 | 1.00 |
| | | | Total | 7,465,500 | | 68 | | | |

Table A3–2. Relative survival of American shad fry stocked at various sites in the Susquehanna River basin, as determined by tetracycline marking of juveniles collected at sites upstream from Holtwood Dar

| Year | Stocking Site | Age at Release (days) | Release Dates | Fry Released Number | % | Juveniles Recovered Number | % | Recovery Rate | Relative Survival |
|---|---|---|---|---|---|---|---|---|---|
| 1996 | Juniata R./ Susq. R. @ Mont. Ferry | 6–8 | 5/24–6/24 | 5,730,200 | 77% | 130 | 80 | 0.23 | 0.65 |
| | Conodoguinet Cr. | 16 | 6/14 | 171,700 | 2% | 3 | 2 | 0.17 | 0.50 |
| | Conestoga R. | 17 | 6/17 | 277,100 | 4% | 0 | 0 | 0.00 | 0.00 |
| | Standing Stone Cr. | 21 | 7/2 | 42,900 | 1% | 1 | 1 | 0.23 | 0.66 |
| | W. Br. Susq. R. | 17 | 6/15 | 561,100 | 8% | 5 | 3 | 0.09 | 0.25 |
| | N. Br. Susq. R. | 13 | 6/19 | 682,500 | 9% | 24 | 15 | 0.35 | 1.00 |
| | | | Total | 7,465,500 | | 163 | | | |

# 1996 American Shad (*Alosa sapidissima*) and Hickory Shad (Alosa mediocris) Culture, Stocking and Assessment Results

***Summary for SRAFRC***

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## Background

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 proposed 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) estimate the contribution of hatchery fish to the adult spawning population and monitor recovery of wild stocks; 5) develop new techniques for marking eggs; 6) design and build an experimental natural spawn system at Conowingo Dam.

*Alosid* populations in Maryland's portion of the Chesapeake Bay are depressed or no longer exist in many tributaries. 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. A natural spawn technique for *Alosids* was developed (Mylonas et al., 1995). Injections of synthetic analogs of gonadotropin-releasing hormone (GnRHa) stimulate pituitary release of endogenous gonadotropin which induces gonadal maturation, ovulation and spawning (Mylonas et al., 1993). A polymeric delivery system developed by Zohar et al. (1990) releases the hormone for up to three weeks. A compassionate exemption from an Investigational New Animal Drug Permit (INAD #9222) was obtained from the U.S. Food and Drug Administration which allows the experimental use of this drug. The Patuxent River was chosen for stocking. A spawning, culture, stocking and assessment experiment was successfully initiated in 1995. In 1996, we stocked American shad larvae in the Susquehanna River according to our agreement with SRAFRC. Hickory shad (*Alosa mediocris*) culture and stocking was incorporated into the project in 1996. American shad and hickory shad larvae and juveniles cultured using natural spawn techniques were stocked in the Patuxent River and Choptank River. New methods for marking large numbers of *Alosids* were explored. An experimental natural spawn system was constructed and operated by Maryland Fisheries Service at the east fish lift on the Conowingo Dam. We intended to demonstrate the inherent advantages of natural spawning compared to traditional strip spawning.

**Adult fish capture and handling**

In the past, American shad broodfish were collected from the Conowingo Dam fish lift and transported to the Fisheries Service hatchery for spawning. The delayed operation of the west lift in 1996 required utilization of the east lift for most broodfish collection. The fish collected in the east lift were subject to several additional handling steps and were more stressed than west lift fish from past years. East lift fish had to be netted from holding tanks on the dam into transport tanks. Fish were transported across the dam and netted into a Fisheries Service tank truck. In order to reduce some handling stress, we collected broodfish from recreational sportfishermen in the Susquehanna

River directly below Conowingo Dam. These fish were less stressed than east lift fish and exhibited good survival.

Since hickory shad are not regularly captured by the fish lift, all hickory shad broodfish were collected by hook and line from recreational fishermen on the banks of the Susquehanna River and Deer Creek.

The east lift provided good quality American shad broodfish for the Fisheries Service experimental natural spawn system constructed on the dam at the lift. Fish were collected in the lift, implanted with GnRHa and placed directly into spawning tanks.

**Larval rearing and marking**

A new larval culture tank system was constructed at Manning Hatchery for 1996. The addition of these six circular tanks provided sufficient space for culture of larvae until stocking.

All *Alosids* stocked as larvae were given oxytetracycline (OTC) immersion marks. Fish stocked as juveniles were given an OTC feed mark and/or implanted with a binary coded wire tag (CWT) from Northwest Marine Technologies.

Larval otolith marks were designated in cooperation with the Pennsylvania Fish and Boat Commission:

| | Susquehanna River | Patuxent River | Choptank River |
|---|---|---|---|
| **American shad** | *days 3, 6* | *days 9, 12* | *days 6, 12* |
| **Hickory shad** | *not stocked* | *day 3* | *day 3* |

Larval fish were 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. Development of an OTC egg mark would provide shorter marking schedules and an increase in the number of available discrete marks. An investigation was initiated in 1996 to develop an egg marking technique for *Alosids*. Beltran et al. (1995) marked whitefish otoliths with OTC using hyperosmotic shock. We conducted several egg marking trials with American shad eggs. We propose to expand this work in 1997.

Larvae were fed a combination of *Artemia* and larval AP100 feed. In 1996, several experiments were conducted relating to nutrition. Work was conducted in conjunction with the Maryland Biotech Center. We hypothesized that providing shad larvae with lipid enriched *Artemia* could result in increased growth and survival. We will continue work in 1997 with enriched *Artemia* and experimental microencapsulated feed supplements.

All hickory shad stocked as juveniles and 70% of American shad stocked as juveniles received CWT. Thirty percent of American shad stocked as juveniles received only feed marks.

**1996 Strip Spawned American Shad Culture Results**

***American shad***

Manning hatchery cultured 50 liters (22,000 eggs/ℓ) of eyed eggs from SRAFRC. The eggs were incubated, hatched, marked and stocked at six days. Approximately 880,000 larvae were stocked offshore in mid-channel at Lapidum.

**1996 Manning Hatchery Natural Spawn Results**

In 1996 we had problems with American shad egg viability. Twenty five percent of all fertilized eggs later died. This phenomenon did not occur in previous years. In 1995, viability was 67%. In 1996, viability was only 41%. Accounting for the portion of Manning fertilized eggs that later died, fertilization was similar each year. It was theorized that spawning success could be affected by ionic concentration variability in water quality. High flow years such as 1996 can possibly result in low egg viability. Since anadromous fish are migrating from higher salinity to freshwater, adult stress caused by low conductivity water could be passed on to the egg, affecting development and maturation. It is possible that low ion concentration in spawning rivers in 1996 accounted for the difference in egg viability. Further investigation in later work will be conducted to monitor these effects.

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***American shad***

Three hundred forty six female shad produced 246 liters of eggs. Fertilization rates varied from 5 to 94 percent with the highest fertilization rates occurring when the largest number of eggs were released. Overall fertilization averaged 31%. Egg counts averaged 44,000 per liter (wet). This resulted in 10.8 million total eggs produced with 3.4 million fertilized eggs produced. There were 2.9 million eggs at hatch and 1.9 million surviving to larval stocking. Of these, 655,000 were stocked as larvae in the Patuxent River and 626,000 were stocked as larvae in the Choptank River. The remainder were stocked in PEPCO ponds to be raised to juvenile size.

***Hickory shad***

Ninety-eight female hickory shad produced 8.549 liters of eggs. Fertilization rates varied from 11 to 89 percent. Overall fertilization averaged 47%. Egg counts averaged 593,000 per liter (wet). This resulted in five million total eggs produced with 2.4 million fertilized eggs produced. There were 1.8 million eggs at hatch and one million surviving to larval stocking. Of these, 750,000 were stocked as larvae in the Patuxent River and 125,000 were stocked as larvae in the Choptank River. The remainder were stocked in PEPCO ponds for juvenile growout.

### 1996 Conowingo Dam Experimental Natural Spawn Results

***American shad***

Thirty two female American shad produced 22.5 liters of eggs. Overall viability averaged 35%. This resulted in 988,680 total eggs produced with 343,072 fertilized eggs produced. There were 308,000 eggs at hatch and 207,000 surviving to larval stocking. These were stocked as larvae in the Susquehanna River.

### 1996 Stocking results for cultured fish

Cultured fish were stocked as OTC immersion marked larvae, early juveniles (Phase I) marked with CWT, late juveniles (Phase II) marked with CWT and late juveniles feed marked with OTC. All CWT batches of fish were subjected to a seven day tag retention and mortality study. Numbers of fish stocked will be adjusted according to the results of these studies.

**American shad stocked**

| | Larvae | Phase I CWT | Phase II CWT | Phase II Feed Mark |
|---|---|---|---|---|
| **Susquehanna River** | *1,086,913* | *0* | *0* | *0* |
| **Patuxent River** | *654,552* | *38,073* | *53,721* | *88,200* |
| **Choptank River** | *626,127* | *44,274* | *70,836* | *0* |

A seine survey conducted in the Patuxent River collected 221 juvenile American shad (70 CWT positive). Choptank River surveys recaptured 107 juvenile American shad (59 CWT positive). Most fish have not been checked for hatchery marks but several samples examined were of larval and juvenile stocking origin. Prior to our 1995 stocking efforts no American shad had been captured in these tributaries in 35 years of sampling.

**<u>Hickory shad stocked</u>**

| | Larvae | Phase I CWT | Phase II CWT | Phase II Feed Mark |
|---|---|---|---|---|
| **Susquehanna River** | *0* | *0* | *0* | *0* |
| **Patuxent River** | *745,870* | *12,659* | *0* | *0* |
| **Choptank River** | *125,000* | *7963* | *0* | *0* |

A seine survey conducted in the Patuxent River collected 44 juvenile hickory shad (one CWT positive). Choptank River surveys recaptured 14 juvenile hickory shad (none CWT positive). Hickory shad juveniles were nonexistent in these tributaries for 35 years prior to these surveys.

**Cultured Alosids used as a stock assessment tool**

Spring sampling to assess returning adults will be accomplished with commercial nets. Initially we propose to only collect adults in the Patuxent River and Choptank River for otolith analysis to determine the contribution of hatchery fish to the spawning stock. When adults are abundant enough, 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. Summer and fall seine surveys will assess the efficacy of larval and juvenile stocking efforts. Water quality parameters collected will be used to examine recruitment factors. Estimates of both adult spawners and juvenile recruitment from our surveys could be used when lifting the American shad fishing moratorium and managing fisheries in Maryland Fishery Management Plans.

Assessment work will be refined in 1997. We will begin preliminary restoration work in the Patapsco River in addition to continuing efforts in the Patuxent River and Choptank River. The contribution of hatchery fish will be assessed comparing our three differently impacted tributaries. Choptank River watershed is rural-impacted by farm and low urban development. Patuxent River is heavily urban-impacted, but has been the subject of numerous mitigation efforts due to its designation as a targeted watershed (ie. sewage treatment upgrades). The Patapsco River watershed is a combination of heavy urban development and industrial use. Historically, dams constructed on the Patapsco River have dramatically impacted spawning run populations of anadromous species. As early as the 1780's, the Ellicott brothers described apparent reductions in the numbers of river herring and shad (Travers, 1990). Several blockages remain today. Water quality, poor by any measure in the 1960's, has improved to the point that this area supports a put-and-take trout fishery. An American shad collected at Bloede Dam fishway (Morin, 1994) suggests that the Patapsco River is a candidate for *Alosid* restoration.

Crecco (1985) found that oscillations in zooplankton, flow and water temperature affected recruitment of American shad. We propose to compare USGS flow and temperature data to examine this effect in study tributaries.

We will begin otolith analysis of adults captured as returning spawners to provide estimates of adult return rates.

only if abundance is known!

**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 and Choptank River. These populations were comprised of fish stocked as larvae, early juveniles and late juveniles. Analysis of recapture data will permit the calculation of abundance and mortality estimates. Lab analysis of samples collected in 1996 will permit in depth population assessment and survival estimates of pre-migratory stocks of American shad and hickory shad in study tributaries. Hatchery origin adults should begin returning in spring 1997. This additional component will aid in assessment of the success of the restoration program. Four parameters comprise this assessment: 1) assess the efficacy of stocking efforts through stocking and juvenile recapture surveys; 2) identify origin of returning adults and quantify spawning stock abundance; 3) use of hatchery fish to assess natural reproduction from reintroduced adult spawners; and 4) reestablish self-sustaining reproduction in study tributaries (Minkkinen et al., 1996). We have met the premise of the first parameter and expect to begin work on parameters two and three in 1997 in the Patuxent River.

**Citations**

**Beltran, R. R., A. Champignuelle and G. Vincent.** 1995. Mass marking of bone tissue of *Coregonus lavaretus L.* and its potential application to monitoring the spacio-temporal distribution of larvae, fry and juveniles of lacustrine fishes. Hydrobiologia 300/301:399-407.

**Crecco, V. A. And T. F. Savoy.** 1985. Effects of biotic and abiotic factors on growth and relative survival of young American shad, *Alosa sapidissima*, in the Connecticut River. Can. J. Fish. Aquat. Sci.. 43:1640-1648.

**Minkkinen, S. P., R. P. Morin and B. M. Richardson.** 1996. The use of cultured *Alosids* for stock assessment in Maryland. National Marine Fisheries Service proposal, PL grant-in-aid funding.

**Morin, R. P.** 1994. Restoration of alewife and blueback herring in the Patapsco River. A report of the Maryland Dept. Of Natural Resources pursuant to NOAA award No. NA46FA0106. 16 p.

**Mylonas, C. C., P. Swanson, L. C. Woods, E. Jonsson, J. Jonasson, S. Stefansson and Y. Zohar**. 1993. GnRHa-induced ovulation and sperm production in striped bass, Atlantic and Pacific salmon using controlled release devices. Proceedings of the World Aquaculture Congress, Torremolinos, Spain.

**Mylonas, C., Y. Zohar, B. Richardson and S. Minkkinen.** 1995. Induced spawning of wild American shad *Alosa sapidissima* using sustained administration of gonadotropin-releasing hormone analog (GnRHa). Journal of the World Aquaculture Society 26(3):240-251.

**Travers, P. J.** 1990 The Patapsco, Baltimore's River of History. Tidewater Pub. Centreville, MD. 220 p.

**Zohar, Y., G. Pagelson, Y. Gothilf, W. W. Dickhoff, P. Swanson, S. Duguay, W. Gombotz, J. Kost and R. Langer.** 1990. Controlled release of gonadotropin releasing hormones for the manipulation of spawning in farmed fish. Proceedings of the International Congress on Controlled Release of Bioactive Materials 17:51-52.

## JOB IV.

## ABUNDANCE AND DISTRIBUTION 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 1996 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 collections was of hatchery origin. Cultured shad larvae were distinctively marked and stocked into the Juniata River, the West and North Branches, three smaller tributaries, and in the Susquehanna River below Conowingo Dam. Juvenile recoveries from all sources were provided to the PA Fish and Boat Commission (PFBC) for analysis.

RMC-Normandeau (Drumore, PA) was contracted by PFBC to perform net collections while PFBC fishery management staff conducted electrofishing. Maryland DNR personnel collected juvenile shad with electrofishing and seining in the Susquehanna Flats. Many individuals supplied information for this report. For their contributions, appreciation is extended to Chris Frese (RMC), Dale Weinrich (Maryland DNR), and Mike Hendricks, Scott Carney, and Mike Kaufmann (PA Fish and Boat Commission). Scott Rhoades and Timothy Wilson processed most of the otoliths and Ted Jacobsen (Ecology III) administered the otolith contract.

### SUMMARY OF ADULT AND JUVENILE SHAD STOCKINGS

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 37,513 adult shad collected at Conowingo Dam in 1996, 33,825 were hauled to stocking sites at Middletown and Columbia during the period 15 April through 11 June. Observed transport and delayed mortalities amounted to 592 fish (1.7%). Overall sex ratio (SR) in these transfers was about 1.1 to one favoring males. This stocking level compares with about 55,000 live shad in 1995 (1.1 to 1 sex ratio); 28,100 in 1994 (SR 1.8:1); 11,200 in 1993 (SR 1.3:1), 14,500 in 1992 (SR 1:1), and 22,000 in 1991 (SR 1.6:1). Only 410 adult blueback herring were stocked above dams in 1996.

During the 1996 shad production season, PFBC biologists reared and released 7.465 million shad fry in the Susquehanna watershed above dams. This stocking level compares with 3 to 10 million fry stocked each year in 1990-1995. All fry were released between 24 May and 2 July in the following numbers and locations (tetracycline marks in parentheses):

| | | |
|---|---|---|
| Juniata River at Millerstown - | 4.787 million aged 6-8 days | (day 3) |
| Susquehanna at Montgomery Ferry - | 0.943 million aged 6-8 days | (day 3) |
| West Branch at Montoursville - | 0.561 million aged 17 days | (days 3, 9, 12) |
| North Branch at Berwick - | 0.683 million aged 13 days | (days 3, 6, 9, 12) |
| Conodoguinet Creek - | 0.172 million aged 16 days | (days 9, 12, 15) |
| Conestoga River - | 0.277 million aged 17 days | (days 3, 9, 12, 15) |
| Standing Stone Creek - | 0.004 million aged 21 days | (days 3, 6, 9) |

In addition to the above, Maryland DNR reared and double-marked (days 3, 6) shad at their Manning Hatchery and stocked 1.09 million fry in the Susquehanna River below Conowingo Dam at Lapidum.

## 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 1996. Haul seining was conducted at Columbia by RMC-Normandeau once each week on 14 dates during the period 16 July through 15 October. Sampling consisted of 6 to 10 hauls per date beginning at sunset and continuing into the evenings with a net measuring 400-ft. x 6-ft. with 3/8-in. stretch mesh.

The 8-ft. square lift net used effectively in past years for sampling juvenile shad at Holtwood's inner forebay could not be deployed in 1996 because the netting platform was destroyed by ice. As an alternative, RMC attempted shad collections at Holtwood using a 10' cast net twice weekly between 16 September and 22 October. Standard effort was 10 casts per date. At Conowingo Dam, RMC checked cooling water strainers for impinged shad bi-weekly from 22 September through 24 November. RMC biologists also inspected intake screen washes at Peach Bottom Atomic Power Station three times each week during October and November.

As part of their annual juvenile *Alosa* recruitment survey, Maryland DNR sampled for shad and herring with electrofishing gear in the Susquehanna Flats during eight weeks between August 14 and October 29. Shad were also taken in Maryland's juvenile seine survey in the upper Bay. Collecting sites used in 1996 are shown in Figures 4-1, 6-2 and 6-5.

Samples of shad from most collections were returned to PFBC's Benner Spring Research Station for analysis of tetracycline marks on 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 indicating tetracycline immersion treatments.

## RESULTS

### Seine Surveys

The principal purpose for seine sampling in the Columbia reach of the lower river during summer and fall months was to document the occurrence and relative abundance of both naturally produced juvenile shad from transplanted adults and hatchery stocked fish. Sampling was concentrated near the Columbia Boro boat launch since this location proved very effective in past years. During the 14-week sampling season, a total of 282 juvenile shad were taken in 105 seine hauls, including a single collection effort of four hauls at nearby Marietta on 17 September. Subsamples of up to 30 fish per date were used for otolith analysis.

Overall shad catch-per-unit-effort (CPUE) with seines at Columbia in 1996 was 2.70 fish per haul and daily CPUE rates ranged from 0 to 9.3. Over approximately the same time period in 1995 and 1994, CPUE in the Columbia vicinity averaged 4.79 and 3.75 shad/haul, respectively. Table 1 shows juvenile shad catch and effort by date for all in-river seine collections in 1996.

**Electrofishing Above Dams**

Electrofishing was conducted by PFBC in an effort to validate the use of this gear to effectively sample for juvenile shad in areas where seining is impractical. Four sites were sampled for a total of 806 minutes of shock time producing 81 shad (Table 2). Most of these fish (64) were taken at Columbia on four dates in 35 runs lasting 350 minutes. The Clemson Island site, located about 6 miles above Clarks Ferry near Halifax, PA, was sampled on four dates and produced 8 shad in 23 runs lasting 218 minutes. Mifflintown on the Juniata River above the Thompsontown hatchery was sampled three times and produced only one shad in 22 runs lasting 178 minutes. A single sample of 8 shad was taken at Long Level in Lake Clarke in 6 runs lasting 60 minutes.

**Holtwood Dam, Peach Bottom APS, and Conowingo Dam**

Cast netting at the Holtwood inner forebay was very unproductive. Over the course of 13 sample dates from mid-September through the third week in October, 130 casts produced only nine shad. This compares to 2,100 shad in 230 lift net samples in 1995. PP&L has agreed to rebuild the lift netting platform for the 1997 sampling season.

With the cooperation of PECO Energy Company, RMC biologists examined intake water travelling screen washes for impinged American shad at the Peach Bottom Atomic Power Station (PBAPS) in lower Conowingo Pond. Screen sampling occurred three times each week (M-W-F) during the period October 1 through November 27 (26 sample dates). Collections for the season amounted to 109 juvenile American shad, of which 55 were taken from a single sampling of Unit 3 on October 21 (Table 3). Other fish in Peach Bottom collections included 316 alewives and 2,331 gizzard shad. Since no anadromous alewives were stocked in 1996, the juveniles at PBAPS are presumed to have come from Raystown Lake. Cooling water strainers at the Conowingo hydroelectric project were examined for impinged shad b-weekly during September 22 - November 24. Only 3 juvenile American shad were collected here. Otoliths were processed from a total of 93 shad taken from these three sampling areas.

Susquehanna River Mouth and Flats

Maryland DNR researchers collected 11 juvenile American shad by electrofisher from the upper Chesapeake Bay during August through October. This compares to 24 shad taken with comparable effort in 1995, 36 in 1994, and 31 in 1993. An additional 120 shad were collected in DNR's juvenile finfish seine survey in the upper Bay. Otoliths were processed from 125 fish taken in DNR collections. Electrofisher collection results by location and date are provided in Table 6 of Job VI.

Otolith Mark Analysis

Otoliths from 526 juvenile American shad taken in summer and fall collections by RMC, PFBC, and Maryland DNR were analyzed for hatchery marks. A total of 308 shad from seine and electrofishing collections above Holtwood Dam was successfully processed. Overall, 165 of the fish (54%) were marked and the remaining 143 fish (46%) were wild. All fish from Clemson Island and Long Level collections were hatchery produced and the one fish from Mifflintown was wild. Seine collections at Columbia were evenly split, but the October 7 electrofishing sample from this site was comprised of 80% hatchery fish.

Of the 165 marked fish from these combined collections, 130 (78.8%) were single-marked on day 3 indicating that they were stocked as 6-8 day old larvae in the Juniata River or at Montgomery Ferry. Remaining marked shad in seine collections included 24 fish (14.5%) with the quadruple mark on days 3, 6, 9, and 12 stocked in the North Branch at Berwick; 5 fish (3%) marked on days 3, 9, and 12 which were stocked in the West Branch at Montoursville; 3 fish (1.8%) marked on days 9, 12, and 15 stocked in Conodoguinet Creek; and one fish marked on days 3, 6, and 9 stocked in Standing Stone Creek. There were no recoveries of shad stocked in Conestoga River and two fish carried marks which could not be distinguished.

Of the 93 shad otoliths processed from Holtwood, Peach Bottom, and Conowingo collections, 69 (74%) were hatchery origin. Similar to what was seen in upstream samples, most marked fish (45 or 65%) were from single-marked fry plants in the Juniata and mainstem Susquehanna at Montgomery Ferry, and 16 fish (23%) were from the North Branch stocking.

Only 21 of 125 shad otoliths (17%) examined from DNR collections in the upper Bay were hatchery marked. Nine of these carried the double mark from the Manning hatchery indicating they were stocked below Conowingo Dam. The other 12 hatchery marks were too diffuse to categorize. The remaining 104 fish (83%) were wild, a similar ratio to that seen in 1995.

Otolith analysis of shad samples from all collecting dates and sites above and below Conowingo Dam is presented in Table 4. Above Conowingo, the 401 shad examined included samples from every week between 16 July and 23 October. Monthly sample sizes for otolith analysis ranged from 33 in July to 160 in October for all sites combined. Overall, a total of 234 fish (58.4%) were tetracycline marked and 167 (41.6%) were wild. In 1995, the hatchery component in the combined collections was 90%.

Single-marked shad stocked as 6-8 day old fry in the Juniata River and at Montgomery Ferry made up 175 of hatchery fish (75.8%) in all collections above Conowingo Dam. Remaining hatchery fish included 40 (17.3%) stocked in the North Branch; 10 (4.3%) stocked in the West Branch; 5 fish (2.2%) stocked in Conodoguinet Creek; and, one fish (0.4%) stocked in Standing Stone Creek.

## DISCUSSION

### In-Stream Movements and Outmigration Timing

Although the juvenile shad outmigration was not effectively sampled at Holtwood as in past years, it appears that the majority of fish movement from the river occurred during the last two weeks of October and in early November as water temperature declined from about 16°C to under 10°C. Outmigrants were assisted by two large flow events, with the river reaching 184,000 cfs on October 22 and 262,000 on November 11 (Safe Harbor gauge). Juveniles collected with seines at Columbia after 1 October were generally smaller than those taken in prior weeks indicating the appearance of fish from upstream waters. Peach Bottom collections peaked on October 21-23.

Single-marked fish appeared in the earliest seine collections at Columbia (16 July). These fish were first stocked on 24 May in the Juniata River suggesting that pre-migratory movements of about 60 miles were accomplished in 53 days or less. Shad fry stocked in the North Branch at Berwick on 19

June first appeared in Columbia collections on 7 August, having migrated 120 miles in as little as 49 days. The 1996 nursery season was characterized by highly variable flow rates.

## 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, seine collections included 105 hauls on 14 dates over 14 weeks from mid-July through mid-October. With a catch of 283 juvenile shad, the overall catch per unit effort (CPUE) was about 2.7 fish per haul. CPUE was highest during August (6.30) and lowest in October (1.12). Individual hauls produced between zero and 31 fish.

The table below compares female adult and fry stocking numbers and juvenile recovery data from 1996 with overall seine catch and effort at similar sites in the river during the prior 4-year period.

| Year | Adult Females | Fry Stocked | Seine Dates | Shad Catch | No. Hauls | Juvenile CPUE |
|---|---|---|---|---|---|---|
| 1997 | 34K | 8.01M | 7/17 10/20 | 879 | 90 | 9.77 |
| 1996 | 16,200 | 7.46M | 7/16-10/15 | 283 | 105 | 2.70 |
| 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 |

Electrofishing catch per effort (fish per hour) at Columbia increased from zero on 14 August to 40.0 on 7 October. It appears that catch effectiveness with this gear gradually improved as fish gained in size. Cooling water intake screens at Peach Bottom are passive samplers. Although catch numbers are typically small each year, collections here are not influenced by vagaries of net sampling and weather conditions. Juvenile shad CPUE at Peach Bottom in 1996 (from dates of first and last occurrence in October) was 9.9 fish per sampling date, less than the 12.6 noted in 1995 but substantially greater than that observed in 1992-1994 (0.03 to 1.13).

In past years, the lift net CPUE at Holtwood Dam was determined to be the best indicator of stock abundance since this gear sampled the entire outmigration period. Unfortunately, lift netting was not conducted in 1996. A cursory review of Columbia haul seine data suggests that stock abundance (based on CPUE) in 1996 was comparable to the 1992-1995 average (2.77 fish/haul). Shad collections from Peach Bottom screens, Conowingo strainers, and Holtwood cast nets were too small to use for abundance comparison.

## Growth

Wild juvenile shad collected with seines and/or electrofishing at Columbia averaged 68 mm total length (TL) in late July (range 53-81 mm) and grew to an average 126 mm (range 116-136 mm) by early October. Hatchery fish in these collections were about the same size as wild fish, improving from an average 66 mm TL (range 60-73 mm) to 125 mm (range 76-128 mm).

Recoveries of 19 quadruple-marked fish which were stocked in the North Branch at Berwick were only slightly shorter (4-8 mm) than single-marked fish stocked into the Juniata and at Montgomery Ferry. This small difference is likely related to the earlier stocking time of Juniata fry. Conversely, the four recoveries of juveniles stocked in the West Branch were younger but averaged over 10 mm longer than single-marked fish in collections. Three fingerlings taken in early October at Columbia from stockings in the Conodoguinet Creek on 14 June were the smallest fish in collections averaging 20 mm shorter than single-marked fish.

Otoliths were processed from 52 shad taken in a single day sample at Peach Bottom on 21 October. Of these, 36 were hatchery marked and 16 were wild. Wild fish displayed an average total length of 136 mm (range 112-180 mm) and four cohorts of hatchery fish averaged between 121 and 144 mm. Largest stocked fish came from the North Branch and smallest from Conodoguinet Creek.

Juvenile shad collected by DNR in the Susquehanna Flats in mid-July were of comparable size to those taken at the same time period in the Susquehanna River at Columbia (wild fish averaged 66 mm and hatchery fish 57 mm). Thereafter, however, mean sizes of Bay caught shad (hatchery and wild) were considerably smaller than river fish with no specimens exceeding 100 mm, even in October.

**Stock Composition and Mark Analysis**

Of the 401 juvenile shad otoliths analyzed from collections above Conowingo Dam, 42% were unmarked. This compares to only 10% wild fish in 1995 collections and 21-58% in 1991-1994. Of hatchery fish in all collections above Conowingo, 76% (175 of 231) were single-marked and representative of the 5.73 million fry (77% of total) stocked into the Juniata River and at Montgomery Ferry. Forty fish (17%) were from the North Branch stocking which comprised only 9% of total releases; 10 fish (4%) were from the West Branch (8% of release); 5 fish (2%) were from Conodoguinet Creek (2% of release); and one fish (0.4%) represented the 1% of fry stocked in Standing Stone Creek.

Relative survival of larval shad from the various stocking locations, in terms of their recovery rates above and below Holtwood Dam, is discussed in Appendix 3 of Job III. Although that analysis did not take into account the egg origin of the fry released, it determined that fish stocked in the North Branch showed the highest relative survival, followed by Juniata-Montgomery Ferry, Conodoguinet, and West Branch releases. During the period 1989-1994, when individual egg sources were distinctively marked, a considerable survival advantage averaging 4.3 to one was noted for Hudson River fish when compared to Delaware fish.

As expected, most tetracycline-marked recoveries at all downstream locations resulted from fish marked on day three and released at Millerstown and Montgomery Ferry at 6-8 days of age. These stockings included 3.20 million (56%) Delaware River source fish and 2.51 million (44%) Hudson River source fish. All fry stocked in the North Branch but only 57% of the fry stocked in the West Branch were Hudson source. The remainder of the West Branch release and all fry stocked into the Conestoga River, Conodoguinet and Standing Stone creeks were Delaware origin fish.

Total downstream recovery rate for the known Hudson River fry release (North Branch) was 0.000059 (40 of 682,500); and for known Delaware source fry (Conodoguinet, Conestoga, and Standing Stone) it was 0.000012 (6 of 491,700). Relative survival of these cohorts, all stocked at 13-17 days of age favored Hudson fish by a factor of 4.9, a result similar to that seen in earlier years. If this ratio of Hudson to Delaware fry survival could be assumed for mixed Juniata-Montgomery

Ferry and West Branch stockings, then egg source origin rather than age at stocking may account for much of the variability in apparent relative survival rates.

The 83% wild fish component in upper Chesapeake Bay shad collections in 1996 compares to 80% in 1995 and 61% in 1994.

## SUMMARY

The haul seine was relatively effective in taking juvenile shad at Columbia during mid-July through mid-October. Overall catch per unit effort with this gear of 2.70 shad per haul was less than that recorded in 1995 but comparable to earlier year results. Outmigration from the river apparently occurred between mid-October and the first week in November coinciding with two high flow events and rapidly dropping water temperatures. The Holtwood lift net which has provided the best CPUE information in past years was not used for shad collections in 1996.

Hatchery released fry grew well, reaching an average size of about 125 mm within 4-months of release. Wild shad grew at about the same rate as hatchery fish and maintained similar average sizes in combined monthly collections. Downstream recovery rates of hatchery-marked shad indicated that, relative to their abundance at stocking, Hudson source shad survived better than Delaware source fish, and that fish released in the Juniata River and the mainstem Susquehanna at Montgomery Ferry and Berwick survived better than those released in the West Branch and smaller tributaries. Wild fish comprised 42% of all juvenile shad collections above Conowingo Dam compared to only 10% in 1995.

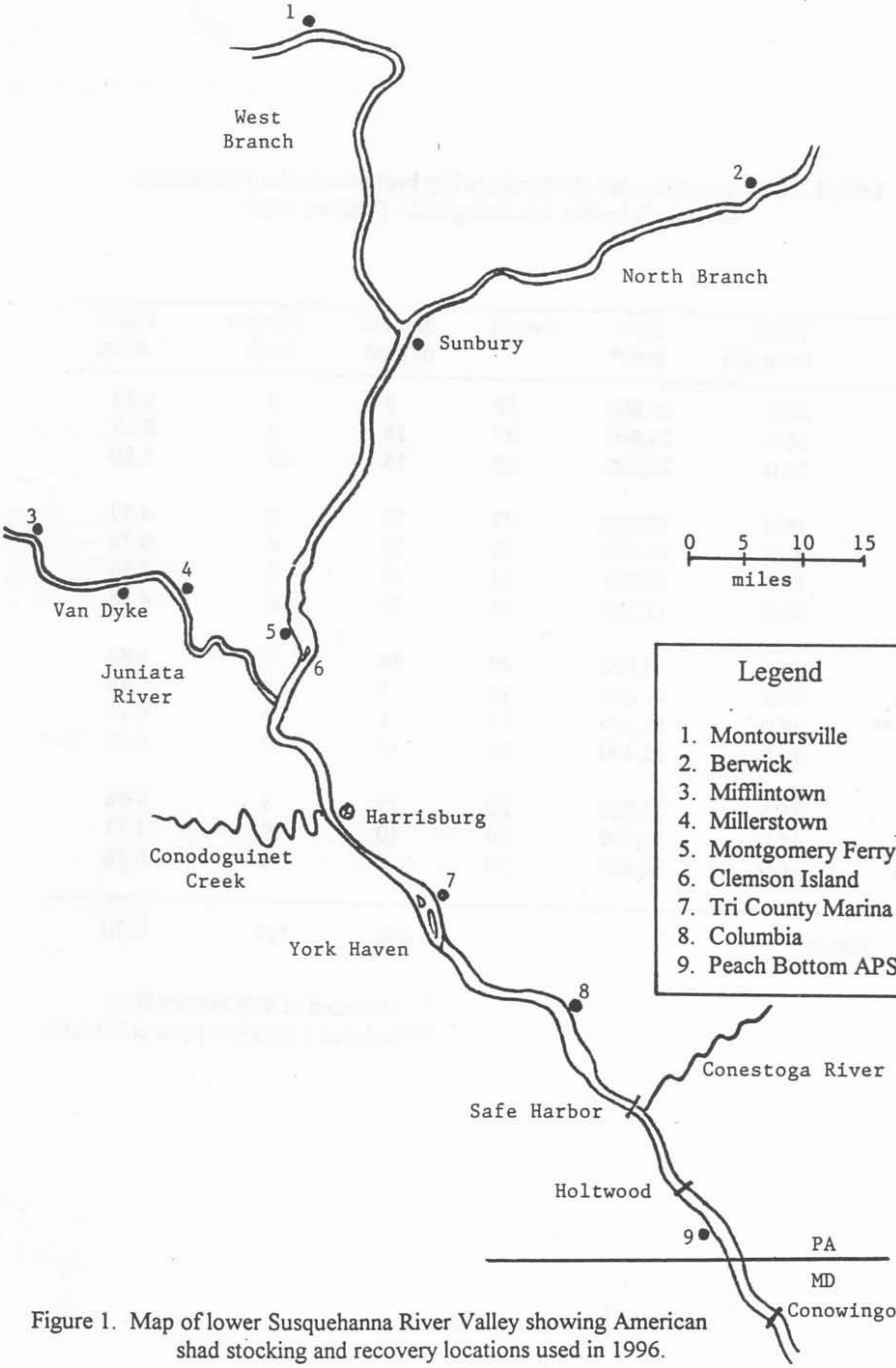


Figure 1. Map of lower Susquehanna River Valley showing American shad stocking and recovery locations used in 1996.

Table 1. Summary of juvenile shad collected by haul seine in the Susquehanna River at Columbia, PA during July - October, 1996.

| Date | Water temp (C) | Flow (cfs)* | Secchi | Number of shad | Number hauls | Catch/ effort |
|---|---|---|---|---|---|---|
| 07/16 | 26.0 | 26,600 | 32 | 2 | 6 | 0.33 |
| 07/25 | 26.0 | 28,800 | 27 | 18 | 7 | 2.57 |
| 07/31 | 26.0 | 28,300 | 39 | 15 | 10 | 1.50 |
| 08/07 | 28.0 | 18,300 | 47 | 32 | 7 | 4.57 |
| 08/13 | 23.0 | 18,800 | 30 | 56 | 6 | 9.30 |
| 08/20 | 27.5 | 11,200 | 31 | 43 | 6 | 7.16 |
| 08/27 | 26.5 | 11,300 | 36 | 39 | 8 | 4.88 |
| 09/03 | 26.5 | 7,500 | 29 | 34 | 7 | 4.86 |
| 09/10 | 25.3 | 41,600 | 16 | 3 | 7 | 0.43 |
| 09/17** | 18.0 | 55,100 | 11 | 1 | 7 | 0.14 |
| 09/26 | 19.0 | 32,300 | 28 | 12 | 9 | 1.33 |
| 10/01 | 18.5 | 35,300 | 20 | 15 | 8 | 1.88 |
| 10/08 | 14.0 | 20,700 | 20 | 10 | 9 | 1.11 |
| 10/15 | 15.0 | 14,800 | 34 | 3 | 8 | 0.38 |
| Totals | | | | 283 | 105 | 2.70 |

* Measured at Safe Harbor Dam

** Includes 1 shad in 4 hauls at Marietta

Table 2. Summary of juvenile American shad collected by electrofishing in the Juniata and Susquehanna rivers during August - October, 1996.

| Date | Site | Fishing Time (min.) | Number of runs | Shad caught | CPUE catch/hour |
|---|---|---|---|---|---|
| 08/07 | Clemson Isl. | 62 | 6 | 1 | 0.97 |
| 08/08 | Mifflintown | 52 | 7 | 1 | 1.14 |
| 08/14 | Columbia | 120 | 12 | 9 | 4.50 |
| 08/14 | Mifflintown | 30 | 4 | 0 | 0 |
| 08/15 | Clemson Isl. | 54 | 7 | 0 | 0 |
| 08/26 | Columbia | 110 | 11 | 1 | 0.55 |
| 09/03 | Mifflintown | 56 | 6 | 0 | 0 |
| 09/04 | Clemson Isl. | 52 | 5 | 7 | 8.05 |
| 09/26 | Columbia | 60 | 6 | 14 | 14.00 |
| 09/30 | Long Level | 60 | 6 | 8 | 8.00 |
| 10/07 | Columbia | 60 | 6 | 40 | 40.00 |
| 10/07 | Mifflintown | 40 | 5 | 0 | 0 |
| 10/10 | Clemson Isl. | 50 | 5 | 0 | 0 |
| Totals | | 896 | 86 | 81 | 5.42 |

Table 3. Collection of juvenile American shad and alewives from cooling water intake screens at Peach Bottom Atomic Power Station in the lower Susquehanna River during October and November, 1996.

| Date | Water temp. (C) | Flow (cfs)* | Number of shad | Number of alewives** |
|---|---|---|---|---|
| 10/01 | 18.0 | 35,300 | 0 | 0 |
| 10/02 | 17.5 | 35,000 | 3 | 0 |
| 10/04 | 16.0 | 31,600 | 0 | 0 |
| 10/07 | - | 21,400 | 4 | 0 |
| 10/09 | 15.0 | 23,000 | 10 | 0 |
| 10/11 | 14.0 | 18,600 | 1 | 0 |
| 10/14 | 14.0 | 14,800 | 11 | 0 |
| 10/16 | 14.5 | 14,300 | 1 | 0 |
| 10/18 | 16.0 | 13,800 | 4 | 0 |
| 10/21 | 11.5 | 183,300 | 55 | 2 |
| 10/23 | 12.0 | 143,000 | 18 | 231 |
| 10/25 | 12.0 | 89,100 | 1 | 55 |
| 10/28 | 12.5 | 54,000 | 0 | 0 |
| 10/30 | 13.0 | 41,400 | 0 | 1 |
| 11/01 | 12.0 | 36,700 | 0 | 0 |
| 11/04 | 9.5 | 29,800 | 0 | 0 |
| 11/06 | 8.8 | 26,100 | 0 | 0 |
| 11/08 | 9.5 | 27,500 | 0 | 0 |
| 11/11 | 9.3 | 261,700 | 0 | 0 |
| 11/13 | 6.0 | 146,900 | 1 | 25 |
| 11/15 | 5.5 | 90,700 | 0 | 1 |
| 11/18 | 5.0 | 57,000 | 0 | 1 |
| 11/20 | 5.0 | 44,000 | 0 | 1 |
| 11/22 | 5.0 | 42,100 | 0 | 0 |
| 11/25 | 4.5 | 35,300 | 0 | 0 |
| 11/27 | 4.5 | 40,000 | 0 | 0 |
| Totals | | | 109 | 316 |

* Measured at Safe Harbor Dam
** Presumably from Raystown Lake

Table 4. Analysis of juvenile American shad otoliths collected in the Susquehanna River, 1996.

| | | Immersion marks | | | | | | | Hatchery | | Wild | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collection Site | Coll. Date | Day 3 | Days 3,6,9 | Days 9,12,15 | Days 3,9, 12,15 | Days 3,9,12 | Days 3,6, 9,12 | Days 3,6 | Mark Indeter– minate* | Total | Micro– structure Not Marked | Total |
| Mifflintown | 8/8/96 | | | | | | | | | 0 | 1 | 1 |
| Clemson I. | 8/7/96 | | | | | | 1 | | | 1 | | 1 |
| | 9/4/96 | 1 | | | | 1 | 3 | | 2 | 7 | | 7 |
| Marrietta | 9/17/96 | 1 | | | | | | | | 1 | | 1 |
| Columbia | 7/16/96 | 2 | | | | | | | | 2 | | 2 |
| | 7/25/96 | 9 | | | | | | | | 9 | 9 | 18 |
| | 7/31/96 | 7 | | | | | | | | 7 | 6 | 13 |
| | 8/7/96 | 11 | | | | | 1 | | | 12 | 16 | 28 |
| | 8/13/96 | 12 | | | | | 1 | | | 13 | 16 | 29 |
| | 8/14/96 | 3 | | | | | 1 | | | 4 | 5 | 9 |
| | 8/20/96 | 10 | | | | | 1 | | | 11 | 19 | 30 |
| | 8/26/96 | | | | | | 1 | | | 1 | | 1 |
| | 8/27/96 | 15 | | | | | | | | 15 | 15 | 30 |
| | 9/3/96 | 12 | 1 | | | | 1 | | | 14 | 15 | 29 |
| | 9/10/96 | | | | | | | | | 0 | 3 | 3 |
| | 9/12/96 | 2 | | | | | 1 | | | 3 | 5 | 8 |
| | 9/26/96 | 8 | | | | 3 | 2 | | | 13 | 12 | 25 |
| | 10/1/96 | 7 | | | | | | | | 7 | 8 | 15 |
| | 10/7/96 | 22 | | 1 | | 1 | 8 | | | 32 | 8 | 40 |
| | 10/8/96 | 3 | | 1 | | | 2 | | | 6 | 4 | 10 |
| | 10/15/96 | 1 | | 1 | | | | | | 2 | 1 | 3 |
| Long Level | 9/30/96 | 4 | | | | | 1 | | | 5 | | 5 |
| Above Holtwood | | 130 | 1 | 3 | 0 | 5 | 24 | 0 | 2 | 165 | 143 | 308 |
| Percent | | 42% | 0% | 1% | 0% | 2% | 8% | 0% | 1% | 54% | 46% | |

Table 4. (continued).

| Collection Site | Coll. Date | Immersion marks: Day 3 | Days 3,6,9 | Days 9,12,15 | Days 3,9,12,15 | Days 3,9,12 | Days 3,6,9,12 | Days 3,6 | Hatchery: Mark Indeter-minate* | Total | Wild Micro-structure Not Marked | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Holtwood | 9/16/96 | 1 | | | | | | | | 1 | | 1 |
| | 10/10/96 | 2 | | | | | | | | 2 | 2 | 4 |
| | 10/19/96 | | | | | | 1 | | | 1 | 1 | 2 |
| Peach Bottom | 10/2/96 | 2 | | | | 1 | | | | 3 | | 3 |
| | 10/7/96 | 1 | | | | | 1 | | | 2 | 1 | 3 |
| | 10/9/96 | 7 | | | | | 1 | | | 8 | 2 | 10 |
| | 10/11/96 | | | | | | | | | 0 | 1 | 1 |
| | 10/14/96 | 3 | | | | | 3 | | | 6 | | 6 |
| | 10/16/96 | | | | | | | | | 0 | 1 | 1 |
| | 10/18/96 | 2 | | | | | 2 | | | 4 | | 4 |
| | 10/21/96 | 23 | | 2 | | 4 | 7 | | 1 | 37 | 15 | 52 |
| | 10/23/96 | 3 | | | | | 1 | | | 4 | | 4 |
| | 10/25/96 | | | | | | | | | 0 | | 0 |
| Conowingo Strainers | 10/11/96 | 1 | | | | | | | | 1 | 1 | 2 |
| Holt./P. Bot./Con. | | 45 | 0 | 2 | 0 | 5 | 16 | 0 | 1 | 69 | 24 | 93 |
| Percent | | 48% | 0% | 2% | 0% | 5% | 17% | 0% | 1% | 74% | 26% | |
| Total (above Con.) | | 175 | 1 | 5 | 0 | 10 | 40 | 0 | 3 | 234 | 167 | 401 |
| Percent | | 44% | 0% | 1% | 0% | 2% | 10% | 0% | 1% | 58% | 42% | |
| Below Conowingo | | | | | | | | | | | | |
| Howell Pt. | 7/15/96 | | | | | | | | | 0 | 5 | 5 |
| Ordaniary Pt. | 7/15/96 | | | | | | | | | 0 | 1 | 1 |
| Elk Neck Park | 7/16/96 | | | | | | | | | 0 | 12 | 12 |
| Plum Pt. | 7/17/96 | | | | | | | | | 0 | 19 | 19 |
| Tydings Park | 7/17/96 | | | | | | | 2 | 6 | 8 | 14 | 22 |
| Tydings Estate | 7/17/96 | | | | | | | | | 0 | 1 | 1 |
| Poplar Pt. | 7/16/96 | | | | | | | | | 0 | 3 | 3 |

Table 4. (continued).

| Collection Site | Coll. Date | Immersion marks: Day 3 | Days 3,6,9 | Days 9,12,15 | Days 3,9, 12,15 | Days 3,9,12 | Days 3,6, 9,12 | Days 3,6 | Hatchery: Mark Indeter–minate* | Total | Wild: Micro–structure Not Marked | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Howell Pt. | 8/12/96 | | | | | | | | | 0 | 9 | 9 |
| Welch Pt. | 8/13/96 | | | | | | | | | 0 | 7 | 7 |
| Poplar Pt. | 8/13/96 | | | | | | | | | 0 | 3 | 3 |
| Hyland Pt. | 8/13/96 | | | | | | | | | 0 | 4 | 4 |
| Elk Neck | 8/13/96 | | | | | | | | 1 | 1 | 1 | 2 |
| Poplar Pt. | 8/14/96 | | | | | | | | 1 | 1 | 1 | 2 |
| Tydings Park | 8/14/96 | | | | | | | 2 | 2 | 4 | 1 | 5 |
| Tydings Estate | 8/14/96 | | | | | | | | 1 | 1 | 1 | 2 |
| Cell 7 | 8/14/96 | | | | | | | | | 0 | 1 | 1 |
| Carpenter Pt. | 8/14/96 | | | | | | | 1 | | 1 | 2 | 3 |
| Plum Pt. | 8/14/96 | | | | | | | | | 0 | 2 | 2 |
| Cell 19 | 8/27/96 | | | | | | | | | 0 | 1 | 1 |
| Cell 20 | 8/27/96 | | | | | | | | | 0 | 1 | 1 |
| Poplar Pt. | 9/6/96 | | | | | | | | | 0 | 2 | 2 |
| Welch Pt. | 9/6/96 | | | | | | | | | 0 | 2 | 2 |
| Ordaniary Pt. | 9/6/96 | | | | | | | | | 0 | 2 | 2 |
| Cell 3 | 9/9/96 | | | | | | | | | 0 | 1 | 1 |
| Elk Neck Pk. | 9/9/96 | | | | | | | | | 0 | 1 | 1 |
| Tydings Park | 9/18/96 | | | | | | | 2 | 1 | 3 | | 3 |
| Carpenter pt. | 9/18/96 | | | | | | | | | 0 | 3 | 3 |
| Site 21 | 10/2/96 | | | | | | | | | 0 | 1 | 1 |
| Cell 18 | 10/10/96 | | | | | | | 2 | | 2 | 1 | 3 |
| Cell 19 | 10/10/96 | | | | | | | | | 0 | 2 | 2 |
| Total (below Con.) | | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 12 | 21 | 104 | 125 |
| Percent | | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 10% | 17% | 83% | |

Stocking sites for immersion marks:
Day 3: Juniata R. at Millerstown
Days 3,6,9: Standing Stone Cr.
Days 9,12,15: Conodoguinet Cr.
Days 3,9,12,15: Conestoga R.
Days 3,9,12: W. Br. Susquehanna R.
Days 3,6,9,12: N. Br. Susquehanna R.
Days 3,6: Below Conowingo Dam

* Mark present but spacing too close to determine precise sequence. All indeterminate marked fish collected below Conowingo Dam are presumed to have been marked on days 3 and 6.

Job V., Task 1. Analysis of adult American shad otoliths, 1996

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Abstract

A total of 383 adult American shad otoliths were processed from adult shad sacrificed at the Conowingo Dam fish lifts in 1996. Based on tetracycline marking and otolith microstructure, 45% of the 379 readable otoliths were identified as wild and 55% hatchery. Only 1 of 207 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 (70%) than that found in Conowingo Fish Lift collections (45%). Double marked fish (releases below Conowingo Dam) represented 6% of the marked fish in the Conowingo Lift samples and 10% 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 1986-1990 year classes, stocking of approximately 435 hatchery larvae was required to return one adult to the lifts. For wild fish, transport of 1.30 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.

Since mark retention did not approach 100% until 1987, adult hatchery shad from cohorts produced before 1987 did not exhibit 100% marking. For the years in which these fish were recruited into the fishery, marking rates could therefore be used only to determine minimum contribution of hatchery-reared fish. For fish which did not exhibit a mark, otolith microstructure (Hendricks et al., 1994) was used to distinguish hatchery fish from wild fish. This report presents results of evaluation of otoliths from adult American shad collected in 1996.

## 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 in the upper

Chesapeake Bay as well as the Chester and Nanticoke Rivers 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 for mark analysis in permount on a microscope slide, while the other was mounted for ageing on clear tape in acrylic. Otoliths were delivered to Benner Spring Fish Research Station.

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

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

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 independent observers 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 Upper Bay 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 1996. Age composition data was gathered as follows: for 1996, age composition data was collected from the otolith analysis above. For 1991-1995, age composition data was taken from scale samples collected from the fish used for otolith analysis. These samples were collected by sacrificing every 100th fish collected in the lifts, and as such, represent a truly random sample. For 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 383 shad was sacrificed for otolith analysis from the lift catch at Conowingo Dam in 1996. For 4 of those, otoliths were broken, not extracted, or had unreadable grinds, leaving 379 readable otoliths (Table 1). A total of 172 (45%) otoliths exhibited wild microstructure and no tetracycline mark. A total of 55% of the specimens were identified as hatchery in origin. Only one otolith (<1%) had hatchery microstructure and no tetracycline mark. Two-hundred and six otoliths exhibited tetracycline marks including single, double, triple, quadruple and quintuple 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 triple immersion mark (days 3, 13, and 17) and a triple feed mark indicative of Upper Spring Creek Pond 3 culture in 1993 or 1994.

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 1989-1996 ranged from 55% to 89% (Table 2, Figure 1). Although the proportion of wild fish in the Conowingo Lift collections was low prior to 1996, the numbers of wild fish have been increasing steadily since 1993 (Figure 2).

Analysis of otoliths of adult American shad collected in Upper Chesapeake Bay pound nets suggests that the pound nets and fish lifts are sampling intermixed stocks. Wild fish constituted 52% of the pound net catch in 1993, 44% of the pound net catch in 1994, 42% of the pound net catch in 1995, and 70% of the pound net catch in 1996. The lift catch included only 17% wild fish in 1993, 10 % wild fish in 1994, 16% wild fish in 1995, and 45% wild fish in 1996 (Table 2). Based on a Chi-square Test of Independence, we concluded that the proportion of wild and hatchery fish was <u>dependent</u> upon the collection site (Chi-square = 22.16, df =1, 1996 data) and therefore the samples at those two sites have different stock constituencies. Similar results were obtained in 1993 through 1995. One possible explanation for this is that Upper Bay stocks, whether wild or hatchery, do not have a strong urge to move upstream and do not enter the lifts with the same frequency as do fish which originated upstream.

Otoliths were extracted and analyzed from adult shad collected by MDNR in the Nanticoke and Chester Rivers (Table 3). All 36 otoliths analyzed from the Nanticoke River were wild. This contrasts with a sample taken there in 1995 in which 5 of 20 (25%) of the otoliths exhibited marks. For the Chester River, four of six otoliths analyzed exhibited marks (Table 3). Two of the marked fish were stocked below Conowingo Dam (double marks) and two were stocked above the Dam. One of the double marked fish also exhibited a double feed mark, indicative of culture in the MDNR ponds at Elkton in 1991 (111,500 fingerlings stocked).

Age frequencies for Susquehanna River fish were analyzed using otolith age data (Table 4). Overall mean age was 3.8 years for males and 4.9 years for females. For wild fish, mean ages were 3.6 for males and 4.5 for females and sex ratios were 2.5 to 1, males to females (Table 5). It is interesting to note that the increase in returns of wild fish experienced in 1996 (Figure 2) were predicted last year (Hendricks, 1996) based on mean ages and sex ratios in the 1995 sample.

For hatchery fish, mean age was higher; 4.1 for males and 5.0 for females, and sex ratios were .9 to 1, males to females. This was related to the decrease in return of hatchery fish in 1996 as a result of poor hatchery production in 1992 and 1993 (see Table 2, Job III). The low frequencies of age 3 and 4 hatchery males, in relation to wild males also suggests poor performance of hatchery fish in 1992 and 1993. These data suggest that capture of hatchery fish in the Conowingo Fish Lifts in 1997 may be the lowest since 1993.

Length frequencies and mean length at age are tabulated in Tables 6 to 9. As expected, females were larger than males. The apparent differences in length frequencies between wild and hatchery fish for both sexes were related to differences in age composition resulting from the poor hatchery production in 1992 and 1993. No consistent difference was apparent in mean length at age between hatchery and wild fish for either males or females.

Adult shad collected at the lifts were partitioned into their respective year classes using scale or otolith age data and corrected for hatchery contribution (Table 10). Total recruitment of hatchery-reared fish to the lifts by year class ranged from 76 for the 1974 year class to 34,602 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 10). In addition, year classes after 1990 are not fully recruited. Thus, the only truly reliable data is for year classes from 1987 to 1990. For this period, the number of hatchery larvae required to produce one returning adult ranged from 162 to 541. For the 1986 year class, 576 larvae were required to produce one returning adult. This is a minor under-estimate since the 241 adults recruited in 1988 (Table 10) undoubtedly included some wild fish. For the five year classes from 1986 to 1990, an average of 435 hatchery larvae were required to produce one returning adult. For this analysis, fish stocked below Conowingo Dam or fish stocked as fingerlings were excluded from the hatchery contribution. Hendricks (1996) erroneously included these fish and consequently reported fewer fry required to return one adult to the lifts.

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 11). Once again, data for year classes prior to 1987 and after 1990 are of limited value because they were not partitioned into hatchery and wild or they have not been fully recruited. For the period 1986 to 1990, it took an average of 1.30 adults transported to produce one returning adult, below replacement. The actual stock/recruitment ratio would be higher still since some of the wild fish which entered the lifts would have been of Upper Bay origin. 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.

# Literature Cited

Hendricks, M.L. 1996. Analysis of adult American shad otoliths based on otolith microstructure and tetracycline marking, 1995. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1995. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.W.H. Backman, and D.L. Torsello. 1991. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad in the Susquehanna River. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1990. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1986. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1985. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1987. American shad hatchery operations. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Hendricks, M.L., T.R. Bender, and V.A. Mudrak. 1991. Multiple marking of American shad otoliths with tetracycline antibiotics. North American Journal of Fisheries Management. 11: 212-219.

Hendricks, M.L., D. L. Torsello, and T.W.H. Backman. 1994. Use of otolith microstructure to distinguish between wild and hatchery-reared American shad (Alosa sapidissima) in the Susquehanna River. North American Journal of Fisheries Management.

Lorson, R.D. and V.D. Mudrak. 1987. Use of tetracycline to mark otoliths of American shad fry. N. Am. J. Fish. Mgmt. 7:453-455.

Ott, L. 1977. An introduction to statistical methods and data analysis. Duxberry Press, Belmont, California 730 p.

Young, L.M. 1987. Juvenile American shad outmigration assessment. In Restoration of American shad to the Susquehanna River, Annual Progress Report, 1986. Susquehanna River Anadromous Fish Restoration Committee.

Figure 1. Estimated composition of adult American shad caught at Conowingo Dam, based on otolith microstructure and tetracycline marking, 1989-1996.

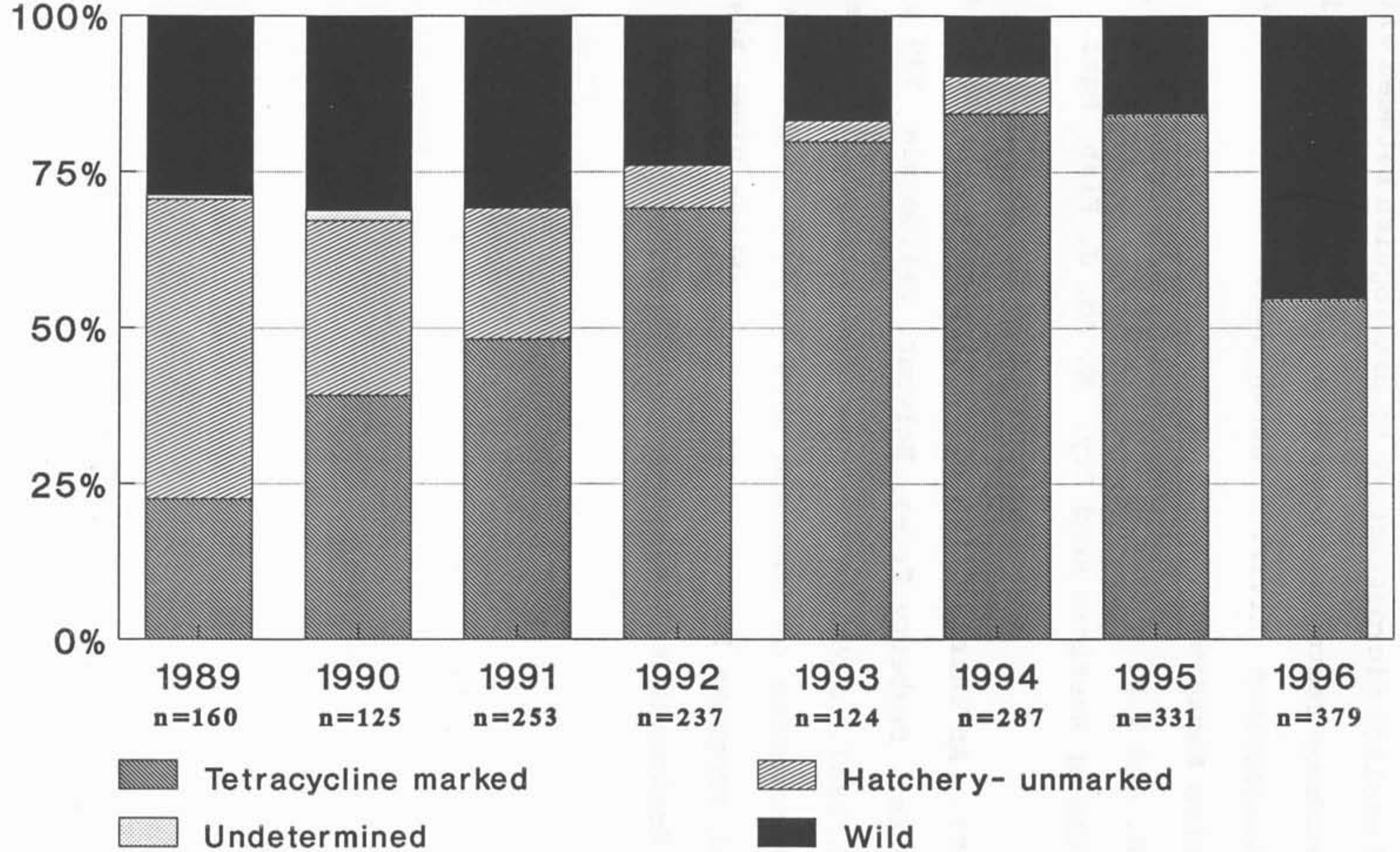

Figure 2. Catch of adult American shad at the Conowingo Dam Fish Lifts, 1972-1996.

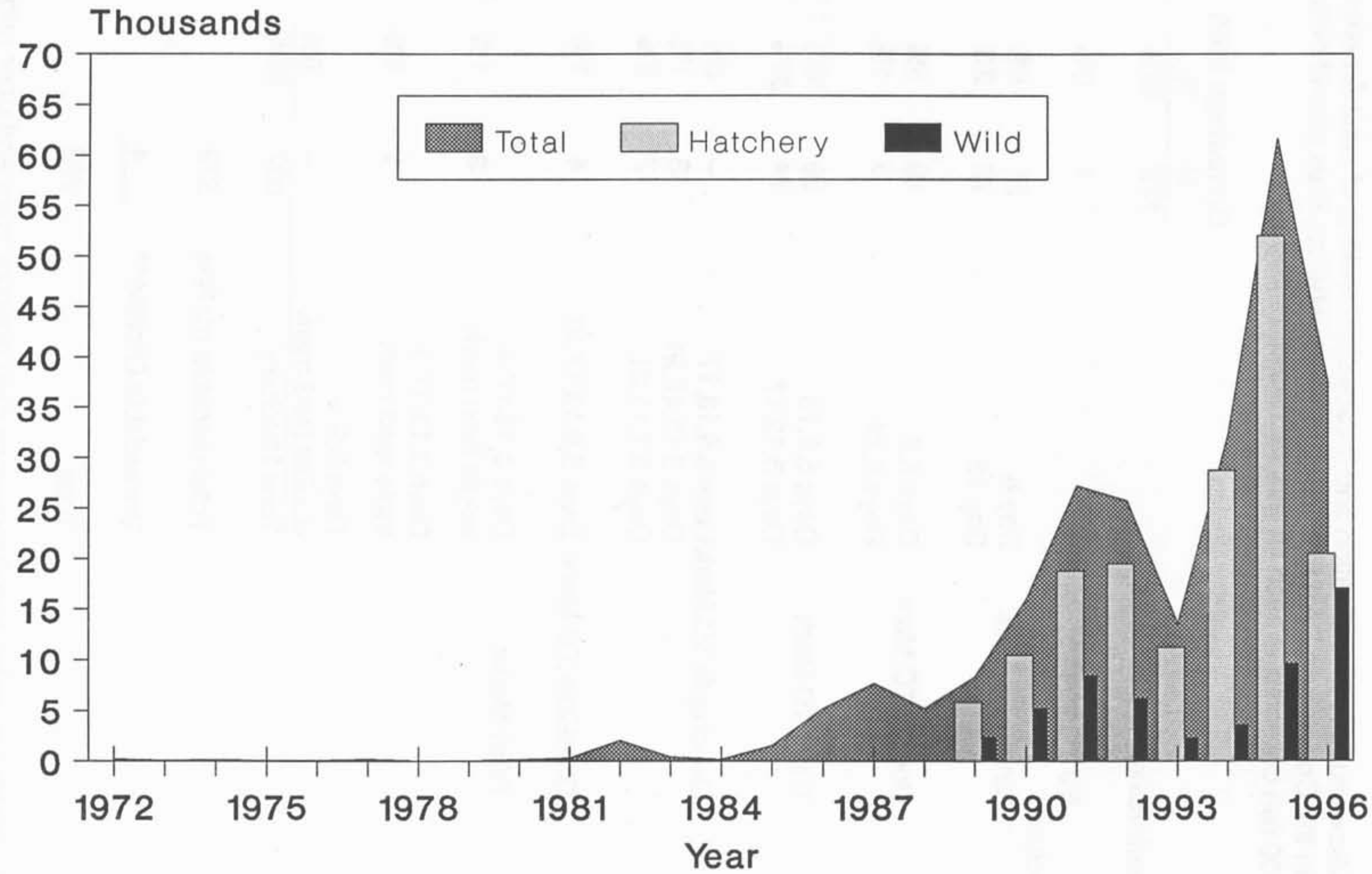

Table 1. Microstructure classification and tetracycline marking of adult American shad collected in the Conowingo Dam Fish Lifts and Susquehanna Flats pound nets, 1996. One of every 100 fish collected in each lift was sacrificed.

| | | | Conowingo Dam | | Susq. Flats | |
|---|---|---|---|---|---|---|
| | | | N | % | N | % |
| Wild Microstructure, No TC Mark | | | 172 | 45% | 81 | 70% |
| Hatchery Microstructure | No TC Mark* | | 1 | 0% | – | 0% |
| | Single TC Mark | Day 5 | 21 | 6% | 4 | 3% |
| | | Day 18 | 12 | 3% | 2 | 2% |
| | Double TC Mark | Days 5,9 | 19 | 5% | 12 | 10% |
| | | Days 5,19 | 3 | 1% | – | 0% |
| | Triple TC Mark | Days 5,9,13 | 59 | 16% | 7 | 6% |
| | | Days 3,13,17 | 74 | 20% | 7 | 6% |
| | Quadruple TC Mark | Days 5,9,13,17 | – | 0% | – | 0% |
| | | Days 3,13,17,21 | 3 | 1% | – | 0% |
| | | Days 3,7,11,21 | 7 | 2% | – | 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 3,13,17 + triple feed mark | 1 | 0% | – | 0% |
| | | Days 5,9 + double feed mark | – | 0% | 2 | 2% |
| | | Total Hatchery | 207 | 55% | 34 | 30% |
| | | Total readable otoliths | 379 | | 115 | |
| | | Unreadable Otoliths** | 4 | | 3 | |
| | | Total | 383 | | 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, 1989–1996. 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%** | |
| | Trap Catch | 2,371 | 51 | 3,947 | 1,849 | 5,796 | 8,218 |
| 1990 | N (sample) | 32 | 2 | 42 | 49 | 91 | 125 |
| | % (sample) | 26% | 2% | 34% | 39% | 73% | |
| | **% (population)** | **31%** | **2%** | **28%** | **39%** | **67%** | |
| | Trap Catch | 4,930 | 252 | 4,375 | 6,162 | 10,537 | 15,719 |
| 1991 | N (sample) | 68 | 0 | 63 | 122 | 185 | 253 |
| | % (sample) | 27% | 0% | 25% | 48% | 73% | |
| | **% (population)** | **31%** | **0%** | **21%** | **48%** | **69%** | |
| | Trap Catch | 8,430 | 0 | 5,668 | 13,129 | 18,797 | 27,227 |
| 1992 | N (sample) | 54 | 0 | 19 | 164 | 183 | 237 |
| | % (sample) | 23% | 0% | 8% | 69% | 77% | |
| | **% (population)** | **24%** | **0%** | **7%** | **69%** | **76%** | |
| | Trap Catch | 6,111 | 0 | 1,811 | 17,798 | 19,610 | 25,721 |
| 1993 | N (sample) | 21 | 0 | 4 | 99 | 103 | 124 |
| | % (sample) | 17% | 0% | 3% | 80% | 83% | |
| | **% (population)** | **17%** | **0%** | **3%** | **80%** | **83%** | |
| | Trap Catch | 2,322 | 0 | 409 | 10,815 | 11,224 | 13,546 |
| 1994 | N (sample) | 28 | 0 | 17 | 242 | 259 | 287 |
| | % (sample) | 10% | 0% | 6% | 84% | 90% | |
| | **% (population)** | **11%** | **0%** | **5%** | **84%** | **89%** | |
| | Trap Catch | 3,442 | 0 | 1,627 | 27,261 | 28,888 | 32,330 |
| 1995 | N (sample) | 52 | 0 | 1 | 278 | 279 | 331 |
| | % (sample) | 16% | 0% | 0% | 84% | 84% | |
| | **% (population)** | **15%** | **0%** | **1%** | **84%** | **85%** | |
| | Trap Catch | 9,488 | 0 | 383 | 51,779 | 52,162 | 61,650 |
| 1996 | N (sample) | 172 | | 1 | 206 | 207 | 379 |
| | % (sample) | 45% | 0% | 0% | 54% | 55% | |
| | **% (population)** | **44%** | **0%** | **1%** | **54%** | **56%** | |
| | Trap Catch | 16,634 | 0 | 489 | 20,389 | 20,878 | 37,512 |

Table 3. Microstructure classification and tetracycline marking of adult American shad collected by MDNR in the Nanticoke and Chester Rivers, 1996.

| | | | Nanticoke R. | | Chester R. | |
|---|---|---|---|---|---|---|
| | | | N | % | N | % |
| Wild Microstructure, No TC Mark | | | 36 | 100% | 2 | 33% |
| Hatchery Microstructure | No TC Mark* | | – | 0% | – | 0% |
| | Single TC Mark | Day 5 | – | 0% | – | 0% |
| | | Day 18 | – | 0% | 1 | 17% |
| | Double TC Mark | Days 5,9 | – | 0% | 1 | 17% |
| | | Days 5,19 | – | 0% | – | 0% |
| | Triple TC Mark | Days 5,9,13 | – | 0% | 1 | 17% |
| | | Days 3,13,17 | – | 0% | – | 0% |
| | Quadruple TC Mark | Days 5,9,13,17 | – | 0% | – | 0% |
| | | Days 3,13,17,21 | – | 0% | – | 0% |
| | | Days 3,7,11,21 | – | 0% | – | 0% |
| | Quintuple TC Mark | Days 5,9,13,17,21 | – | 0% | – | 0% |
| | Feed Marks | Days 3,13,17 + single feed mark | – | 0% | – | 0% |
| | | Days 3,13,17 + triple feed mark | – | 0% | – | 0% |
| | | Days 3,7,11,21 + single feed mark | – | 0% | – | 0% |
| | | Days 5,9 + double feed mark | – | 0% | 1 | 17% |
| | | Total Hatchery | 0 | 0% | 4 | 67% |
| | | Total readable otoliths | 36 | | 6 | |
| | | Unreadable Otoliths** | – | | – | |
| | | Total | 36 | | 6 | |

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

Table 4. Age by sex of adult American shad sacrificed for otolith analysis, Conowingo fish lifts, Susquehanna River, 1996.

| Sex | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ?? | Totals | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Male | 4 | 80 | 70 | 47 | 1 | 2 | 0 | 11 | 215 | 3.8 |
| Female | 0 | 1 | 44 | 75 | 18 | 5 | 0 | 13 | 156 | 4.9 |
| Unknown | | 1 | 5 | 4 | 1 | | | 1 | 12 | 4.5 |
| Totals | 4 | 82 | 119 | 126 | 20 | 7 | 0 | 25 | 383 | 4.3 |

Table 5. Age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo Fish Lifts, Susquehanna River, 1996.

| Sex | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ?? | Totals | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Male– Wild | 3 | 54 | 41 | 15 | | | | 8 | 121 | 3.6 |
| Male– Hatc. | 1 | 25 | 29 | 32 | 1 | 2 | | 2 | 92 | 4.1 |
| Female– Wild | | 3 | 20 | 14 | 6 | | | 6 | 49 | 4.5 |
| Female– Hatc. | | | 24 | 60 | 10 | 5 | | 6 | 105 | 5.0 |
| Totals | 4 | 82 | 114 | 121 | 17 | 7 | 0 | 22 | 367 | 4.2 |

Table 6. Length frequency by sex of adult American shad sacrificed for otolith analysis, Conowingo Fish Lifts, 1996.

| Sex | 301–325 | 326–350 | 351–375 | 376–400 | 400–425 | 426–450 | 451–475 | 476–500 | 501–525 | 526–550 | 551–575 | 576–600 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Male | 3 | 10 | 56 | 52 | 48 | 24 | 18 | 3 | | | 1 | | 215 |
| Female | | 2 | 3 | | 20 | 31 | 57 | 30 | 9 | | | | 152 |
| Unknown | | | 1 | 2 | | 4 | 4 | | | 1 | | | 12 |
| Totals | 3 | 12 | 60 | 54 | 68 | 59 | 79 | 33 | 9 | 1 | 1 | 0 | 379 |

Table 7. Length frequency by sex and origin of adult American shad sacrificed for otolith analysis, Conowingo Fish Lifts, 1996.

| Sex | 301–325 | 326–350 | 351–375 | 376–400 | 400–425 | 426–450 | 451–475 | 476–500 | 501–525 | 526–550 | 551–575 | 576–600 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Male– Wild | 2 | 7 | 39 | 31 | 25 | 7 | 8 | 1 | | | | | 120 |
| Male– Hatc. | 1 | 2 | 16 | 21 | 23 | 17 | 10 | 2 | | | | | 92 |
| Female– Wild | | 2 | 1 | | 11 | 10 | 14 | 7 | 2 | | | | 47 |
| Female– Hatc. | | | 2 | | 9 | 20 | 42 | 23 | 7 | | | | 103 |
| Totals | 3 | 11 | 58 | 52 | 68 | 54 | 74 | 33 | 9 | 0 | 0 | 0 | 362 |

Table 8. Mean length at age by sex of adult American shad sacrificed for otolith analysis, Conowingo fish lifts, Susquehanna River, 1996.

| Sex | 2 | (n) | 3 | (n) | 4 | (n) | 5 | (n) | 6 | (n) | 7 | (n) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Male | 345 | (4) | 373 | (80) | 408 | (70) | 427 | (47) | 465 | (1) | 435 | (2) |
| Female | | | 403 | (1) | 444 | (44) | 465 | (74) | 470 | (16) | 471 | (5) |

Table 9. Mean length at age by sex by origin of adult American shad sacrificed for otolith analysis, Conowingo Fish Lifts, Susquehanna River, 1996.

| Sex | 2 | (n) | 3 | (n) | 4 | (n) | 5 | (n) | 6 | (n) | 7 | (n) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Male– Wild | 357 | (3) | 371 | (54) | 404 | (41) | 437 | (15) | | | | |
| Male– Hatc. | 308 | (1) | 378 | (25) | 415 | (29) | 423 | (32) | 465 | (1) | 435 | (2) |
| Female– Wild | | | 403 | (1) | 429 | (20) | 466 | (14) | 459 | (6) | | |
| Female– Hatc. | | | | | 457 | (24) | 464 | (59) | 476 | (10) | 471 | (5) |

Table 10. 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.

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Hat. Contri. | Number of Adult shad collected in trap by Year Class 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1973 | 65 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1974 | 121 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1975 | 87 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1976 | 82 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 2 | | | | | | | | | |
| 1977 | 165 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 28 | 3 | | | | | | | | |
| 1978 | 54 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 31 | 9 | 1 | | | | | | | |
| 1979 | 50 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 12 | 28 | 9 | 1 | | | | | | |
| 1980 | 139 | | | 2.7 | 33.2 | 57.1 | 6.5 | | | 4 | 46 | 79 | 9 | | | | | | |
| 1981 | 328 | | | 1.9 | 11.6 | 51.6 | 32.9 | 1.9 | | 0 | 6 | 38 | 169 | 108 | 6 | | | | |
| 1982 | 2,039 | | | 1.7 | 24.7 | 61.9 | 11.7 | | | | 0 | 35 | 503 | 1262 | 238 | 0 | | | |
| 1983 | 413 | | 2.7 | 28.3 | 55.8 | 9.3 | 3.9 | | | | | 11 | 117 | 231 | 38 | 16 | 0 | | |
| 1984 | 167 | 0.0 | 7.4 | 12.1 | 8.7 | 59.7 | 12.1 | 0.0 | | | | | 0 | 12 | 20 | 15 | 100 | 20 | |
| 1985 | 1,546 | 0.0 | 1.7 | 6.9 | 30.2 | 50.8 | 10.5 | 0.0 | | | | | | 0 | 26 | 106 | 466 | 786 | 162 |
| 1986 | 5,195 | 0.0 | 1.6 | 10.5 | 35.1 | 35.9 | 16.6 | 0.4 | | | | | | | 0 | 82 | 543 | 1824 | 1865 |
| 1987 | 7,667 | 0.0 | 3.9 | 13.8 | 25.8 | 45.7 | 10.6 | 0.2 | | | | | | | | 0 | 301 | 1055 | 1978 |
| 1988 | 5,146 | 0.0 | 4.0 | 31.7 | 38.1 | 21.2 | 4.7 | 0.4 | | | | | | | | | 0 | 204 | 1629 |
| 1989 | 8,218 | 0.0 | 4.3 | 18.1 | 41.5 | 30.2 | 5.6 | 0.2 | 0.70 | | | | | | | | | 0 | 250 |
| 1990 | 15,719 | 0.1 | 5.5 | 32.7 | 45.2 | 15.0 | 1.5 | | 0.66 | | | | | | | | | 15 | 575 |
| 1991 | 27,227 | | 10.7 | 36.7 | 38.4 | 12.4 | 1.7 | | 0.65 | | | | | | | | | | 0 |
| 1992 | 25,721 | 0.6 | 12.3 | 35.7 | 36.8 | 11.7 | 2.9 | | 0.72 | | | | | | | | | | |
| 1993 | 13,546 | 0.0 | 3.2 | 21.6 | 52.8 | 21.6 | 0.8 | 0.0 | 0.65 | | | | | | | | | | |
| 1994 | 32,330 | 0.0 | 3.3 | 22.6 | 54.7 | 19.3 | 0.0 | 0.0 | 0.81 | | | | | | | | | | |
| 1995 | 61,650 | 0.0 | 4.1 | 22.1 | 61.5 | 11.7 | 0.6 | 0.0 | 0.78 | | | | | | | | | | |
| 1996 | 37,513 | 0.0 | 2.0 | 5.6 | 35.2 | 33.2 | 22.9 | 1.1 | 0.47 | | | | | | | | | | |
| | | | | | | | | | Tot. Recruits to Lifts: | 76 | 93 | 174 | 799 | 1,613 | 329 | 219 | 1,411 | 3,904 | 6,458 |
| | | | | | | | | | Fry releases (above Cono.) | 0 | 0 | 518,000 | 968,901 | 2,124,000 | 629,500 | 3,526,275 | 2,029,650 | 5,018,800 | 4,047,600 |
| | | | | | | | | | **stock\recruit ratio (X 1000)** | | | 0.34 | 0.83 | 0.76 | 0.52 | 0.06 | 0.69 | 0.78 | 1.60 |
| | | | | | | | | | **#fry to produce 1 adult** | | | 2,982 | 1,212 | 1,317 | 1,913 | 16,097 | 1,439 | 1,286 | 627 |

Note: 1991 and 1992 year classes are not fully recruited.
Corrected for classification errors and tag recoveries from fingerlings or fish stocked below Conowingo Dam.

(Shaded) Corrected for hatchery contribution.

Table 10. (continued).

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Hat. Contri. | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1973 | 65 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1974 | 121 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1975 | 87 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1976 | 82 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1977 | 165 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1978 | 54 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1979 | 50 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | |
| 1980 | 139 | | | 2.7 | 33.2 | 57.1 | 6.5 | | | | | | | | | | | |
| 1981 | 328 | | | 1.9 | 11.6 | 51.6 | 32.9 | 1.9 | | | | | | | | | | |
| 1982 | 2,039 | | | 1.7 | 24.7 | 61.9 | 11.7 | | | | | | | | | | | |
| 1983 | 413 | | 2.7 | 28.3 | 55.8 | 9.3 | 3.9 | | | | | | | | | | | |
| 1984 | 167 | 0.0 | 7.4 | 12.1 | 8.7 | 59.7 | 12.1 | 0.0 | | | | | | | | | | |
| 1985 | 1,546 | 0.0 | 1.7 | 6.9 | 30.2 | 50.8 | 10.5 | 0.0 | | | | | | | | | | |
| 1986 | 5,195 | 0.0 | 1.6 | 10.5 | 35.1 | 35.9 | 16.6 | 0.4 | | 861 | | | | | | | | |
| 1987 | 7,667 | 0.0 | 3.9 | 13.8 | 25.8 | 45.7 | 10.6 | 0.2 | | 3504 | 810 | | | | | | | |
| 1988 | 5,146 | 0.0 | 4.0 | 31.7 | 38.1 | 21.2 | 4.7 | 0.4 | | 1962 | 1092 | 241 | | | | | | |
| 1989 | 8,218 | 0.0 | 4.3 | 18.1 | 41.5 | 30.2 | 5.6 | 0.2 | 0.70 | 1041 | 2387 | 1734 | 319 | | | | | |
| 1990 | 15,719 | 0.1 | 5.5 | 32.7 | 45.2 | 15.0 | 1.5 | | 0.66 | 3403 | 4704 | 1558 | 151 | 0 | | | | |
| 1991 | 27,227 | | 10.7 | 36.7 | 38.4 | 12.4 | 1.7 | | 0.65 | 1891 | 6469 | 6768 | 2190 | 299 | 0 | 0 | | |
| 1992 | 25,721 | 0.6 | 12.3 | 35.7 | 36.8 | 11.7 | 2.9 | | 0.72 | 108 | 2274 | 6606 | 6823 | 2166 | 541 | 0 | | |
| 1993 | 13,546 | 0.0 | 3.2 | 21.6 | 52.8 | 21.6 | 0.8 | 0.0 | 0.65 | 0 | 0 | 282 | 1905 | 4656 | 1905 | 71 | 0 | |
| 1994 | 32,330 | 0.0 | 3.3 | 22.6 | 54.7 | 19.3 | 0.0 | 0.0 | 0.81 | | 0 | 0 | 691 | 4762 | 11522 | 4071 | 0 | 0 |
| 1995 | 61,650 | 0.0 | 4.1 | 22.1 | 61.5 | 11.7 | 0.6 | 0.0 | 0.78 | | | | | 1964 | 10577 | 29465 | 5590 | 302 |
| 1996 | 37,513 | 0.0 | 2.0 | 5.6 | 35.2 | 33.2 | 22.9 | 1.1 | 0.47 | | | | | 0 | 348 | 995 | 6271 | 5922 |
| Tot. Recruits to Lifts: | | | | | | | | | | 12,770 | 17,736 | 17,189 | 12,079 | 13,848 | 24,893 | 34,602 | 11,861 | 6,224 |
| Fry releases (above Cono.) | | | | | | | | | | 11,995,690 | 6,227,590 | 9,899,430 | 5,179,790 | 6,450,685 | 13,464,650 | 5,619,000 | 7,218,000 | 3,039,400 |
| **stock\recruit ratio (X 1000)** | | | | | | | | | | 1.06 | 2.85 | 1.74 | 2.33 | 2.15 | 1.85 | 6.16 | 1.64 | 2.05 |
| **#fry to produce 1 adult** | | | | | | | | | | 939 | 351 | 576 | 429 | 466 | 541 | 162 | 609 | 488 |

Average 1986–1990: 435

Note: 1991 and 1992 year classes are not fully recruited.
Corrected for classification errors and tag recoveries from fingerlings or fish stocked below Conowingo Dam.

(Shaded) Corrected for hatchery contribution.

Table 11. Stock/recruitment ratio by year class for American shad collected in the Conowingo Dam Fish lifts and transported above dams in the Susquehanna River.

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Wild Contri. | Number of Adult shad collected in trap by Year Class 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | | |
| 1973 | 65 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | | |
| 1974 | 121 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 2 | | | | | | | | | | |
| 1975 | 87 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 15 | 2 | | | | | | | | | |
| 1976 | 82 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 47 | 14 | 2 | | | | | | | | |
| 1977 | 165 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 38 | 94 | 28 | 3 | | | | | | | |
| 1978 | 54 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 1 | 13 | 31 | 9 | 1 | | | | | | |
| 1979 | 50 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | 0 | 1 | 12 | 28 | 9 | 1 | | | | | |
| 1980 | 139 | | | 2.7 | 33.2 | 57.1 | 6.5 | | | 0 | 0 | 4 | 46 | 79 | 9 | | | | | |
| 1981 | 328 | | | 1.9 | 11.6 | 51.6 | 32.9 | 1.9 | | | | 0 | 6 | 38 | 169 | 108 | 6 | | | |
| 1982 | 2,039 | | | 1.7 | 24.7 | 61.9 | 11.7 | | | | | | 0 | 35 | 503 | 1262 | 238 | 0 | | |
| 1983 | 413 | | 2.7 | 28.3 | 55.8 | 9.3 | 3.9 | | | | | | | 11 | 117 | 231 | 38 | 16 | 0 | |
| 1984 | 167 | 0.0 | 7.4 | 12.1 | 8.7 | 59.7 | 12.1 | 0.0 | | | | | | | 0 | 12 | 20 | 15 | 100 | 20 |
| 1985 | 1,546 | 0.0 | 1.7 | 6.9 | 30.2 | 50.8 | 10.5 | 0.0 | | | | | | | | 0 | 26 | 106 | 466 | 786 |
| 1986 | 5,195 | 0.0 | 1.6 | 10.5 | 35.1 | 35.9 | 16.6 | 0.4 | | | | | | | | | 0 | 82 | 543 | 1824 |
| 1987 | 7,667 | 0.0 | 3.9 | 13.8 | 25.8 | 45.7 | 10.6 | 0.2 | | | | | | | | | | 0 | 301 | 1055 |
| 1988 | 5,146 | 0.0 | 4.0 | 31.7 | 38.1 | 21.2 | 4.7 | 0.4 | | | | | | | | | | | 0 | 204 |
| 1989 | 8,218 | 0.0 | 4.3 | 18.1 | 41.5 | 30.2 | 5.6 | 0.2 | 0.29 | | | | | | | | | | | 0 |
| 1990 | 15,719 | 0.1 | 5.5 | 32.7 | 45.2 | 15.0 | 1.5 | | 0.33 | | | | | | | | | | | 8 |
| 1991 | 27,227 | | 10.7 | 36.7 | 38.4 | 12.4 | 1.7 | | 0.31 | | | | | | | | | | | |
| 1992 | 25,721 | 0.6 | 12.3 | 35.7 | 36.8 | 11.7 | 2.9 | | 0.24 | | | | | | | | | | | |
| 1993 | 13,546 | 0.0 | 3.2 | 21.6 | 52.8 | 21.6 | 0.8 | 0.0 | 0.17 | | | | | | | | | | | |
| 1994 | 32,330 | 0.0 | 3.3 | 22.6 | 54.7 | 19.3 | 0.0 | 0.0 | 0.11 | | | | | | | | | | | |
| 1995 | 61,650 | 0.0 | 4.1 | 22.1 | 61.5 | 11.7 | 0.6 | 0.0 | 0.16 | | | | | | | | | | | |
| 1996 | 37,513 | 0.0 | 2.0 | 5.6 | 35.2 | 33.2 | 22.9 | 1.1 | 0.45 | | | | | | | | | | | |
| | | | | | Tot. Recruits to Lifts: | | | | | 103 | 123 | 76 | 93 | 174 | 799 | 1,613 | 329 | 219 | 1,411 | 3,896 |
| | | | | | Adults transported (above Cono.) | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 842 |
| | | | | | **stock\recruit ratio (X 1000)** | | | | | | | | | | | | | | | 4,627 |
| | | | | | **# trans. to return 1 adult** | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0.22 |

Note: The 1991 and 1992 year classes are not fully recruited.
Wild fish of upper Chesapeake Bay origin could not be distinguished and are therefore included in the total recruits to the lift.

Table 11. (continued).

| Year | Trap Catch | % Age Composition 8 | 7 | 6 | 5 | 4 | 3 | 2 | Wild Contri. | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1972 | 182 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1973 | 65 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1974 | 121 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1975 | 87 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1976 | 82 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1977 | 165 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1978 | 54 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1979 | 50 | | | 2.1 | 23.2 | 56.9 | 17.0 | 1.9 | | | | | | | | | | | |
| 1980 | 139 | | | 2.7 | 33.2 | 57.1 | 6.5 | | | | | | | | | | | | |
| 1981 | 328 | | | 1.9 | 11.6 | 51.6 | 32.9 | 1.9 | | | | | | | | | | | |
| 1982 | 2,039 | | | 1.7 | 24.7 | 61.9 | 11.7 | | | | | | | | | | | | |
| 1983 | 413 | | 2.7 | 28.3 | 55.8 | 9.3 | 3.9 | | | | | | | | | | | | |
| 1984 | 167 | 0.0 | 7.4 | 12.1 | 8.7 | 59.7 | 12.1 | 0.0 | | | | | | | | | | | |
| 1985 | 1,546 | 0.0 | 1.7 | 6.9 | 30.2 | 50.8 | 10.5 | 0.0 | | 162 | | | | | | | | | |
| 1986 | 5,195 | 0.0 | 1.6 | 10.5 | 35.1 | 35.9 | 16.6 | 0.4 | | 1865 | 861 | | | | | | | | |
| 1987 | 7,667 | 0.0 | 3.9 | 13.8 | 25.8 | 45.7 | 10.6 | 0.2 | | 1978 | 3504 | 810 | | | | | | | |
| 1988 | 5,146 | 0.0 | 4.0 | 31.7 | 38.1 | 21.2 | 4.7 | 0.4 | | 1629 | 1962 | 1092 | 241 | | | | | | |
| 1989 | 8,218 | 0.0 | 4.3 | 18.1 | 41.5 | 30.2 | 5.6 | 0.2 | 0.29 | 104 | 432 | 990 | 720 | 132 | | | | | |
| 1990 | 15,719 | 0.1 | 5.5 | 32.7 | 45.2 | 15.0 | 1.5 | | 0.33 | 287 | 1696 | 2345 | 777 | 75 | 0 | | | | |
| 1991 | 27,227 | | 10.7 | 36.7 | 38.4 | 12.4 | 1.7 | | 0.31 | 0 | 906 | 3100 | 3243 | 1049 | 143 | 0 | 0 | | |
| 1992 | 25,721 | 0.6 | 12.3 | 35.7 | 36.8 | 11.7 | 2.9 | | 0.24 | | 36 | 758 | 2202 | 2274 | 722 | 180 | 0 | | |
| 1993 | 13,546 | 0.0 | 3.2 | 21.6 | 52.8 | 21.6 | 0.8 | 0.0 | 0.17 | | 0 | 0 | 74 | 497 | 1216 | 497 | 18 | 0 | |
| 1994 | 32,330 | 0.0 | 3.3 | 22.6 | 54.7 | 19.3 | 0.0 | 0.0 | 0.11 | | | 0 | 0 | 181 | 1244 | 3009 | 1063 | 0 | 0 |
| 1995 | 61,650 | 0.0 | 4.1 | 22.1 | 61.5 | 11.7 | 0.6 | 0.0 | 0.16 | | | | | | 394 | 2124 | 5916 | 1122 | 61 |
| 1996 | 37,513 | 0.0 | 2.0 | 5.6 | 35.2 | 33.2 | 22.9 | 1.1 | 0.45 | | | | | | 0 | 333 | 951 | 5992 | 5659 |
| Tot. Recruits to Lifts: | | | | | | | | | | 6,023 | 9,397 | 9,095 | 7,255 | 4,209 | 3,719 | 6,143 | 7,948 | 7,114 | 5,720 |
| Adults transported (above Cono.) | | | | | | | | | | 36 | 0 | 967 | 4,172 | 7,202 | 4,736 | 6,469 | 15,075 | 24,662 | 15,674 |
| **stock\recruit ratio (X 1000)** | | | | | | | | | | 167,319 | | 9,405 | 1,739 | 584 | 785 | 950 | 527 | 288 | 365 |
| **# trans. to return 1 adult** | | | | | | | | | | 0.01 | 0.00 | 0.11 | 0.58 | 1.71 | 1.27 | 1.05 | 1.90 | 3.47 | 2.74 |

Note: The 1991 and 1992 year classes are not fully recruited.
Wild fish of upper Chesapeake Bay origin could not be distinguished and are therefore included in the total recruits to the lift.

(Shaded) Corrected for hatchery contribution.

Average 1986–1990: 1.30

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

Fisheries Administration, Maryland Department of Natural Resources 301 Marine Academy Drive, Stevensville, MD 21666

## Introduction

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

## Methods and Materials

Collection procedures for adult American shad in 1996 were nearly identical to those in 1995. 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 1996 was again monitored by project personnel with a 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 1996.

**Results**

Pound net tagging for 1996 began on 19 March and continued until 17 May, while hook and line effort commenced on 29 April and ended 31 May. Of the 1,402 adult American shad captured, 835 (59.6%) were tagged and 154 (11.0%) subsequently recaptured (Table 1). Of these 154 recaptures, none occurred outside the upper Bay system. The 154 total does not reflect the 77 multiple recaptures, 2 unverifiable tag numbers, and 27 fish tagged prior to 1996.

Recapture data for the 1996 season is summarized as follows:

a. 154 fish recaptured by the Conowingo Fish Lifts (does not include 77 multiple recaptures, 27 pre-1996 tagged fish, and 2 fish with unverifiable tag numbers)

  0 fish recaptured by pound net

  0 fish recaptured by hook and line from the tailrace

  0 fish recaptured outside the system

**b.** 129 fish recaptured originally caught by hook and line

25 fish recaptured originally caught by pound net

**c.** 129 fish recaptured in the same area as initially tagged

25 fish recaptured upstream of their initial tagging site

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

longest period at large: 58 days (1996 fish only)

mean number days at large: 17.2

**e.** number of pre-1996 tagged fish recaptured: 27

The 1996 adult American shad Petersen population estimate for the upper Chesapeake Bay was 203,216 (Table 2), and has been increasing exponentially since 1980 ($r^2$=0.79, $P \leq 0.0001$)(Figure 3). The Conowingo tailrace population estimate was 112,217 (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 1996 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 569 adult American shad (300 pound net, 269 hook and line) were examined for physical characteristics by DNR biologists in 1996 (Table 5). The 1992 year-class (age 4, sexes combined) was the most abundant year-class sampled in the upper Bay by pound net and hook and line, accounting for 34% and 36.4%, respectively, of the total catch (Table 5). Age frequency modes occurred at age 4 for males in both pound net and hook and line catches. Age frequency modes for females occurred at ages 4 and 5 in pound net catches and at age 6 in hook and line catches. Both sexes (gears combined) were present in age groups 4-6; there was one age 3 and 19 age 7 females. 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 increased from 3.9% in 1995 to 13.6 in 1996. Similarly, female American shad repeat spawning increased from 11.2% in 1995 to 19% in 1996.

Directed juvenile *Alosa* sampling in the upper Bay during 1996 collected 11 juvenile American shad with the boat electrofisher, while supplemental haul seine sampling by the Department's Juvenile Seine Survey captured another 120 (Figure 5). Table 6 provides a breakdown by cell and date of the juvenile American shad collected by electrofishing during 1996.

Table 1. Number of American shad captured and tagged by location and method of capture, upper Chesapeake Bay, March-June 1996.

| GEAR TYPE | LOCATION | CATCH | NUMBER TAGGED |
|---|---|---|---|
| Pound Net | Cherry Tree | 315 | 75 |
| | Rocky Point | 330 | 206 |
| | White Pt. | 311 | 144 |
| | Total | 956 | 425 |
| Hook and Line | Conowingo Tailrace Susquehanna River | 446 | 410 |
| Fish Lift | Conowingo Tailrace Susquehanna River | 37,513 | |
| | TOTALS | 38,915 | 835 |

Table 2. Population estimate of adult American shad in the upper Chesapeake Bay during 1996 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 1996 survey -

C = 38,888
R = 154
M = 810

Therefore -

$$N = \frac{(38{,}838 + 1)\ (810 + 1)}{(154 + 1)}$$

= **203,216**

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)

$$\text{Upper } N^* = \frac{(38{,}838 + 1)\ (810 + 1)}{131.52 + 1} = 237{,}688$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(38{,}838 + 1)\ (810 + 1)}{180.32 + 1} = 173{,}717$$ @ .95 confidence limits

* M adjusted for 3% tag loss

Table 3. Population estimate of adult American shad in the Conowingo tailrace during 1996 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 1996 survey -

C = 36,561
R = 129
M = 398

Therefore -

$$N = \frac{(36{,}561 + 1)\ (398 + 1)}{(129 + 1)}$$

= **112,217**

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)

$$\text{Upper } N^* = \frac{(36{,}561 + 1)\ (398 + 1)}{117.56 + 1} = 123{,}045$$ @ .95 confidence limits

$$\text{Lower } N^* = \frac{(36{,}561 + 1)\ (398 + 1)}{144.28 + 1} = 100{,}415$$ @ .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 1980-1996 tagging program in the upper Chesapeake Bay.

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

Table 4, continued.

| YEAR | LOCATION | DAYS FISHED | TOTAL CATCH | CATCH PER POUND NET DAY | POPLN. EST. |
|---|---|---|---|---|---|
| **A. Pound Net** | | | | | |
| 1995 | Cherry Tree | 57 | 472 | 8.28 | |
| | Rocky Point | 48 | 425 | 8.85 | |
| | Beaver Dam | 23 | 262 | 11.39 | |
| | | 128 | 1159 | 9.05 | 333,891 |
| 1996 | Cherry Tree | 60 | 315 | 5.25 | |
| | Rocky Point | 58 | 330 | 5.69 | |
| | White Point | 40 | 311 | 7.76 | |
| | | 158 | 956 | 6.05 | 203,216 |

| YEAR | HOURS FISHED | TOTAL CATCH | CPUE CPAH* | CPUE HTC** | POPLN. EST. |
|---|---|---|---|---|---|
| **B. Hook and Line** | | | | | |
| 1982 | *** | 88 | - | - | 37,551 |
| 1983 | *** | 11 | - | - | 12,059 |
| 1984 | 52.0 | 126 | 2.42 | 0.41 | 8,074 |
| 1985 | 85.0 | 182 | 2.14 | 0.47 | 14,283 |
| 1986 | 147.5 | 437 | 2.96 | 0.34 | 22,902 |
| 1987 | 108.8 | 399 | 3.67 | 0.27 | 27,354 |
| 1988 | 43.0 | 256 | 5.95 | 0.17 | 38,386 |
| 1989 | 42.3 | 276 | 6.52 | 0.15 | 75,820 |
| 1990 | 61.8 | 309 | 5.00 | 0.20 | 123,830 |
| 1991 | 77.0 | 437 | 5.68 | 0.18 | 141,049 |
| 1992 | 62.8 | 383 | 6.10 | 0.16 | 105,255 |
| 1993 | 47.6 | 264 | 5.55 | 0.18 | 47,563 |
| 1994 | 88.5 | 498 | 5.63 | 0.18 | 129,482 |
| 1995 | 84.5 | 625 | 7.40 | 0.14 | 333,891 |
| 1996 | 44.3 | 446 | 10.10 | 0.10 | 203,216 |

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

Table 5. Catch (N), age composition (%), number and percent of repeat spawners(Rpts.), and mean fork length (mm) and range by sex and age group for adult American shad collected by gear type during the 1996 upper Chesapeake Bay spring tagging operation.

| | MALE | | | | FEMALE | | | |
|---|---|---|---|---|---|---|---|---|
| AGE GROUP | N(%) | RPTS. | MEAN | RANGE | N(%) | RPTS. | MEAN | RANGE |
| **Pound Net** | | | | | | | | |
| III | 47(16) | 0 | 339 | 285-375 | 0 | - | - | - |
| IV | 57(19) | 2 | 380 | 335-445 | 45(15) | 0 | 413 | 380-485 |
| V | 49(16) | 13 | 429 | 370-465 | 45(15) | 8 | 447 | 395-490 |
| VI | 15(5) | 5 | 459 | 435-485 | 31(10) | 9 | 486 | 460-510 |
| VII | 0 | - | - | - | 11(4) | 7 | 502 | 460-525 |
| % Repeat Spawners | | 11.9 | | | | 18.2 | | |
| **Hook and Line** | | | | | | | | |
| III | 22(8) | 0 | 343 | 290-365 | 1(<1) | 0 | 355 | - |
| IV | 61(23) | 0 | 379 | 345-445 | 37(14) | 0 | 420 | 390-480 |
| V | 47(17) | 11 | 425 | 378-475 | 31(12) | 4 | 448 | 404-484 |
| VI | 18(7) | 12 | 454 | 432-473 | 44(16) | 13 | 483 | 449-511 |
| VII | 0 | - | - | - | 8(3) | 7 | 495 | 480-523 |
| % Repeat Spawners | | 15.5 | | | | 19.8 | | |
| **All gears combined** | | | | | | | | |
| III | 69(12) | 0 | 340 | 285-375 | 1(<1) | 0 | 355 | - |
| IV | 118(21) | 2 | 379 | 335-445 | 82(14) | 0 | 416 | 380-485 |
| V | 96(17) | 24 | 427 | 370-475 | 76(13) | 12 | 447 | 395-490 |
| VI | 33(6) | 17 | 456 | 432-485 | 75(13) | 22 | 484 | 449-511 |
| VII | 0 | 0 | - | - | 19(3) | 14 | 499 | 460-525 |
| % Repeat Spawners | | 13.6 | | | | 19.0 | | |

Table 6. Juvenile American shad captured by date and cell and associated catch-per-unit-effort (American shad caught per shock hour) during the 1996 upper Chesapeake Bay electrofishing survey. No sampling at a particular date and cell is represented by a blank space.

| CELL NO | AUG. 14 | AUG 27 | SEPT. 9 | OCT. 2 | OCT. 10 | OCT. 16 | OCT. 23 | OCT. 29 | CATCH | SHOCK TIME (SEC.) | CPUE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | X | X | | | X | | 0 | 1500 | 0.0 |
| 2 | X | X | X | X | | | X | X | 0 | 3000 | 0.0 |
| 3 | | X | 1 | X | | X | | X | 1 | 2500 | 1.4 |
| 4 | 1 | | X | X | | | | | 1 | 1500 | 2.4 |
| 5 | | X | | | | | | | 0 | 500 | 0.0 |
| 6 | | | | | | | | | 0 | 0 | 0.0 |
| 7 | 1 | X | | | | X | X | X | 1 | 2500 | 1.4 |
| 8 | X | | X | X | | X | | | 0 | 2000 | 0.0 |
| 9 | | | | | | | X | X | 0 | 1000 | 0.0 |
| 10 | | | | | | | | | 0 | 0 | 0.0 |
| 11 | | | | | X | | | | 0 | 500 | 0.0 |
| 12 | X | | | X | X | | X | X | 0 | 2500 | 0.0 |
| 13 | | X | | | | X | X | | 0 | 1500 | 0.0 |
| 14 | | X | | | | | | X | 0 | 1000 | 0.0 |
| 15 | X | | | | | X | X | X | 0 | 2000 | 0.0 |
| 16 | X | X | | | X | X | X | | 0 | 2500 | 0.0 |
| 17 | | | | X | | | | | 0 | 500 | 0.0 |
| 18 | | | | | 3 | | | | 3 | 500 | 21.6 |
| 19 | | 1 | | | 2 | 1 | | | 4 | 1500 | 9.6 |
| 20 | X | 1 | | X | X | X | | X | 1 | 3000 | 1.2 |
| 21 | X | | | 1 | X | X | X | X | 1 | 3000 | 1.2 |
| TOTAL | 2 | 2 | 1 | 1 | 5 | 1 | 0 | 0 | 12 | 33,000 | 1.3 |

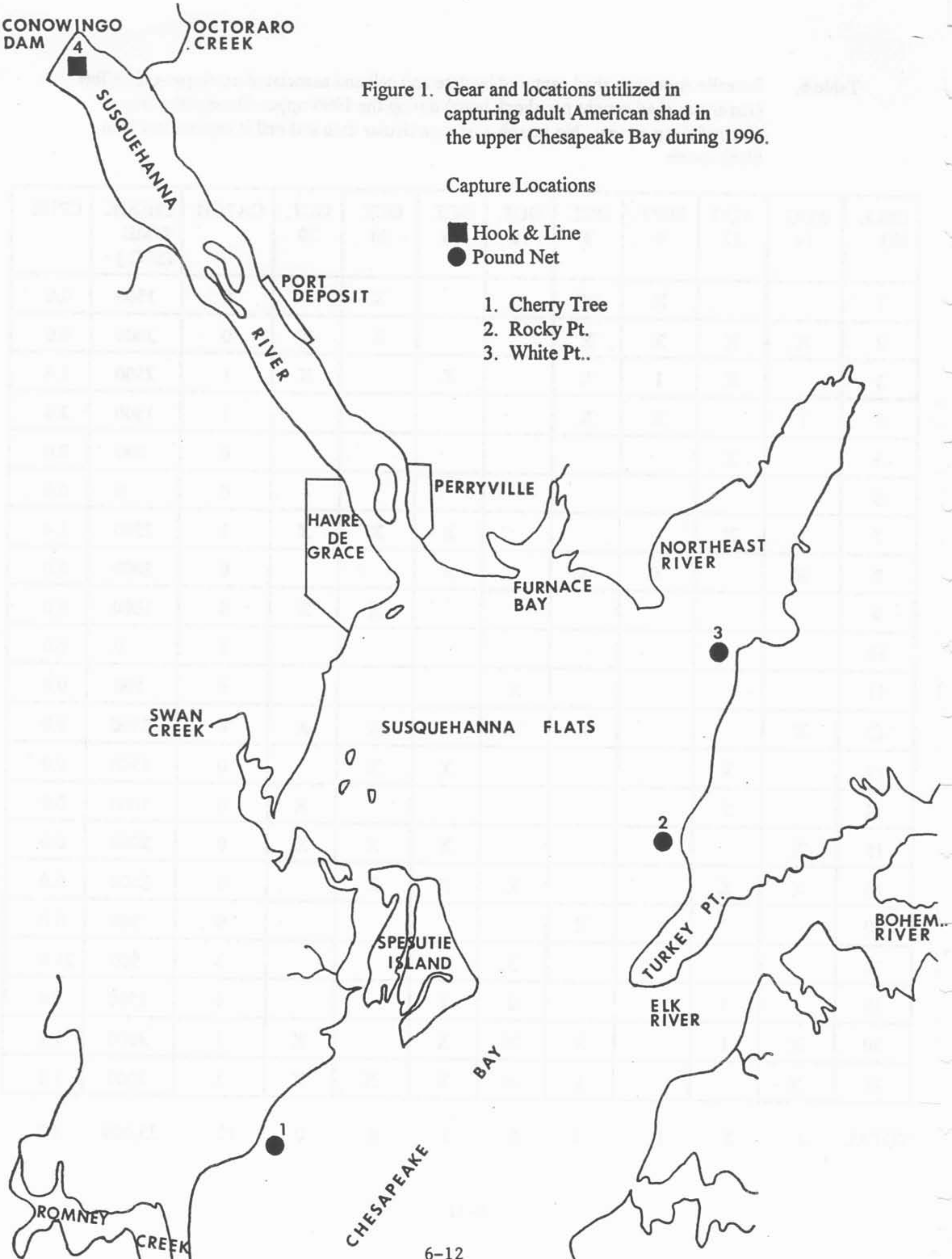



Figure 1. Gear and locations utilized in capturing adult American shad in the upper Chesapeake Bay during 1996.

Figure 2. Upper Chesapeake Bay electrofishing cells sampled during the 1996 juvenile *Alosa* survey.

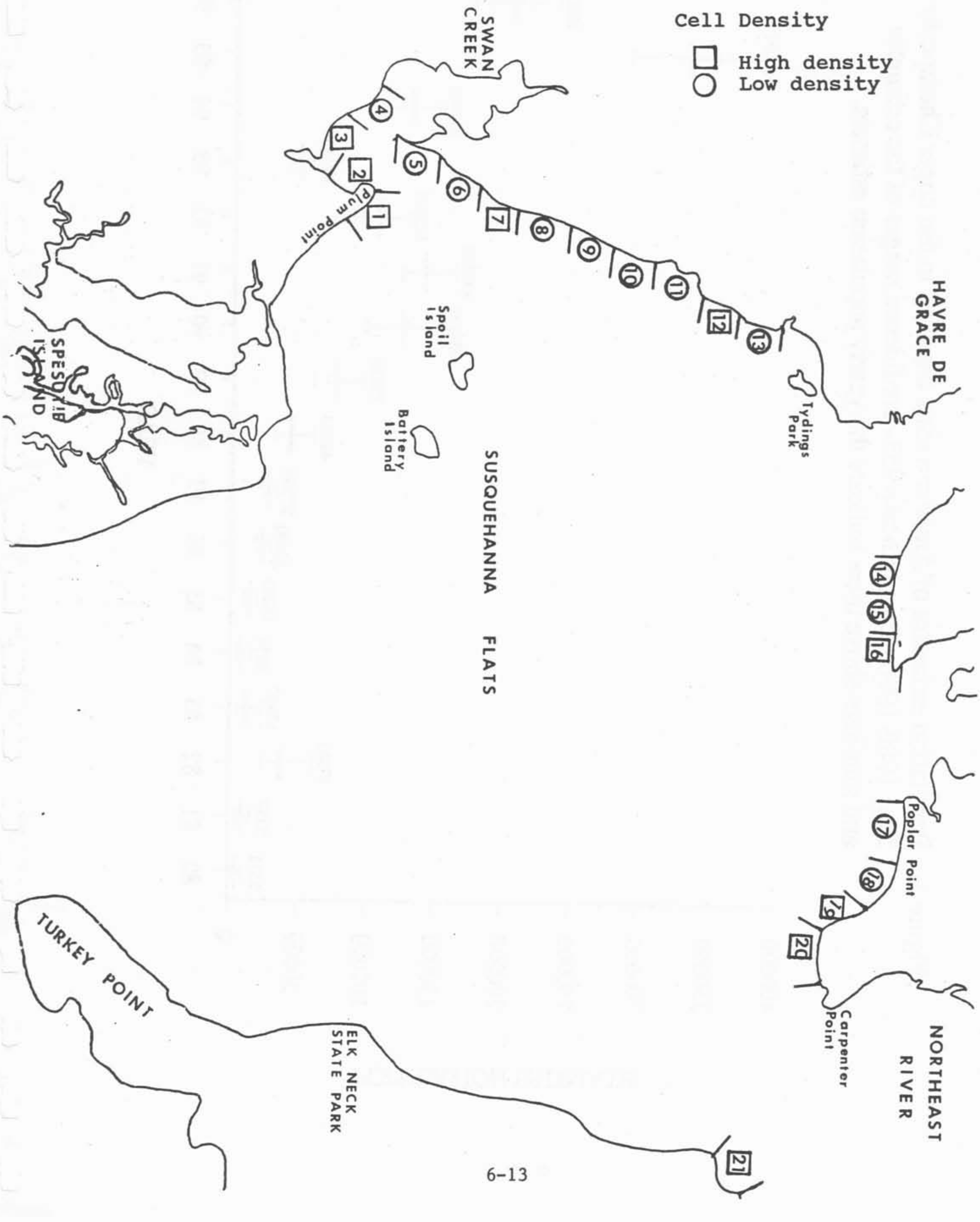


Figure 3. Population estimates of American shad captured in the upper Chesapeake Bay, 1980-1996. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.

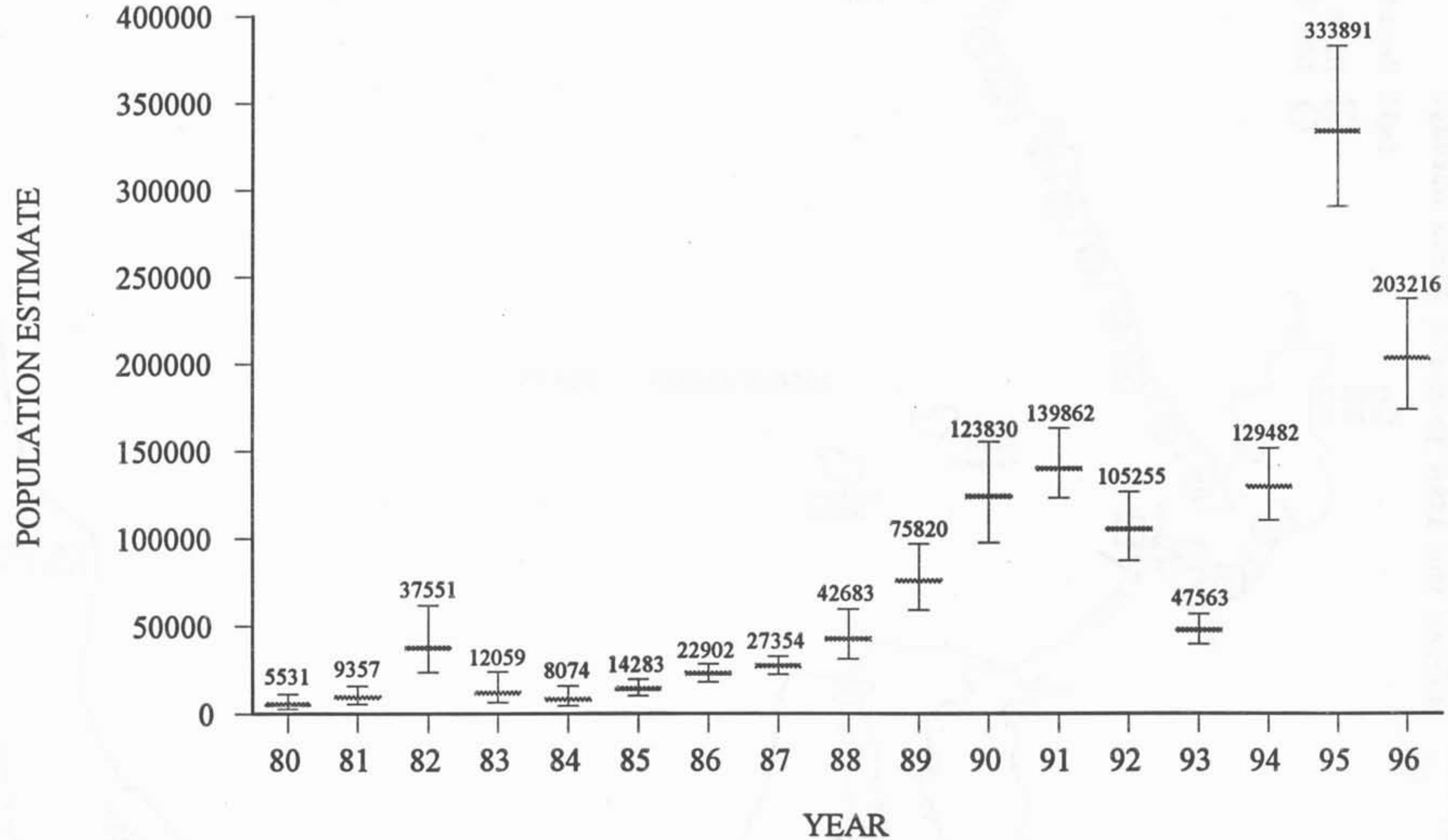


Figure 4. Population estimates of American shad captured in the Conowingo Dam tailrace, 1984-1996. Bars indicate 95% confidence ranges of the estimates and numbers above them indicate the yearly population estimate.

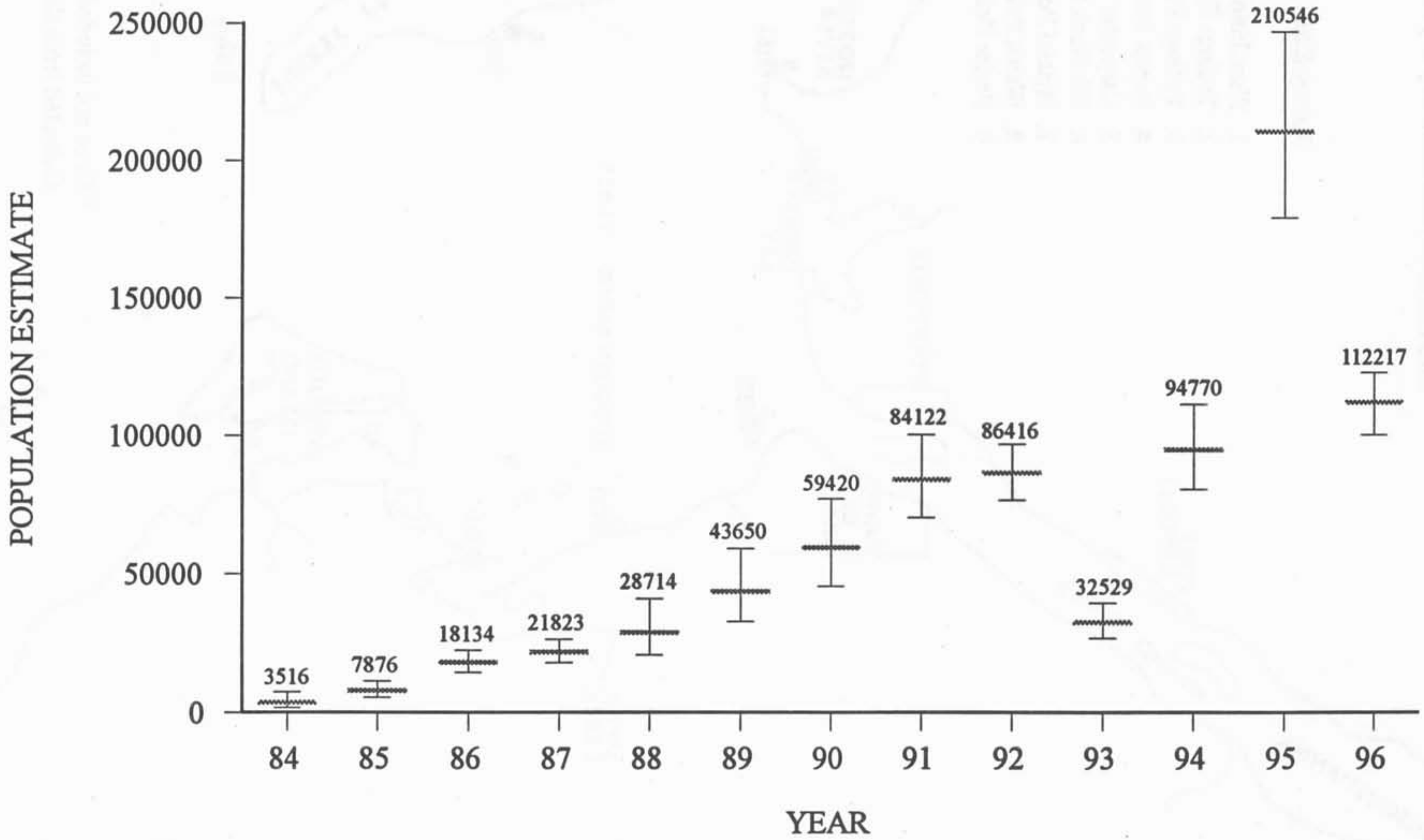
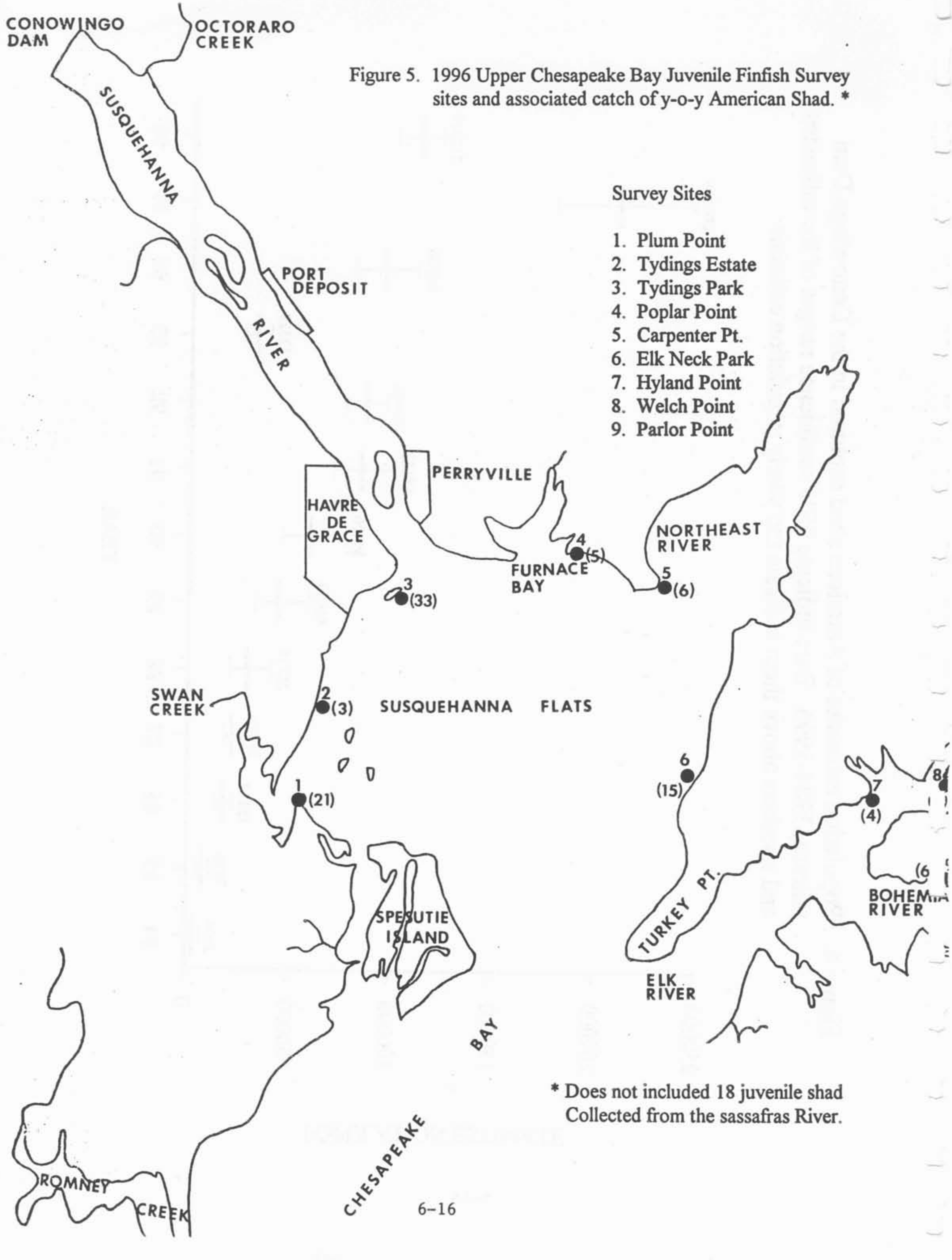


Figure 5. 1996 Upper Chesapeake Bay Juvenile Finfish Survey sites and associated catch of y-o-y American Shad. *




Survey Sites

1. Plum Point
2. Tydings Estate
3. Tydings Park
4. Poplar Point
5. Carpenter Pt.
6. Elk Neck Park
7. Hyland Point
8. Welch Point
9. Parlor Point

* Does not included 18 juvenile shad Collected from the sassafras River.